Comparative Economic Research

Central and Eastern Europe

Volume 27 No. 4/2024

WYDAWNICTWO UNIWERSYTETU ŁÓDZKIEGO

WYDZIAŁ EKONOMICZNO-SOCJOLOGICZNY Uniwersytet Łódzki

COPE Member since 2018 JM13708

Institute of Economics • University of Łódź

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Printed directly from camera-ready materials provided to the Lodz University Press

Journal affiliated with the Faculty of Economics and Sociology of the University of Lodz

Published by Lodz University Press
First Edition. W.11575.24.0.C
Printing sheets 24.25

ISSN 1508-2008
e-ISSN 2082-6737

Lodz University Press
90-237 Łódź, 34A Matejki St.
www.wydawnictwo.uni.lodz.pl
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Contents

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.28

Responsible Business Conduct in the European Union's Investment Policy

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Abstract

This paper aims to characterize the role of responsible business conduct (RBC)/corporate social responsibility (CSR) within the European Union's (EU) common investment policy. It explores how the EU uses CSR/RBC to promote sustainable development in the context of foreign direct investment (FDI). The main research objectives include an assessment of the potential impact of the provisions on CSR/RBC included in the EU's international trade/investment agreements on achieving the sustainable goals in host and home countries of FDI, methods of implementing these provisions in international relations, and the future role of the World Trade Organization's (WTO) Investment Facilitation Framework for Development (IFD) Agreement in reshaping the EU's investment policy. The study employs qualitative methods, supported by the examination of examples of the EU's new generation of international trade and economic partnership agreements (Korea, Canada, and Japan). The EU treats RBC/CSR as a crucial tool for achieving the UN Agenda 2030's sustainable development goals. Responsible business behavior is promoted and supported by the instruments of the EU's trade and investment policies. Since RBC/CSR is voluntary, agreements are enforced through soft measures and actions. The only strong instrument, i.e., trade sanctions, is treated as the last resort and has not been used so far.
The newly negotiated WTO Investment Facilitation for Development (IFD) Agreement is expected to enhance the re-orientation of the EU's policy towards facilitating foreign investment in relations with developing countries. The paper's main contribution lies in its examination of the EU's approach towards CSR/RBC in its international trade/investment agreements. It also analyses the problems associated with implementing RBC/CSR provisions within these agreements.

Keywords: EU investment policy, foreign direct investment (FDI), international trade and investment agreements, responsible business conduct, corporate social responsibility, sustainable development

JEL: F15, M14, O24

Received: 15.06.2023. Verified: 17.06.2024. Accepted: 3.09.2024

Introduction

The European Union (EU) conducts a common investment policy for foreign direct investment (FDI) based on the provisions of the Treaty on the Functioning of the European Union (TFEU), Articles 206 and 207. One key instrument of this policy is negotiating and signing international investment agreements (IIAs) with third countries. Recent IIAs include provisions related to sustainable development, with particular reference to environmental and social issues. This represents a novel approach compared to traditional IIAs between the EU and third countries.

Achieving the UN Agenda 2030's sustainable development goals (SDGs), which the EU strives for, requires public and private sector involvement at both EU and Member State levels. Responsible Business Conduct (RBC) or Corporate Social Responsibility (CSR) are treated as crucial factors of sustainable development strategies in the private sector.

The paper aims to assess:

- If CSR/RBC provisions included in EU's IIAs could help solve problems related to achieving the SDGs in the host and home countries of foreign direct investment (FDI).
- How the provisions of IIAs should be executed if CSR/RBC activities are voluntary.
- What the future role of the World Trade Organisation's (WTO) Investment Facilitation Framework for Development (IFD) Agreement might be in reshaping EU investment policy.

The paper will use official information on the EU's investment policy and independent analyses. It will also consider the potential impact of the newly negotiated WTO/IFD Agreement on changes in the EU's investment policy.

Corporate Social Responsibility versus Responsible Business Conduct

According to the contemporary literature, CSR encompasses '[…] the economic, legal, ethical, and discretionary [later referred to as philanthropic] expectations that society has of organizations at a given point in time' (Carroll and Shabana 2010). Although various definitions of CSR exist, the following core characteristics are widely accepted (Bondy, Moon, and Matten 2012; Crane, Matten, and Spence 2014):

- CSR activities are voluntary.
- CSR focuses on integrating or managing the external effects that arise when products or services are delivered/rendered by companies.
- CSR targets various stakeholder groups (including stockholders and investors, employees, communities, competitors, and the media).
- CSR integrates social, environmental, and economic responsibility with everyday business operations and decision-making.
- CSR ideas are embedded in business practice and a company's system of values.
- CSR goes beyond philanthropy and focuses on operational considerations.

Significantly, the definitions of CSR embrace several aspects of the **voluntary** integration of social, economic, and environmental issues into a business's activities and its relationships with stakeholders. Another important aspect is the readiness of businesses to **sacrifice profit** for the sake of certain social interests (Benabou and Tirole 2010).

While the CSR concept mainly targets the business world, it has also garnered significant interest from governments and international organizations. These entities play a dual role, formulating their own CSR definitions and actively promoting the concept in both private and public sectors. Given the significance of CSR for the business world, 'corporate' social responsibility in the public sphere is less obvious. However, there are strong proponents for implementing CSR principles in the public sector as well.

Alternative terms related to business responsibility have been formulated alongside discussions on understanding the CSR concept and its practices: **responsible business conduct (RBC),** introduced by the OECD, and **Business and Human Rights**, endorsed by the UN (European Commission 2019a). The notion of RBC is articulated in the *OECD Guidelines for Multinational Enterprises*, which provide **voluntary** principles and standards of good practice for responsible business conduct that align with applicable laws and internationally recognized standards (OECD 2023). The Guidelines embrace several sections related to information disclosure, human rights, employment and industrial relations, the environment, combating bribery, bribe solicitation and extortion, consumer interests, science and technology, competition, and taxation. Although there is no formal definition of responsible business conduct, the OECD offers the following explanation: "[…] RBC principles and standards expect that all companies – regardless of their legal status, size, ownership or sector – should 1) make a positive contribution to the economic, environmental and social progress of the countries in which they operate and 2) avoid and address negative impacts of their activities, including in the supply chain." (OECD n.d.).

In other words, the responsible behavior of multinational enterprises should positively influence the societies and economies of both home and host countries and lead to sustainable development. At the same time, the OECD Guidelines foresee legally binding commitments for the governments that adhere to them. The Guidelines cover several areas, including setting up authorities (National Contact Points) to promote the idea of RBC, responding to inquiries, and providing mediation and conciliation platforms when the OECD Guidelines are not respected.

To provide practical support to companies in implementing RBC, *the OECD Due Diligence Guidance for Responsible Business Conduct* was adopted in 2018 (OECD 2018; Shavin 2019). Its role is to promote a mutual understanding of RBC due diligence, give practical recommendations to businesses, and help them positively contribute to the UN Agenda 2030's SDGs.

Although the *OECD Guidelines for Multinational Enterprises* and associated *OECD Due Diligence Guidance* are considered soft law, they are seen as a valuable tool in promoting greater corporate responsibility regarding human rights and the environment, as well as strengthening the legal framework on corporate accountability (Ingrams and Booth 2023). A more stringent international regulation on the *Multilateral Treaty on Due Diligence* has been proposed (Yannaca-Small 2022). Countries would adopt and enforce laws that would be mandatory for companies under their jurisdiction. Consequently, the soft nature of the *OECD Due Diligence Guidance* would be changed.

Both CSR and RBC share the common characteristic of being **voluntary.** They also distinguish the same dimensions of business responsibility, i.e., **social, economic, and environmental issues**, which are significant for a country's sustainable development. However, the two approaches differ in their view of government roles. In CSR, the role of government is reduced to promoting the concept, while in RBC, governments are more active. They are expected to act as promotors, respond to inquiries, and mediate potential conflicts.

Despite the different perspectives on the role of governments, the key characteristics of CSR and RBC justify treating them as largely synonymous. For example, the European Union uses the notions of CSR[1] and RBC in its documents and analyses interchangeably (SWD 2019). Since the same dimensions of business responsibility are considered in these terms, this paper will also treat them as equivalent.

It is important to acknowledge the ongoing debate surrounding these concepts. Some argue that RBC is replacing CSR as the dominant concept because RBC refers not only to social issues but also to development issues (Sauvant 2022). However, as previously outlined, the concept of CSR also includes development aspects.

1 The EU defines CSR as "the responsibility of enterprises for their impact on society" (European Commission 2011, p. 6).

An alternative perspective suggests distinguishing three distinct social responsibility notions: **Corporate Social Responsibility, Responsible Business Conduct** and **Corporate Responsibility to Respect** (CRtoR) (Fasciglione 2020). The last one expresses the business and human rights approach of **the UN Guiding Principles on Business and Human Rights** (UNGPs) and is more regulatory-oriented than the other two.

The UNGPs, endorsed by the United Nations Human Rights Council in 2011, provide a framework for states and companies to prevent and address human rights abuses committed in business operations (UN 2011). They establish a clear division of responsibility: "…states have the duty to protect against human rights abuses by all actors in society, including businesses," while "[…] business enterprises have the responsibility to respect human rights wherever they operate and whatever their size or industry. This responsibility means companies must know their actual or potential impacts, prevent and mitigate abuses, and address adverse impacts with which they are involved" (UN 2011). The UN document interprets this responsibility within a broad legal context.

In light of the UN Guiding Principles, both states and enterprises have distinct but complementary responsibilities, which might be viewed as legal responsibility in "a pyramid of CSR" models, i.e., "After profit obligations" models or the legal domain in the "Three-Domain Model of CSR" (Schwartz and Carroll 2003).

The European Union's general approach towards CSR/RBC

The EU has defined its attitude towards the concept and practice of CSR/RBC in official documents. Its support for CSR/RBC has a long history, beginning with the EU Lisbon Strategy, which emphasized the significance of CSR. The next steps embraced the European Commission's 2001 *Green Paper on Promoting a European Framework for Corporate Social Responsibility*, which launched a debate on CSR, and the follow-up introduction of the European strategy to promote CSR (European Commission 2001; 2002).

The EU's CSR policy was further developed in *A renewed EU Strategy 2011–14 for Corporate Social Responsibility* (European Commission 2011). It had a horizontal character and was interlinked with EU policies and global approaches to CSR. The EU's internal focus was on promoting CSR and adapting it to the individual characteristics of environmental and trade policies, public procurement, transparency reporting and sectors of economies. These activities aimed to enhance understanding of CSR, increase its visibility, disseminate good practices, encourage disclosure of social and environmental information, and reward companies for strong CSR performance.

The interaction between European and global approaches to CSR aims to integrate internationally recognized principles and guidelines into the EU's own CSR policies, implement the *UN Guiding Principles on Business and Human Rights,*

and positively impact the economies of third countries through the promotion of responsible business models.

The progress made under the 2011–2014 strategy was reviewed in the 2019 *Staff Working Document* (SWD 2019). The report highlights the EU institutions' efforts to ensure coherence between CSR/RBC actions, EU policies, and legal aspects arising from the UNGPs and the UN 2030 Agenda for Sustainable Development.

The EU has undertaken significant legal work that aligns with the legal domain of CSR/RBC. This resulted in the adoption of directives and regulations related to the protection and enforcement of fundamental rights, the prevention of and remedies for discrimination on any grounds, and data protection. The EU has also taken important steps to ensure due diligence in respecting human rights along the supply chain. Key actions include the EU Non-Financial Reporting Directives (European Union 2022), regulations on responsible sourcing of timber, minerals, and diamonds, as well as sectoral due diligence measures in textile, garment and leather supply chains, which were implemented in cooperation with international organizations (OECD, UN, ILO).

Beyond these activities, the EU promotes sustainable finance, encourages socially and environmentally friendly business practices, and promotes CSR/RBC and Business and Human Rights in multilateral fora and bilaterally. It also promotes these principles outside the EU through trade and development practices (SWD 2019).

Promoting CSR/RBC through trade and investment outside the EU

The EU uses its involvement in global trade and FDI, as well as its trade and investment policies, to support the idea of CSR in international economic relations. **Trade policy** is one of the "old" policies, and the EU institutions have at their disposal a set of instruments allowing them to shape external trade relations. Some of them, i.e., Free Trade Agreements, Economic Partnership Agreements, and unilateral trade preferences, are used to promote CSR/RBC in economic relations with third countries. Apart from that, numerous actions and initiatives are undertaken to promote and, to a certain extent, execute this idea in global value chains (SWD 2019).

The EU's common investment policy towards FDI, based on Articles 206 and 207 of the Treaty on the Functioning of the European Union (TFEU 2012), is conducted on behalf of the EU Member States as part of the EU's common trade policy. One of the objectives of the investment policy is to '[…] encourage investment that supports sustainable development, respect for human rights and high labor and environmental standards – this includes promoting corporate social responsibility

and responsible business practices' (European Commission n.d., *Investment*). Therefore, one of the aims of this policy is to promote socially responsible behavior of international business in the EU's economic relations.

The EU's common investment policy instruments include trade agreements, which contain investment rules or standalone investment agreements, screening frameworks for FDI, rules of investment dispute settlements, and investment facilitation rules (European Commission n.d., *Investment*).

Trade agreements containing investment rules or standalone investment agreements are used as traditional instruments to encourage and facilitate foreign investment flows between countries, to protect foreign investors' interests without undermining the state's sovereign rights to regulate and protect citizens' interests, and to establish investor-to-state-settlement (ISDS) procedures. These agreements might also play a significant role in promoting and exercising responsible business conduct in bilateral relations.

Over the last 50 years, it is estimated that countries worldwide have signed more than 3200 bilateral investment treaties, 1400 of which involved EU Member States (European Commission 2015). Pursuant to the TFEU, the EU broadened its competencies and took responsibility for negotiating new trade and investment agreements with third countries. These agreements are either comprehensive, including provisions on investment, or focus solely on protecting and facilitating foreign investment. Since gaining competencies in investment policy, the EU has signed 17 treaties with investment provisions (UNCTAD 2023a). Existing bilateral investment agreements within the EU are expected to be terminated as they conflict with the single market principle of non-discrimination among EU investors under EU law (European Commission 2018).

The screening framework for FDI is a new EU instrument to protect key strategic industries and assets in the Member States (OJEU 2019). This framework allows Member States to assess whether investment projects are suitable for the strategic aims of a recipient country and evaluate how they will impact the economy. RBC is not explicitly enumerated in the Regulation of 2019 (Article 4) as a factor to be considered by the Member States or the Commission when determining whether foreign direct investment is likely to affect security or public order. However, the EU screening mechanism could be a useful tool, especially for assessing the potential consequences of FDI for the environment and human health. While the mechanism might appear restrictive towards FDI, it is a softer instrument than "negative lists". It also creates some opportunities to conduct responsible business practices in recipient countries.

Investor-to-State-Dispute Settlements (ISDS) constitute a severe problem that involves investors, states, and societies. Disputes might arise in different spheres, even those not regulated by law. In such cases, appealing to CSR might be a solution.

Although there is no global system of dispute settlements, attempts to deal with problems arising in investor-to-state relations are applied at international levels. They include arbitration rules of the United Nations Commission on International Trade Law (UNCITRAL), rules of transparency of the United Nations Convention on Transparency in Treaty-based Investor-State Arbitration (the *Mauritius Convention on Transparency*), as well as procedures and rules used by the World Bank's International Centre for Settlements of Investment Disputes (ICSID) (UN 2015; UNCTAD 2023b; ICSID 2022).

However, since these rules and procedures lack clear and precise rules on investment protection or the state's right to regulate, the EU promotes its own approach to these issues. As a result of reforms, **the Investment Court System (the ICS)** was created to replace the old model of arbitral tribunals established *ad hoc* for specific disputes. Installing a permanent investment court system means that the parties can no longer choose their own arbitrators. The EU's new investment policy uses this institutionalized adjudicative body for dispute resolution. This new legal solution has been applied in **bilateral** investment negotiations. Its implementation in the Comprehensive Economic and Trade Agreement (CETA) with Canada paved the way for agreements with Vietnam, Singapore, and Mexico (European Commission 2023a). Additionally, the EU advocates for establishing a **Multilateral Investment Court** through intergovernmental discussions within the United Nations Commission on International Trade Law. However, the progress of reforming ISDS under the auspices of UNITRAL has been slow (EESC 2023).

Traditionally, both host and home countries have employed **investment facilitation measures** to attract foreign investors. These policies aimed to maximize the net benefits for the host countries while supporting the investment expansion of home countries. The objectives of the policies formulated within a traditional framework were sometimes hindered by unforeseen circumstances (UNCTAD 1999).

Investment facilitation was under the spotlight in international negotiations on *The Investment Facilitation for Development Agreement* within the WTO (IFD/WTO). In this context, investment facilitation is understood as "[…] the setting up of a more transparent, efficient and investment-friendly business climate […]" (WTO 2023, p. 2). Moreover, both the home and host countries seek cooperative and mutually beneficial approaches to promote more sustainable investment. Importantly, the IFD Agreement includes a section dedicated to RBC and anti-corruption measures. The WTO negotiations recognized the need to complement past liberalization efforts by streamlining administrative procedures and making information on investment rules public and easily available. The EU, representing the Member States, actively participated in the WTO negotiations on the new agreement. In the meantime, the European Commission announced its intention to pursue sustainable investment agreements with Africa and Southern Neighborhood countries (European Commission 2023b).

Therefore, the EU's trade and investment policies are intended not only to liberalize foreign trade and investment but also to achieve a broader goal, i.e., sustainable development on a global scale. Regarding CSR/RBC, the EU prioritizes human rights, labor rights, and social and environmental aspects in global value chains. Additionally, it expects Member States to enforce common regulations related to imported goods and services, as well as domestically manufactured products (European Commission 2015).

The EU's trade and investment strategy, entitled "Trade for all. Towards a more responsible trade and investment policy," adopted by the Commission in 2015, forms the basis for trade and investment policies for the benefit of both Member States and third countries. According to the EU Treaties, trade and investment policies should be consistent with other EU external actions (European Commission 2015).

The strategy was followed by numerous documents, programs and initiatives to promote CSR/RBC and business and human rights outside the EU. They included the updated *EU Aid for Trade strategy* of 2017, initiatives to promote fair and ethical trade, support for CSR/RBC throughout the value chains, as well as responsible investment, sustainable trade, and inclusive business models in partner countries. Specific programs were also conducted in some regions and countries, such as Asia and the South Mediterranean, including the Agriculture Financing Initiative, the Electrification Financing Initiative, and the SWITCH To Green program. Together with the International Labour Organization (ILO), the EU strives to eliminate and prevent forced and child labor and violations of freedom of association (European Commission 2019a). Finally, the recently concluded EU trade and investment agreements contain specific provisions committing the partners to promoting CSR/RBC, which are in line with the *Trade for all* strategy. The last issue will be discussed more thoroughly in the next section.

Responsible business conduct in the EU's trade/investment agreements

According to the new rules introduced by the TFEU, the EU institutions draft negotiating mandates if the grouping plans to sign international trade or investment agreements. In the case of the newly negotiated agreements, more prominence in these mandates is given to provisions related to sustainable development and CSR/RBC issues. It is a novelty in comparison to traditional agreements. The "new generation" of trade/investment agreements promotes investment that is mindful of environmental and labor standards, human rights, RBC, and sustainable development. These agreements establish a legal framework to achieve these goals. This framework includes provisions that ensure that strong labor and environmental standards are incorporated into the national legal

frameworks of the agreement parties. These standards must align with internationally recognized principles. In turn, investors are also expected to comply with these standards and responsible business conduct principles, accordant with the internal legal systems. Therefore, investors are legally bound by all legal obligations of the host country, including the highest levels of environmental and labor protection standards (European Commission 2024).

In practice, enforcing responsible business conduct and sustainable development provisions in international trade and investment relations might pose problems that require special solutions.

The Free Trade Agreement (FTA) between the EU and **South Korea**, signed in 2010, is the first of the "new generation" agreements. While promoting FDI in bilateral relations, the agreement emphasizes that this activity must not undermine environmental, labor, or occupational health and safety standards set by the laws of the parties (Article 1.1 (h)). The Agreement contains a chapter related to trade and sustainable development issues, which also refers to investment and corporate social responsibility (Chapter 16) (OJEU 2011).

The Comprehensive Economic and Trade Agreement (CETA) between the EU and **Canada**, which contains a provision indicating the importance of addressing specific sustainable development issues (Article 22.3), foresees the commitments of both parties to review, monitor and assess the impact of the implementation of the Agreement on sustainable development in their territories. This should identify any need for action that may arise in connection with the Agreement (OJEU 2017).

The Agreement between the EU and Japan for an Economic Partnership includes a general statement related to creating a better climate for the development of trade and investment between the parties, as well as for the progressive and reciprocal liberalization of trade in services and investment, and cooperation on electronic commerce (Article 8.1.1). Furthermore, the Agreement confirms the parties' rights to adopt regulatory measures within their territories that are necessary for the protection of public health, safety, the environment, public morals, social or consumer protection, as well as the promotion and protection of cultural diversity (Article 8.1.2) (OJEU 2018).

Apart from the aforementioned agreements, the EU negotiated and signed several agreements that contain investment-related provisions. These include agreements with Colombia, Ecuador, and Peru (2012), Ukraine, Moldovia, Georgia (2014), Armenia (2017), Singapore and Vietnam (2018). The agreements with Singapore and Vietnam are targeted at investment protection between the cooperating parties (UNCTAD 2023a).

The EU also concluded in principle the negotiations on the Comprehensive Agreement on Investment (CAI) with China in 2020. According to information from the European Commission, both sides are now working towards finalizing the text of the agreement

(European Commission 2023c). It is China's first agreement that contains a section on "investment and sustainable development". China agreed to accept particularly important commitments related to labor, the environment, and climate. The agreement also includes the obligation not to lower environmental and labor standards to attract investment, as well as the obligation to promote responsible business conduct. The agreed commitments will be subject to a specifically constructed enforcement mechanism. Given a high degree of transparency, it involves an independent panel of experts and the participation of civil society (European Commission 2023c).

Due to its novelty, the CAI is expected to play a significant role in developing international economic policy. Chaisse (2022, p. 3) stated: "CAI's Section IV on investment and sustainable development can become a major source of inspiration for a new generation of trade and investment treaties worldwide."

To sum up, after gaining competence in investment policy, the EU has been striving to include sustainable development and RBC into the "new generation" of international trade and investment agreements. These agreements often include general clauses on sustainable development and RBC that emphasize:

- The importance of addressing specific sustainability issues and RBC/CSR,
- The promotion of FDI without lowering or reducing environmental and labor standards,
- The need for cooperation in the field of sustainable development.

While both parties retain their "rights to regulate" within the territories they treat as a vested interest, the enforcement mechanisms for these agreements are seen as relatively weak, often referred to as "soft law." These mechanisms include:

- Reviewing, monitoring, and assessing how implementing the agreements impacts sustainable development in their territories.
- Individual and joint assessments of how well the agreements' provisions are being followed.
- Consulting and seeking solutions to resolve problems arising between the parties.
- Appealing to a panel of experts established under the agreement's rules.

These options support the view that the current enforcement measures are not particularly strong. The only stronger action listed by the EU is 'Strengthening enforcement by means of trade sanctions as a measure of last resort' (European Commission 2023d). Nevertheless, the European Commission launched the first enforcement case regarding the labor commitments of South Korea under the EU–South Korea trade agreement (Van der Loo and Hahn 2020).

Box 1
The EU–South Korea dispute settlements case under the EU–South Korea trade agreement

On 17 December 2018, the EU requested **formal consultation** with the government of South Korea regarding the implementation of sustainable development commitments under the EU–South Korea FTA of 2010. The provisions of the Korean Trade Union Act appeared to be inconsistent with Korea's obligations related to multilateral labor standards and the Agreement with the EU.
On 4 July 2019, the second phase of arbitration started when the consultation did not provide a satisfactory solution. The EU requested **a panel of experts** to examine the problem.
On 25 January 2021, **the panel report** was published, confirming the EU's concerns that South Korea had not acted consistently with its trade and sustainable development obligations under the EU–South Korea trade agreement. The independent panel concluded that South Korea needed to adjust its labor laws and practices and swiftly continue ratifying four fundamental ILO Conventions to comply with the agreement.
The implementation of the panel's recommendations will be monitored by the Trade and Sustainable Development Committee created under the terms of the EU–South Korea trade agreement.

Source: European Commission n.d., *Korea…*; European Commission 2019b; 2021.

The execution of corporate sustainability due diligence

The implementation of responsible business behavior presents problems that have motivated the EU to seek legal solutions in this field. The European Commission's proposal to implement *the Directive on Corporate Sustainability Due Diligence* can be viewed as an attempt to overcome these problems in value chains (European Commission 2022a).

The proposal is based on Articles 50 and 114 of the Treaty on the Functioning of the European Union. It aims to foster sustainable and responsible corporate behavior throughout global value chains with special reference to the effective protection of human rights and the environment. Unlike the previous voluntary approach to CSR/RBC, two groups of **EU companies and non-EU companies** that operate in the EU now face legal obligations regarding due diligence. To comply, companies must integrate due diligence into their policies, identify potential adverse impacts of their activities on human rights and the environment, and, where necessary, prevent, mitigate, or bring to an end these impacts.

Companies subject to this new law are defined by the number of employees and the amount of net turnover worldwide[2]. The proposal applies to the operations of these companies, their subsidiaries, and their value chains, which means that both direct and indirect established business relationships should be subject to the regulation. National

2 Group 1 includes all EU limited liability companies of substantial size and economic power (with 500+ employees and EUR 150 million+ in net turnover worldwide). Group 2: Other limited liability companies operating in defined high impact sectors, which do not meet both Group 1 thresholds, but have more than 250 employees and a net turnover of EUR 40 million worldwide and more (European Commission 2022b).

administrative authorities appointed by the Member States will enforce these mandatory rules. **Non-compliance** may result in fines and legal actions for damages by victims. The proposal also introduces directors' duties to establish and oversee the implementation of due diligence and to integrate it into the corporate strategy. Additionally, supporting measures are planned to help all companies adjust to the new legal situation, with special consideration for small and medium enterprises that might be indirectly affected by the new law (European Commission 2020a; 2022b).

While the legislative process for this directive is ongoing, with the final text yet to be determined, the character and potential role of the document can already be evaluated at this stage. The proposal can be seen as complementary to the existing **voluntary** international standards on RBC. Nevertheless, it will introduce **mandatory** human rights and environmental due diligence in value chains. This should better integrate social, environmental, and economic responsibility with everyday business operations and decision-making and embed CSR/RBC ideas in business practice and corporate value systems.

However, the shift from voluntary to mandatory RBC creates dissonance in the traditional understanding of CSR/RBC, which emphasizes voluntary action as an intrinsic feature.

The directive has both horizontal and sectoral dimensions. Its regulations target companies of substantial size and economic power, regardless of sector, as well as less economically powerful companies that operate in defined high-impact sectors. The directive foresees "strong" measures of enforcement, which contrast with the "soft" ones found in trade/investment treaties.

Some EU Member States have already introduced their own measures to deal with problems of due diligence, often using the existing international voluntary standards on responsible business conduct, while others are currently developing their own legal frameworks in this area. France and Germany have adopted mandatory national due diligence laws. However, this diversity in legal frameworks leads to fragmentation and barriers within the EU single market, creating additional burdens and costs for companies that operate across borders (Spinaci 2022). In this context, the EU's initiative to regulate due diligence in value chains might be viewed as a complementary element of the EU's investment policy.

Negotiations on the WTO Agreement on Investment Facilitation for Development – the EU's position

FDI policies range from liberal to restrictive models of policymaking, depending on the global situation and the country's attitudes. With a recent trend towards more restrictive FDI policies, the WTO member states' initiative to negotiate an agreement on facilitating investment is a welcome development. The IFD Agreement covers all sectors, i.e., services and non-services sectors. However, it will not address issues such as market access, investment protection, or investor–state dispute settlements (ISDS) (WTO 2023).

Investment facilitation aims to create a more transparent, efficient, and investment-friendly business climate, making it easier for investors to invest, conduct everyday business, and develop existing investment projects. Both host and home countries benefit from mutually beneficial cooperation that supports and attracts sustainable investment. Investment facilitation will create conditions that are conducive for international investment flows.

An informal dialogue on investment facilitation started in the WTO in 2017 at the initiative of developing and least-developed countries. Formal negotiations were launched in 2020, and the single negotiating text, the "Draft IFD Agreement," was circulated among the participants of the negotiations in December 2022. In November 2023, the participants finalized the text of IFD Agreement. It should complement the WTO Members' efforts to facilitate investment undertaken so far (WTO 2023; 2024).

The IFD Agreement targets key areas for facilitating investment and addressing problems in this area. They include:

- Transparency of investment measures
- Streamlining and speeding up administrative procedures
- Establishing focal points
- Promoting domestic regulatory coherence and cross-border cooperation on investment facilitation
- Supplier-development programs
- Providing special and differential treatment for developing and least-developed countries
- Encouraging **sustainable investment**.

The section on sustainable investment focuses on responsible business conduct and anti-corruption measures (WTO 2024).

Sustainable investment is "investment that, while being commercially viable, involves best efforts towards directly making a reasonable contribution to the economic, social and environmental development of host countries, and takes place in the context of fair governance mechanisms" (Berger et al. 2021). Analyses suggest that the agreement offers limited measures to encourage the flow of such investment. Responsible business conduct, which could contribute to achieving sustainable development goals, will likely be promoted as a **voluntary** activity (Berger et al. 2021). Consequently, the measurable outcomes for achieving the Agreement's main objectives would be limited.

The EU has participated in the WTO's investment facilitation negotiations from the outset and has declared its commitment to this process (European Commission 2019a). This stance was confirmed by the EU's decision to open negotiations on an investment facilitation agreement with Angola, including all elements of the WTO/IFD Agreement's proposals. *The EU-Angola Sustainable Investment Facilitation Agreement* (SIFA) entered into force in 2023 (European Commission 2023e). These developments suggest that negotiations on the WTO/IFD agreement have already helped reorient the EU's investment policy towards facilitating sustainable development in host countries.

Regarding CSR/RBC, the EU supports promoting the adoption of these practices by enterprises and investors. This aims to contribute to sustainable development by disseminating and using relevant, internationally agreed instruments in this area and exchanging information and best practices related to responsible business behavior. However, the EU's stance on corporate sustainability due diligence, as presented in the previous section, indicates that it is pursuing stronger legal measures to enforce corporate sustainability.

Conclusion

Corporate Social Responsibility and Responsible Business Conduct have a common feature: they are voluntary. Both approaches also recognize the same dimensions of business responsibility – social, economic, and environmental issues in business activities – which are significant for countries' sustainable development. Thus, it is justified to treat these notions as interchangeable. However, the two concepts treat the role of government differently. In CSR, the government's role is reduced to promoting the concept, while in RBC, governments have some commitments and are expected to act as promotors, respond to inquiries, and mediate potential conflicts.

The EU promotes CSR/RBC within the single market, implementing the subsequent strategies and undertaking numerous actions, and in international relations, using trade and investment cooperation. The EU sees CSR/RBC as a vital tool for achieving the UN Agenda 2030's SDGs. Hence, its trade/investment policy instruments

support voluntary responsible business behavior. One of them is trade agreements, which contain investment rules or standalone investment agreements negotiated and signed with third countries.

The EU has introduced special provisions on sustainable development and CSR/RBC into a new generation of trade/investment agreements, such as the agreements with South Korea, Canada, and Japan. The main motive behind this attitude is the desire to achieve environmental, social, and economic progress in sustainable development through international cooperation. The main problem with this strategy, however, is enforcing the obligations related to responsible business conduct.

All but one of the measures introduced in the new generation of trade/investment agreements should be categorized as soft. The only strong instrument, i.e., trade sanctions, is treated as a last resort and has not yet been used.

Adopting *the Directive on Corporate Sustainability Due Diligence* foresees a change in the character of responsible business conduct in value chains. The previously voluntary RBC will be replaced by mandatory human rights and environmental due diligence in value chains. The WTO's *Agreement on Investment Facilitation Framework for Development* faces the same problem that the EU is trying to address: the choice between voluntary and mandatory RBC. It is likely that RBC will be promoted as a voluntary activity.

The EU's common investment policy is adapting to address new challenges in international economic relations. The new instruments are used to liberalize and facilitate foreign direct investment and to support the achievement of a broader goal, which is sustainable development on a global scale. The negotiations on the WTO/IFD Agreement could further accelerate the re-orientation of the EU's policy.

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Odpowiedzialne prowadzenie działalności biznesowej w świetle polityki inwestycji Unii Europejskiej

Celem artykułu jest zbadanie roli odpowiedzialnego prowadzenia biznesu (RBC)/społecznej odpowiedzialności biznesu (CSR) we wspólnej polityce inwestycji Unii Europejskiej (UE) w odniesieniu do bezpośrednich inwestycji zagranicznych (BIZ), w kontekście szerszego celu, jakim jest zrównoważony rozwój. Unia prowadzi wspólną politykę inwestycji na mocy Traktatu o funkcjonowaniu Unii Europejskiej. W ramach tej polityki UE wykorzystuje swoje prawo do negocjowania nowej generacji umów o handlu i inwestycjach. Nowym rozwiązaniem w tych umowach jest uwzględnienie postanowień o zrównoważonym rozwoju oraz RBC/CSR. W artykule prezentowane są przykłady takich postanowień, zawartych w umowach między UE a Republiką Korei, Kanadą i Japonią. Unia postrzega RBC/CSR jako ważny środek osiągnięcia celów zrównoważonego rozwoju, ustanowionych w Agendzie 2030. Odpowiedzialne prowadzenie działalności biznesowej jest promowane i wspierane przez instrumenty polityki handlowej i inwestycyjnej UE. Ze względu na fakt, że RBC/CSR mają dobrowolny charakter, wdrożenie umownych zobowiązań może polegać jedynie na „miękkich" środkach i działaniach. Jedyny „silniejszy" instrument pozostający do dyspozycji stron umowy, tj. sankcje handlowe, jest traktowany jako wyjątkowy i nie był dotychczas wykorzystywany. Oczekuje się, że zakończone negocjacje w ramach WTO, dotyczące umowy o ułatwieniach dla inwestycji, wzmocnią reorientację polityki UE w kierunku ułatwiania inwestycji w stosunkach z krajami rozwijającymi się.

Słowa kluczowe: polityka inwestycyjna UE, bezpośrednie inwestycje zagraniczne (BIZ), handel międzynarodowy, odpowiedzialne prowadzenie działalności biznesowej, społeczna odpowiedzialność przedsiębiorstw, zrównoważony rozwój

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.29

Determinants of Industry 4.0 Readiness in the Manufacturing of the V4 Economies

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Abstract

The article presents the results of research aimed at identifying the determinants of Industry 4.0 (I4.0) readiness in manufacturing and assessing the relevant progress made by the Visegrad Group (V4; i.e. the Czech Republic, Hungary, Poland and Slovakia) countries between 2011 and 2021.

The investigation relies on the authors' proposal for twelve variables that constitute the basis for a study using principal component analysis (PCA). Based on the calculation of factor loadings, the study produces a composite indicator of I4.0 readiness. It is followed by an assessment of the V4 economies against the backdrop of the other EU Member States.

The V4 economies showed relatively low levels of I4.0 readiness and made no significant progress. The top performer was the Czech Republic, ranked 12th, on average, between 2011 and 2021. It was closely followed by Hungary (14th) and Slovakia (17th). Poland was ranked the lowest (20th).

The main contribution is the proposal of a set of determinants of I4.0 readiness in manufacturing. Measuring the progress of I4.0 readiness in the V4 economies and identifying barriers to I4.0 implementation in manufacturing may have application value for public policies

Keywords: Industry 4.0, Industry 4.0 readiness, Industry 4.0 transformation, manufacturing, Visegrad Group

JEL: O14, O33

Received: 21.02.2024. Verified: 30.05.2024. Accepted: 24.09.2024

Introduction

Technology changes over time, revolutionising production systems and thus shaping economic systems, social structures and public policies. Although the three main industrial revolutions, which began in the second half of the 18th century, had distinguishing features, the focus was always on the introduction of breakthrough technologies. By integrating material and digital resources, the ongoing Fourth Industrial Revolution has redefined production and working methods. In the context of organising manufacturing, it is characterised by breakthrough Industry 4.0 (I4.0) technologies, such as artificial intelligence (AI), the Internet of Things (IoT), additive manufacturing, robotics and cloud computing. The implementation of those solutions offers a wide range of benefits, including increased production efficiency, reduced costs, improved product quality and adaptation to ever-changing market needs. However, it involves strict cooperation between IT and production, as well as organisational flexibility in adapting to the fast pace of change in the business environment. Over the past decade, in response to the challenges of global competition, the majority of European Union (EU) governments have recognised I4.0 as a priority, adopting strategic action plans to transform existing divisions of industry, enhancing productivity and upgrading personnel skills with regard to advanced technologies. Despite this consensus, however, I4.0 readiness in manufacturing is a relatively new concept, and measuring it and selecting determinants remain a challenge.

The Visegrad Group, or V4, refers to a cultural and political alliance of four Central European countries: the Czech Republic, Hungary, Poland, and Slovakia. These nations have a significant manufacturing sector, contributing an average of 20% to their economies (according to UNIDO 2024). Additionally, they play a major role in global manufacturing supply chains, with an average participation rate of 65% (OECD 2024). Given this strong manufacturing base, the article explores the concept of I4.0 readiness within the V4 economies.

The research presented here identifies the determinants of I4.0 readiness in manufacturing and assesses the relevant progress made by the V4 countries between 2011 and 2021. A literature review allowed us to define such factors considering the challenges of the Fourth Industrial Revolution. The investigation was carried out using principal component analysis (PCA) based on twelve variables divided into four themes: production and export capacity, human capital, research and development infrastructure, and the use of ICT. Based on the factor loadings calculated for the first principal component, a composite indicator of I4.0 readiness was developed. It allowed us to estimate the V4 countries' I4.0 readiness in manufacturing and rank all of the EU economies.

The article begins by presenting a review of the literature on the essence and determinants of I4.0. It is followed by a description of the methodology and a discussion of the results. In the conclusion, the article confronts the key findings with the barriers to implementing I4.0 identified in the literature review.

Defining the essence of Industry 4.0 in manufacturing

Despite its popularity, the definition of I4 remains unclear (Ojra 2019; Rupp et al. 2021). Often described as the integration of complex physical machinery, equipment and devices with networked sensors and software, I4.0 aims to optimise planning and control for better business performance (Hermann, Pentek, and Otto 2016). Properly implemented I4.0 solutions are expected to enable the intelligent networking of all industrial processes and products, resulting in improved quality and efficiency (Kora and Beluli 2022).

I4.0 covers the whole value chain, from design and development through production, management and logistics, to the distribution of final products. Therefore, it involves new business models and strategies (Prause 2015). The distinguishing feature of process networking and digitisation is the horizontal and vertical integration of production systems, determined by real-time data exchange and flexible production adapted to market and customer needs (Wodnicka 2021). The core technology, as revolutionary as those related to the previous revolutions, is that of cyber-physical systems (CPS). They enable the development of autonomous production processes, which, based on double representation, become intelligent, i.e., communication algorithms and decision-making components that can determine their production line configuration (Lee, Bagheri, and Kao 2015). The development of advanced production is also referred to as smart manufacturing or an adaptable system where flexible lines automatically adjust production processes to many types of products and changing conditions (Wang et al. 2016).

The term I4.0 is frequently used more broadly to capture the sum of all breakthrough innovative solutions developed and implemented in a value chain or even identified with the Fourth Industrial Revolution (Frank, Dalenogare, and Ayala 2019). However, an industrial revolution is a more complex phenomenon which cannot be defined solely based on breakthrough technologies (Klingenberg, Borges, and Antunes 2022). Innovation certainly drives subsequent industrial revolutions, becoming their tool, but the overall outcomes are deep, structural and socio-economic changes.

Industry 4.0 readiness – the methodological assumptions

The examination proposes an indicator of I4.0 readiness, developed using PCA. In various fields of study, it is one of the most frequently used multivariate statistical methods, first proposed by Karl Pearson (1901) and then formalised and popularised by Harold Hotelling (1933). The method makes it possible to transform high-dimensional data into lower dimensional data, albeit with some loss of information regarding the original variables (Ding and He 2004).

Multivariate analysis relies on the principle of compromise or trade-off, which means that a complex system of dependencies between multiple variables is presented in simplified terms and in a strongly reduced number of dimensions. However, this simplification results in an inaccurate mapping of particular original variables (Sagan 2004). An appropriate aggregation of the original variables used in PCA produces orthogonal, uncorrelated variables, referred to as principal components (Sztemberg-Lewandowska 2017). In the next step, these components are ordered by the amount of variance that each component explains (Wnorowski 2011; Abdi, Williams, and Valentin 2013).

The mathematical model in principal component analysis can be represented as the following system of linear equations:

$$\begin{aligned} X_1 &= a_{11}Z_1 + a_{12}Z_2 + \ldots + a_{1p}Z_p \\ X_2 &= a_{21}Z_1 + a_{22}Z_2 + \ldots + a_{2p}Z_p \\ &\vdots \\ X_3 &= a_{p1}Z_1 + a_{p2}Z_2 + \ldots + a_{pp}Z_p \end{aligned} \tag{1}$$

where original variables X_i for $i \in \{1,\ldots,p\}$ are expressed as linear combinations of latent variables Z_j for $j \in \{1,\ldots,p\}$, called principal components. The coefficients a_{ij} for $i, j \in \{1,\ldots,p\}$ specify the weight of a given component in the description of empirical variables.

The matrix form of the PCA model is as follows:

$$X = A^{*}Z, \tag{2}$$

where $X = \left[X_1, X_2, \ldots, X_p\right]^T$ is the matrix of standardised variables, $Z = \left[Z_1, Z_2, Z_p\right]^T$ – the matrix of principal components, and $A = [a_{ij}]_{pp}$ is the matrix of coefficients of that principal component (Sztemberg-Lewandowska 2017).

To construct a composite indicator of I4.0 readiness, the values of principal components for each economy were normalised. This normalisation aims to ensure comparability of characteristics under different denominations (Borys 1980; Kukuła 2000). Based on the literature review, zero unitarisation was chosen as the normalisation method. The mathematical notation of the zero unitarisation method is as follows:

$$U_{jnt} = \frac{\left[z_{jnt} - \min\left\{z_{jnt}\right\}\right]}{r_j}, \tag{3}$$

$$r_j = \max\left\{z_{jnt}\right\} - \min\left\{z_{jnt}\right\}, \tag{4}$$

where U_{jnt} – value of the normalised j-th principal component z for the n-th case in year t, r_j – value range for z_{jn}.

The I4.0 readiness indicator relies on variables identified through a critical review of major publications in the field (Fagerberg 1987; Drabińska 2012; Brettel et al. 2014; Haverkort and Zimmermann 2017; Haddud et al. 2017; Siuta-Tokarska 2017; Kamble, Gunasekaran, and Sharma 2018; Genest and Gamache 2020; Nhamo, Nhemachena, and Nhamo 2020; Dou et al. 2021; UN 2023). Table 1 presents a systematisation of the main explanatory variables that reflect an economy's I4.0 readiness. The assessment of the V4 economies was based on a selection of indicators describing four themes: production and export capacity, human capital, research and development infrastructure, and the use of ICT.

Table 1. Explanatory variables used to determine Industry 4.0 readiness

Theme	Indicator	Abbreviation	Data source
Production and export capacity	Medium- and high-tech manufacturing value added (% of total manufacturing value added)	MHVAsh	UNIDO
	Manufacturing value added *per capita*	MVApc	UNIDO
	Medium- and high-tech manufacturing exports (% of total manufacturing exports)	MHXsh	UNIDO
Human capital	Percentage of the population aged 25–34 with tertiary educational attainment (%)	TEAsh	Eurostat
	Employment in high- and medium-high technology manufacturing sectors (% of total employment)	EMHsh	Eurostat
	ICT specialists in employment (% of total employment)	ICTEsh	Eurostat

Theme	Indicator	Abbreviation	Data source
Research and development infrastructure	Research and development expenditure (% of GDP)	RDEsh	Eurostat
	Patent applications (per million inhabitants)	PAvol	Eurostat
	Research and development personnel (% of total labour force)	RDEvol	Eurostat
Use of ICT	Percentage of people employed in manufacturing with access to the Internet for business purposes (% of total employment)	IUMsh	Eurostat
	Percentage of manufacturing enterprises that provided training to develop/upgrade their personnel's ICT skills (% of enterprises)	SKTsh	Eurostat
	E-government activities of individuals via websites (% of the population)	GOVsh	Eurostat

Source: authors' elaboration based on data from Eurostat 2023; UNIDO 2023.

The *production and export capacity* theme comprises indicators of the production capacity of manufacturing, with a particular focus on medium- and high-tech manufacturing sectors. Therefore, the selection includes:

- medium- and high-tech manufacturing value added expressed as a percentage of total manufacturing value added,
- medium- and high-tech manufacturing exports as a percentage of total manufacturing exports,
- a traditional measure of production capacity in the economy, i.e. manufacturing value added *per capita*.

Another theme for the analysis was *human capital*, reflected in the percentage of the population aged 25–34 with a university degree, employment in high- and medium-high technology manufacturing sectors as a percentage of total employment, and ICT specialists in employment as a percentage of total employment. Human capital is of paramount importance to the implementation of I4.0 technologies and, thus, of advanced production methods. Based on the literature review, the selection includes three indicators that describe *research and development infrastructure*: research and development expenditure (% of GDP), patent applications per million inhabitants, and research and development personnel as a percentage of the total labour force.

Intellectual property is essential to the competitiveness of economies and manufacturing, while the R&D sector significantly contributes to creating the framework conditions for the transition towards I4.0. As the last theme for analysis, the use of ICT was selected as a major driver of the Fourth Industrial Revolution. It is even recognised as the outcome of the dynamic expansion of information technology.

To measure ICT implementation, the selection comprises two indicators that only concern manufacturing: the percentage of people employed in manufacturing with access to the Internet for business purposes (% of total employment) and the percentage of manufacturing enterprises that provided training to develop/upgrade their personnel's ICT skills (% of enterprises).

The third selected determinant is the e-government activities of individuals via websites as a percentage of the population. This somewhat reflects the digital literacy and skills of a country's population.

An important stage of the PCA procedure involved determining the principal components. Using RStudio, we generated 12 components that correspond to the 12 explanatory variables under analysis. Table 2 presents the following measures calculated for the principal components: the standard deviation, the proportion of variance, and the cumulative variance.

Table 2. Principal components

Principal component number	Standard deviation	Proportion of variance	Cumulative variance
1	2.51 381	0.528 382	0.528 382
2	1.548 146	0.200 404	0.728 787
3	0.908 721	0.069 047	0.797 834
4	0.772 069	0.049 842	0.847 676
5	0.695 539	0.040 451	0.888 126
6	0.630 969	0.033 289	0.921 415
7	0.545 815	0.024 912	0.946 325
8	0.405 527	0.013 751	0.960 076
9	0.383 926	0.012 325	0.972 401
10	0.361 613	0.010 934	0.983 335
11	0.316 814	0.008 393	0.991 727
12	0.314 548	0.008 273	1

Source: authors' own calculations based on the data identified in Table 1.

Examination of the data in Table 2 reveals a clear decreasing trend in the variance. Each subsequent principal component explains a lower proportion of the total variance. The first two principal components account for 72.8% of information on the original variables, while the first principal component alone explains approx. 53% of total variance. Table 3 provides detailed numerical data regarding factor loadings. Analysing the data in Table 3 allows us to identify correlations between variables and between a variable and the relevant principal component.

Table 3. Factor loading values for the first and second principal components, 2011–2021

Theme	Indicator	First principal component	Second principal component
Production and export capacity	Medium- and high-tech manufacturing value added (% of total manufacturing value added)	0.25326	0.42209
	Manufacturing value added *per capita*	0.25865	0.04188
	Medium- and high-tech manufacturing exports (% of total manufacturing exports)	0.15822	0.48618
Human capital	Percentage of the population aged 25–34 with tertiary educational attainment (%)	0.14593	–0.44553
	Employment in high- and medium-high technology manufacturing sectors (% of total employment)	0.03337	0.54687
	ICT specialists in employment (% of total employment)	0.34109	–0.14443
Research and development infrastructure	Research and development expenditure (% of GDP)	0.34424	0.11306
	Patent applications (per million inhabitants)	0.35030	–0.03736
	Research and development (R&D)	0.36107	–0.01666
Use of ICT	Percentage of people employed in manufacturing with access to the Internet for business purposes (% of total employment)	0.36801	–0.08671
	Percentage of manufacturing enterprises that provided training to develop/upgrade their personnel's ICT skills (% of enterprises)	0.30875	–0.08128
	E-government activities of individuals via websites (% of the population)	0.32068	–0.19160

Source: author's own calculations based on the data identified in Table 1.

When analysing factor loadings, attention must also be given to their signs, not just their values. Negative values indicate negative correlations, whereas a positive value reflects the significance of the variable concerned. The higher the value, the greater the weight of the variable for the principal component in question. Note that all the variables are positively correlated with the first principal component. The values obtained for the variables allowed us to determine the I4.0 readiness indicator.

The factor loadings for the first principal component indicate that countries with high values also maximise the performance of their manufacturing sectors in all the themes under examination, i.e. production and export capacity, human capital, research and development infrastructure, and the use of ICT. The most significant variables were those describing research and development infrastructure, the use of ICT, as well as ICT specialists in employment (ICTEsh) from the human capital theme. The least important variable was employment in high- and medium-high technology manufacturing sectors

(EMHsh). That dimension served to prepare the I4.0 readiness indicator, used to examine the Visegrad countries and the other EU Member States.

Benchmarking results for the Visegrad countries and the other EU Member States

The analysis compares the I4.0 readiness of the V4 countries with the other EU Member States (Table 4). The data reveal that the V4 economies were characterised by average levels of I4.0 readiness and made no significant progress in their performance during the 2011–2021 period. The highest indicator was noted for the Czech Republic, with an average score of 0.4854, although it showed a minor decrease of 0.007 (1.5%). Hungary was second, with an average of 0.3972. It managed to improve its score by 0.005 (1.4%). It was closely followed by Slovakia, with an average of 0.3438. However, as with the Czech Republic, its score at the end of the period was lower than that at the beginning, declining by 1.4% (0.005). Poland was ranked the lowest, with indicator values significantly below those obtained by the other V4 economies. Its average score was a mere 0.2421, despite an increase of 0.06.

No V4 country emerged as a leader in I4.0 readiness throughout the period in question. The Czech Republic ranked highest (12th on average), followed by Hungary (14th), Slovakia (17th) and Poland (20th). Hungary moved up one spot, while the Czech Republic remained stable at 12th. Poland and Slovakia dropped by one and two places, respectively. The EU's front-runners included Finland, Sweden, Denmark and Austria, while the poorest performers were Romania, Bulgaria, Cyprus and Latvia.

Table 4. Industry 4.0 readiness in the European Union Member States

Country	2011		2012		2013		2014		2015	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Austria	6	0.7250	6	0.7474	4	0.7705	4	0.7913	4	0.7947
Belgium	8	0.6710	8	0.6868	8	0.6975	8	0.6976	8	0.6844
Bulgaria	26	0.0999	26	0.1016	26	0.1274	26	0.1042	26	0.1094
Cyprus	22	0.1960	22	0.1818	25	0.1481	25	0.1616	25	0.1430
Czech Republic	**12**	**0.4841**	**12**	**0.4640**	**12**	**0.4710**	**12**	**0.4871**	**12**	**0.4785**
Germany	4	0.7805	4	0.7913	6	0.7525	7	0.7549	6	0.7458
Denmark	3	0.9431	3	0.9469	2	0.9721	3	0.9407	3	0.9270
Estonia	13	0.4156	13	0.4039	14	0.3976	15	0.3521	15	0.3863
Greece	25	0.1814	23	0.1765	22	0.2072	22	0.1996	22	0.2080

Country	2011		2012		2013		2014		2015	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Spain	14	0.3974	15	0.3912	13	0.4157	14	0.4070	13	0.4105
Finland	1	0.9943	2	0.9715	3	0.9693	1	1.0000	2	0.9438
France	11	0.6037	11	0.6046	10	0.6139	10	0.6175	9	0.6399
Croatia	21	0.2108	21	0.2024	20	0.2263	21	0.2127	20	0.2314
Hungary	**16**	**0.3543**	**14**	**0.4005**	**15**	**0.3916**	**13**	**0.4132**	**14**	**0.4046**
Ireland	5	0.7565	5	0.7836	5	0.7641	5	0.7629	7	0.7394
Italy	17	0.3526	17	0.3435	16	0.3530	17	0.3407	17	0.3506
Lithuania	23	0.1863	24	0.1756	23	0.1912	23	0.1995	23	0.2054
Luxembourg	9	0.6518	9	0.6544	9	0.6403	9	0.6561	10	0.6268
Latvia	24	0.1835	25	0.1686	24	0.1621	24	0.1735	24	0.1816
Malta	18	0.3251	18	0.3053	19	0.2719	19	0.2822	18	0.3439
Netherlands	7	0.7051	7	0.6912	7	0.7475	6	0.7552	5	0.7492
Poland	**20**	**0.2251**	**20**	**0.2290**	**21**	**0.2227**	**20**	**0.2183**	**21**	**0.2283**
Portugal	19	0.2724	19	0.2594	18	0.2751	18	0.2845	19	0.2492
Romania	27	0.0573	27	0.0983	27	0.0533	27	0.0461	27	0.0748
Sweden	2	0.9718	1	0.9909	1	0.9777	2	0.9438	1	0.9487
Slovenia	10	0.6191	10	0.6101	11	0.5943	11	0.5732	11	0.5486
Slovakia	**15**	**0.3614**	**16**	**0.3449**	**17**	**0.3118**	**16**	**0.3497**	**16**	**0.3714**

Country	2016		2017		2018		2019		2020		2021	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Austria	4	0.8079	5	0.7879	4	0.7789	5	0.7503	8	0.7072	7	0.6816
Belgium	8	0.6887	8	0.7134	8	0.7253	7	0.7238	6	0.7312	6	0.7715
Bulgaria	26	0.1059	26	0.0912	26	0.1032	26	0.0914	26	0.0693	26	0.0537
Cyprus	25	0.1362	25	0.1582	25	0.1590	25	0.1830	25	0.1953	22	0.2411
Czech Republic	**12**	**0.4568**	**12**	**0.4829**	**12**	**0.5200**	**12**	**0.5089**	**12**	**0.5091**	**12**	**0.4768**
Germany	7	0.7376	7	0.7284	6	0.7343	8	0.7169	7	0.7085	9	0.6223
Denmark	2	0.9348	2	0.9133	2	0.9245	2	0.9063	3	0.9045	3	0.8692
Estonia	15	0.3936	15	0.4006	15	0.3982	13	0.4183	14	0.4049	14	0.3904
Greece	22	0.2020	23	0.1890	23	0.1944	24	0.1865	24	0.2262	25	0.2106
Spain	13	0.4179	14	0.4133	14	0.4063	15	0.3933	15	0.3980	13	0.3910
Finland	3	0.8939	3	0.8967	3	0.8984	3	0.8771	2	0.9271	2	0.9054
France	10	0.6369	10	0.6250	9	0.6438	9	0.6524	9	0.6113	10	0.5845

Country	2016		2017		2018		2019		2020		2021	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Croatia	20	0.2390	21	0.2124	21	0.2254	22	0.2169	23	0.2295	24	0.2383
Hungary	**14**	**0.3998**	**13**	**0.4186**	**13**	**0.4128**	**14**	**0.4083**	**13**	**0.4059**	**15**	**0.3594**
Ireland	5	0.7921	4	0.8039	7	0.7330	6	0.7404	5	0.7439	5	0.7740
Italy	16	0.3538	16	0.3624	16	0.3859	16	0.3727	17	0.3443	17	0.3398
Lithuania	23	0.1896	22	0.2043	22	0.2013	21	0.2445	21	0.2532	20	0.2883
Luxem-bourg	9	0.6537	9	0.6300	10	0.6101	10	0.6242	11	0.5532	8	0.6711
Latvia	24	0.1861	24	0.1829	24	0.1651	23	0.1900	22	0.2350	23	0.2406
Malta	17	0.3530	17	0.3512	18	0.3262	18	0.2808	19	0.2925	16	0.3407
Nether-lands	6	0.7647	6	0.7821	5	0.7748	4	0.7597	4	0.7874	4	0.7901
Poland	**21**	**0.2312**	**20**	**0.2365**	**19**	**0.2563**	**20**	**0.2596**	**20**	**0.2677**	**21**	**0.2882**
Portugal	19	0.2581	19	0.2553	20	0.2458	19	0.2709	18	0.2958	18	0.3189
Romania	27	0.0744	27	0.0707	27	0.0663	27	0.0434	27	0.0114	27	0.0000
Sweden	1	0.9386	1	0.9529	1	0.9382	1	0.9861	1	0.9983	1	0.9986
Slovenia	11	0.5459	11	0.5367	11	0.5474	11	0.5533	10	0.5593	11	0.5676
Slovakia	**18**	**0.3333**	**18**	**0.3254**	**17**	**0.3504**	**17**	**0.3663**	**16**	**0.3555**	**19**	**0.3117**

Source: prepared on the basis of the author's own calculations.

Identifying barriers to Industry 4.0 implementation in manufacturing

Given the limited progress observed in the I4.0 readiness of the V4 economies, identifying barriers to implementation is crucial. The literature review reveals five key categories hindering the adoption of I4.0 solutions in manufacturing: costs, knowledge, attitude to change, the organisation and structure of production, the institutional architecture, and public policies. Table 5 presents a more detailed breakdown and description of these barriers.

Table 5. Barriers to implementing solutions of the Fourth Industrial Revolution

Barrier	Description	Authors
Costs	High capital expenditure on investments in I4.0 technologies. Uncertain return on investment	Geissbauer, Schrauf, and Koch 2014; Kiel, Arnold, and Voigt 2017; Kamble, Gunasekaran, and Sharma 2018; Halse and Jæger 2019; Horváth and Szabó 2019; Da Silva et al. 2020; Cugno, Castagnoli, and Büchi 2021

Barrier	Description	Authors
Knowledge	Lack of key skills, competence, awareness and knowledge with regard to solutions Education and training programmes adapted to I4.0 needs	Hung 2016; Kiel, Arnold, and Voigt 2017; Halse and Jæger 2019; Horváth and Szabó 2019; Karadayi-Usta 2019; Luthra and Mangla 2019; Masood and Sonnrtag 2020; Govindan and Arampatzis 2023
Attitude to change	Fear of and resistance to change on the part of personnel Management commitment and leadership	Haddud et al. 2017; Horváth and Szabó 2019; Huang, Talla Chicoma, and Huang 2019; Machado et al. 2019; Ingaldi and Ulewicz 2020; Kumar, Singh, and Dwivedi 2020; Chauhan, Singh, and Luthra 2021
Organisation and structure of production	Organisational structure of enterprises Low standardisation of production processes	Müller, Buliga, and Voigt 2018; de Sousa et al. 2018; Halse and Jæger 2019; Horváth and Szabó 2019; Bakhtari et al. 2020; Cugno, Castagnoli, and Büchi 2021; Narwane et al. 2021
Institutional architecture and public policies	Public sector support and legislation Availability of infrastructure for ICT	Schröder 2016; Kamble, Gunasekaran, and Sharma 2018; Aggarwal, Gupta, and Ojha 2019; Cugno, Castagnoli, and Büchi 2021

Source: authors' elaboration based on Kamble, Gunasekaran, and Sharma R. 2018, Raj et al. 2020, and Sayem et al. 2022.

The high costs involved in implementing I4.0 solutions present a significant challenge, although there are also considerable risks related to the high degree of complexity of such production systems. Thus, there is a need for significant capital expenditure, increasing business uncertainty and posing a major challenge to corporate liquidity.

A lack of knowledge and know-how creates another hurdle. Many companies have a poor understanding of how I4.0 impacts businesses in the global economy. Additionally, there is a shortage of personnel with the digital skills and expertise to operate these advanced technologies (Luthra and Mangla 2018). Thus, while implementing I4.0 technologies requires personnel with advanced digital competencies, the skills gap in the majority of firms hinders progress (Govindan and Arampatzis 2023).

A third group of barriers is associated with attitudes to change, as evidenced by Ingaldi and Ulewicz (2020), Kumar, Singh, and Dwivedi (2020) and Chauhan, Singh, and Luthra (2021). Personnel's resistance to change and modern technological solutions poses a significant obstacle, adversely affecting transition-related business decisions, particularly in small and medium-sized enterprises. Inadequate leadership and managerial attitudes can be a hindrance, as managers should be advocates of change (Huang, Talla Chicoma, and Huang 2019; Kumar, Singh, and Dwivedi 2020). Leadership plays a key role in the era of I4.0 as business leaders decide on the implementation of solutions and should inspire their personnel (Govindan and Arampatzis 2023). The fear of failing, a low risk tolerance,

or frequently both, pose key barriers to innovation. Perseverance and learning from failures characterise most technology companies. At present, the focus is still on risk minimisation, even though doing things differently or new things is risky (Savage 2022).

The lack of standardised production processes and unsuitable organisation of production can hinder automation (Halse and Jæger 2019). Lastly, some barriers concern public policies and the institutional architecture in general. Given the complexity and dynamics of I4.0, governments must support, facilitate and speed up the digital transition (Bakhtari et al. 2020). Müller, Buliga, and Voigt (2018) pointed out that appropriate policy-making plays a key role in encouraging the adoption of I4.0 solutions.

Conclusions

The article presented the determinants of I4.0 readiness in manufacturing. By analysing these determinants, the study assessed the progress made by the V4 economies. The results reveal that the V4 economies lagged behind the other EU Member States at the end of the period under examination. The countries concerned were leaders of the proposed I4.0 readiness ranking nor did they note any significant improvements. In fact, Poland and Slovakia were lower in the ranking in 2021 compared to the beginning of the period covered.

Considering the pace and scale of the ongoing Fourth Industrial Revolution, this situation may adversely affect the competitiveness of manufacturing in the V4 in the coming years. Their relatively significant (both backward and forward) participation in global value chains, and the substantial contribution of their manufacturing sectors to GDP and employment, determines the need for systemic solutions.

To address this challenge, the article identified barriers to I4.0 implementation, and their analysis clearly points to the need for economic policy instruments to stimulate structural adjustments to improve the I4.0 readiness of the V4 economies. Priority areas include research and development infrastructure, the use of ICT, and human capital. The diffusion and proper implementation of I4.0 technologies are key to the further development and growth of manufacturing in the V4 economies.

An important added value of the research is the proposal of a set of determinants of I4.0 readiness in manufacturing. The index can be a useful research tool to analyse and compare other economies in this area.

The publication was co-financed from a subsidy granted to the Krakow University of Economic – Project No. 075/EEG/2022/POT.

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Determinanty gotowości przetwórstwa przemysłowego gospodarek V4 do wdrożenia Przemysłu 4.0

W artykule zaprezentowano wyniki badania, którego celem była identyfikacja czynników warunkujących poziom gotowości na wdrożenie Przemysłu 4.0 w obszarze przetwórstwa przemysłowego oraz ocena postępów gospodarek Grupy Wyszehradzkiej (V4) w tym zakresie w latach 2011–2021. W opracowaniu przedstawiono autorską propozycję dwunastu zmiennych, stanowiących podstawę badania przeprowadzonego metodą analizy głównych składowych (*Principal Component Analysis* – PCA). W efekcie badania na podstawie wartości ładunków czynnikowych opracowano syntetyczny wskaźnik gotowości na wdrożenie Przemysłu 4.0. Następnie oceniono pozycję gospodarek V4 na tle pozostałych krajów UE. Gospodarki krajów V4 prezentowały w badanym okresie relatywnie niski poziom gotowości na wdrożenie Przemysłu 4.0 i nie dokonały znaczącej poprawy swoich wyników w okresie poddanym analizie. Najwyższą pozycję osiągnęły Czechy, które w latach 2011–2021 plasowały się średnio na 12. miejscu. Tuż za Czechami znalazły się Węgry – średnio na 14. pozycji i Słowacja, której przypadło średnio 17. miejsce. Na najbardziej odległej pozycji znalazła się Polska, która była na 20. miejscu spośród wszystkich gospodarek UE.

Słowa kluczowe: Przemysł 4.0, gotowość na Przemysł 4.0, transformacja Przemysłu 4.0, przetwórstwo przemysłowe, Grupa Wyszehradzka

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.30

The Labour Market Situation of Population Groups in the Visegrád Countries

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Abstract

The paper presents the results of an analysis of selected population groups in the labour markets of the Visegrád Group (V4) countries (i.e., Czechia, Hungary, Poland and Slovakia) from 2015 to 2020. The study assesses the relative situation of these groups, taking into account the skill profiles of their members. Thus, we identify groups with the relatively best and worst employability prospects in the V4 labour markets. To this end, the parameters of a polynomial logit model (representing relative risk ratios for exiting employment or unemployment) are estimated.

The study reveals that in all V4 countries, tertiary graduates were in the best position in the labour markets. The highest-skilled professionals had the best chances of finding a job while being the least likely to become unemployed. The most uncertain labour market situation concerned people aged up to 24 years, the least-educated and low-skilled people, and people aged 55 years and older. This points to the need to provide support programmes targeted at these social groups, implemented within the public policies, i.e., labour market and educational policies, with special

Received: 12.10.2023. Verified: 14.02.2024. Accepted: 27.09.2024

emphasis on the adult learning system. The main contribution of the study is that it includes the task-content approach to analyse the employability prospects in the V4 labour markets.

Keywords: unemployment, employment, labour market situation of population groups

JEL: J21, J64

Introduction

The situation of people in the labour market varies with technological progress, demographic and migratory processes, phases and fluctuations in the economic cycle, and economic restructuring, which influence it with different intensities. This article presents the results of a study on the situation of selected labour force groups in the Visegrád Group (V4) countries (i.e., Czechia, Hungary, Poland and Slovakia) from 2015 to 2020, primarily to determine which of them fared best and worst, taking special account of their members' qualifications[1].

In order to assess the labour market position of particular groups, the parameters of a polynomial logit model (representing the relative risk ratios for exiting employment or unemployment) were estimated. For Czechia, Slovakia and Hungary, individual Labour Force Survey (LFS) data from 2015–2020 provided by Eurostat were used[2]. In the case of Poland, Eurostat's data did not have the four-digit codes for occupations and professions, preventing the identification of occupational groups based on the types of tasks they involve. Therefore, LFS individual data published by Statistics Poland (GUS) were used.

The article is structured as follows. Part 2 is a review of studies pertinent to the subject, and Part 3 presents the key indicators that characterise the V4 labour markets. Part 4 explains the polynomial logit model and the relative risk ratios for exiting employment or unemployment. In the final part, the conclusions from the research are summarised.

1 Based on the classification of occupations and professions, five groups of occupations were distinguished: non-routine cognitive personal (Group 1); non-routine cognitive analytical (Group 2); non-routine manual physical (Group 3); routine cognitive (Group 4); and routine manual (Group 5). The classification follows the one proposed by Acemoglu and Autor (2011).

2 The database was provided by Eurostat within the project "Technical change and polarisation of labour markets in the 'old' and 'new' EU Member States" conducted at the Faculty of Economics and Sociology, University of Lodz.

A review of the literature

Various research centres have long studied the labour market situation of population groups in the V4 countries. Most studies have been designed as literature reviews focused on selected labour market indicators or using the methods of descriptive statistics. More advanced statistical and econometric methods have been used relatively rarely, although recent years have seen an increase in the number of studies using them.

According to existing research, the V4 countries had considerably different levels of innovativeness and utilisation of human capital prior to becoming EU members. The most modern in that respect were the economies of Czechia and Hungary. The development of Poland's economy was primarily hindered by its obsolete structure (Gawrycka and Szymczak 2008).

Studies using the synthetic indicator of labour market development to explore V4 countries in the early years of their EU membership found that while the labour markets improved in all of them, they remained significantly different. The best situation (marking the greatest progress) occurred in Czechia and Slovakia. Compared with the other V4 countries, the labour market in Poland ranked relatively low, both in 2004 and 2008 (Gawrycka and Szymczak 2013), and its ranking did not change significantly in subsequent years. Czechia was an economic and labour market leader due to having the lowest and most stable unemployment rates, the lowest public debt and current account deficit levels, and the highest GDP per capita. Poland and Hungary lagged behind Czechia and Slovakia, even though Poland's economy developed at the fastest rate (Grabia 2014).

Studies of the V4 countries during the Great Recession showed that their unemployment rates increased while employment rates declined, leaving no doubt that their labour markets suffered from the crisis. From 2007 to 2009, the countries' macroeconomic indicators (employment, GDP, real wages, labour productivity, and time worked) showed procyclical tendencies. In Poland, employment and unemployment rates did not change significantly, mainly due to the GDP growth trend and cuts in real wages and working time. In the other four countries, however, changes in the indicators were more pronounced. Czechia and Slovakia experienced substantial decreases in employment related to slow GDP growth and substantial rises in real wages (Kwiatkowski 2011; 2014). Furuoka's (2014) analysis of the hysteresis of unemployment rates in the V4 countries concluded that employment and unemployment in Czechia and Slovakia were less affected by the adverse, long-term consequences of the 2007–2008 financial crisis and the euro crisis, as their labour markets were more dynamic and less vulnerable to external shocks. The Polish and Hungarian labour markets were less resilient, and the hysteresis effect in both countries suggested that they may have suffered more from long-term unemployment.

In the years following the Great Recession, from 2011 to 2013, the employment, unemployment, and economic activity trends in the V4 countries were partly reversed due to changes in the ratios between real wage growth and labour productivity growth, GDP growth, and labour market institutions (i.e., tax wedge, minimum wage, and the degree of legal employment protection) (see Kwiatkowski 2014). However, Zieliński (2015) observed that the crisis also increased the population's economic activity, directly contributing to higher levels of unemployment, especially among young people, but without affecting the labour market situation of women.

Although the labour markets of the V4 countries fared differently in 2015, all of them failed to achieve the target employment rate set out in the Europe 2020 Strategy. The most successful country was Czechia, where the employment rate increased the most in the years under consideration. Poland reported the greatest increase in the annual average rate of employment. Hungary and Slovakia had not seem likely to achieve and did not achieved the EU-recommended employment rate by 2020 (Zalewska and Świetlikowski 2017).

Studies spanning longer periods (from 2004, when they became EU members) have shown that unemployment trends were similar across the V4. From 2004 to 2016, unemployment rates fell in all countries (Miś 2019), following an irregular pattern: declines between 2001 and 2009 were followed by euro crisis-related increases that continued until 2013, when another series of decreases began. However, the V4 countries differed significantly regarding the course of the changes. The adjustment between the unemployment duration and unemployment rate was the shortest in Poland and Hungary, while in Slovakia, it was the longest. The strongest and weakest relationships between the unemployment duration and rate occurred in Poland and Slovakia, respectively (Dmytrów and Bieszk-Stolorz 2019). Szymańska (2017) stated that Slovakia's economic situation between 2004 and 2015 was particularly challenging because, in addition to its unemployment rate exceeding the EU average and being particularly high among young people, a considerable percentage of the population was long-term unemployed. In Poland, the period of being out of work and the share of long-term unemployment were the smallest among the V4 countries. Moreover, low unemployment benefits translated into low net replacement rates of in-work income (Szymańska 2017).

In 2019, Czechia was among the EU countries with the best labour market situation, confirmed by its economic activity and employment and unemployment rates. The Polish, Hungarian, and Slovak rates were closer to the EU average (Bieszk-Stolorz and Dmytrów 2020). However, as the years after 2010 showed, all V4 economies were more 'crisis-proof' than the 'old' EU members, and the fallout in 2012–2014 proved less hurtful for them. After 2012, the V4 unemployment rates, especially among young people, were lower than the EU–15, although the female economic activity rates remained smaller until 2019 (Ambroziak et al. 2021). Notwithstanding their improving economies, the countries

continued to struggle with labour problems, among which relatively high youth unemployment rates, substantial informal employment, and an undersupply of skilled workers were the most onerous (Onyusheva 2022).

More recently, research has focused on the impacts of the COVID–19 pandemic on the V4's labour markets. Zieliński (2022) concluded that they were buffered against economic cycle fluctuations by non-standard employment arrangements, which helped reduce the size of temporary and part-time employment and increase the scale of self-employment. The position of women in the labour market did not deteriorate following the pandemic, but the consequences were damaging for the young, people aged 55–64 years, and the lowest educated. In Hungary, Slovakia, and Czechia, the lowest educated were the most affected by declines in employment, and they showed the largest increases in unemployment.

Similar findings were reported by the team led by Kwiatkowski (2022). Their research showed that the pandemic initially reduced economic activity rates in all V4 countries and the number of people in employment, reversing previous trends. It also showed that in the 3rd quarter of 2020, both indicators started to rise again. The first six months of 2020 saw declines in the number of employees and unemployment rates across the V4, but in the 3rd quarter, they started to grow again. Unemployment trends between 2015 and 2022 were inverse to trends in the number of employees and employment rates. Before the pandemic, the numbers of unemployed people and unemployment rates were falling in the V4 countries. However, with the onset of COVID–19, both indicators started to rise, with their increases being somewhat small in Poland and quite noticeable in Hungary and Slovakia. Fast-growing average wages in Slovakia, Hungary, and Czechia in the 2nd quarter of 2020 (the first wave of COVID–19) implied the emergence of a "composition effect", i.e., a change in the structure of employment due to the loss of low-paid jobs. Another fast increase in average wages in the three countries took place in the 4th quarter of 2020 in relation to the second wave of the pandemic.

Analysis of the basic labour market indicators

The V4 countries occupy 533,600 km^2, which represents 12.6% of the EU–27 area. As of 2021, they were home to 62.7 million people, i.e., more than 14% of the population of the EU–27. Poland has the largest population (59%), followed by Czechia (16.8%), Hungary (15.5%), and Slovakia (8.7%) (Eurostat 2023a).

The V4 economies have relatively high industry shares of gross value added (exceeding the EU–27 average) and an agricultural sector comprising approximately 1.9 million of farms. They frequently compete with each other for foreign investments, and their

main trading partner is Germany (Ambroziak et al. 2021). As of 2020, their aggregate GDP per capita accounted for more than 70% of the GDP of the EU–15.

The measure used to gauge employment intensity is the rate of employment, which indicates what percentage of the working-age population is in work. The level is important for the economy because a higher value helps sustain economic growth in the long term. Figure 1 shows increasing employment rates from 2015 to 2019. An analysis of the fourth quarters shows that the EU–27 employment rate rose from 64.9% to 68.6%. The greatest increases in the employment rate were recorded by Hungary (by 5.5 percentage points) and Slovakia (5 p.p.). In 2015 Czechia was the only country where employment rate exceeded the EU average (70.8% vs 64.9%). In 2019, a higher employment rate than the EU average occurred also in Hungary (70.3%). The Polish and Slovak employment rates were below the EU average (68.5% in both cases). As a result of the economic downturn, employment rates decreased in 2020 in all V4 countries at a varying pace. Even so, the 2020 Czech, Hungarian, and Polish rates (74.3, 70.2, and 69.4%, respectively) were above the EU average of 67.8%, while the Slovak rate (67.8%) was equal to it. In 2021, the employment rates in all four countries rose above 70%, exceeding the EU average of 69.3%. The gap between the highest and lowest rates of employment decreased in the V4 countries, from 7.3 p.p. in 2015 to 4.5 p.p. in 2021. In 2021, the highest employment rate was noted in Czechia (75.3%) and the lowest in Slovakia (70.8%).

Joining the EU influenced the GDP growth rates and the economic structure of the V4 countries. Additionally, their agricultural sectors started to give way to developing services and efforts to sustain the industrial sector. This naturally involved changes in the number of employees and the occupational structure of the labour force.

Between 2015 and 2021, employment increased in all V4 countries, ranging from 7.1% in Hungary to 4.4% in Czechia. In the last year of that period, with 23,544,800 people in employment, the V4 accounted for 14.2% of total employment in the EU. Poland had the most economically active people (13,114,00), while Slovakia had the fewest (2,151,200), which reflected the countries' different demographic situations.

A comparison of the V4 countries in terms of employment structure and the major groups of occupations defined by the International Standard Classification of Occupations 2008 (ISCO–08) shows that in 2015, they were more different than in 2021 (Table 1). In 2015, 'professionals' constituted the largest occupational group in the labour markets of Poland and Hungary (21.3% and 15.5%, respectively); in Czechia and Slovakia, it was technicians and associate professionals (17.4%) and service and sales workers (18.3%). By 2021, 'professionals' had become the largest occupational group in all four labour markets. In the structure of employment, they accounted for 22.6% in Poland, 19.1% in Hungary, 18.0% in Czechia, and 15.1% in Slovakia; the EU–27 average was 21.4%. The proportion increased the most in Hungary (3.9 p.p.) and the least in Poland (1.3 p.p.), where

they were relatively the largest occupational group in each year of the sample, much larger than in the other V4 countries.

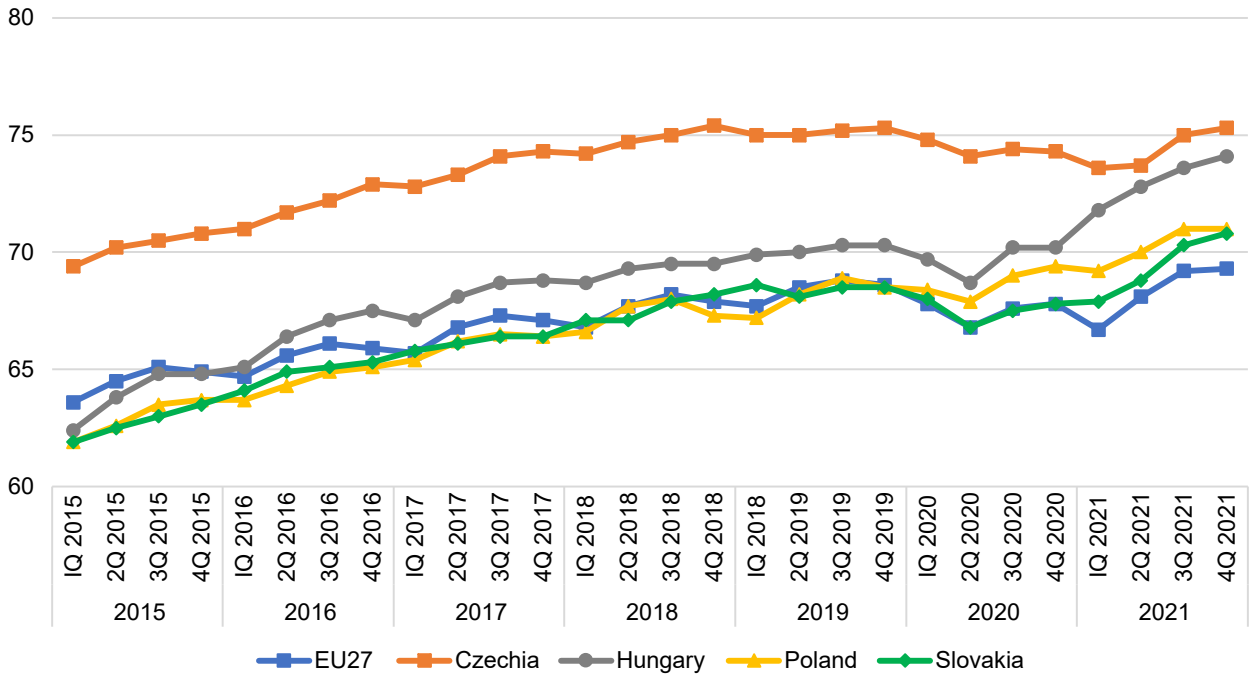

Figure 1. V4 countries' employment rates, 2015–2021 (%)

Source: own elaboration based on Eurostat 2023b.

The changes in the importance of particular occupational groups show that in expanding economies, human capital (knowledge and skills) embodied in the best-educated employees is increasingly appreciated, while the demand for low-skilled workers is declining. A confirmation of this observation is the change in employment shares of 'elementary occupations' and 'craft-related trades workers'. The 'elementary occupations' share of employment decreased the most in Slovakia (by 3.6 p.p., to 6.1% in 2021), but in Czechia, it consistently stayed at the same level of 6.4%. Hungary was the only country where it exceeded the EU average (9.8% vs 9.3%); in Czechia, Poland, and Slovakia, 'elementary occupations' accounted for 6.4%, 6.3%, and 6.1% of employment, respectively, and were below the EU-average.

Table 1. Employment structure in the V4 countries according to the International Classification of Occupations 2008 (ISCO–08) in 2015 and 2021 (%)

Specification	2015					2021				
	EU–27	Czechia	Hungary	Poland	Slovakia	EU–27	Czechia	Hungary	Poland	Slovakia
Managers	4.1	4.7	4.3	5.7	3.5	3.9	4.8	3.7	6.0	4.8
Professionals	17.8	15.0	15.2	21.3	11.6	21.4	18.0	19.1	22.6	15.1
Technicians and associate professionals	17.5	17.4	14.9	13.7	15.5	16.7	17.2	15.5	15.2	17.1
Clerical support workers	11.1	10.2	8.5	7.6	9.9	11.3	10.2	8.5	8.3	11.9
Service and sales workers	16.6	14.2	14.8	13.9	18.3	15.5	13.8	13.5	13.2	16.7
Skilled agricultural, forestry and fishery workers	1.0	0.8	1.3	0.5	0.7	0.9	0.7	1.5	0.5	0.6
Craft-related trades workers	12.0	15.1	14.7	16.2	13.6	11.3	13.4	13.5	14.6	12.1
Plant and machine operators and assemblers	8.6	15.8	14.2	11.6	16.6	8.2	15.2	14.5	11.6	14.8
Elementary occupations	10.4	6.4	11.6	8.2	9.7	9.3	6.4	9.8	6.3	6.1
Armed forces occupations	0.8	0.4	0.4	0.8	0.6	0.7	0.4	0.5	0.8	0.7
n/a	0.2	0.0	0.0	0.4	0.0	0.6	0.0	0.0	0.8	0.0

Source: own elaboration based on Eurostat 2023c.

The share of the 'craft-related trades workers' group also decreased between 2015 and 2021, but the changes were smaller (from 1.8 p.p. in Czechia to 1.2 p.p. in Hungary) and similar across the V4. In 2021, the group's share of employment exceeded the EU average of 11.3% in all four countries, reaching 13.4% in Czechia, 14.6% in Poland, 12.1% in Slovakia, and 13.5% in Hungary.

The share of 'clerical support workers' also increased in all four countries between 2015 and 2021, from 0.1 p.p. in Czechia to 2.1 p.p. in Slovakia. In 2021, it was estimated at 10.2% in Czechia, 8.5% in Hungary, 8.3% in Poland, and 11.9% in Slovakia (the EU average was 11.3%).

The changes in the structure of employment in all V4 countries imply that their labour markets were becoming more modern, which resulted in a greater demand for highly skilled and qualified personnel.

A good measure of the labour market situation is the rate of unemployment. According to Figure 2, Slovakia had the highest rate of unemployment, greater than the EU average until the 3rd quarter of 2016, across the study period. However, as the level steadily

fell in subsequent quarters, in the last quarter of 2021, it exceeded the EU average by only 0.1 p.p. In the other three countries, unemployment rates were well below the EU average. Czechia and Poland are among the EU countries with very low levels of unemployment (Kwiatkowski 2022).

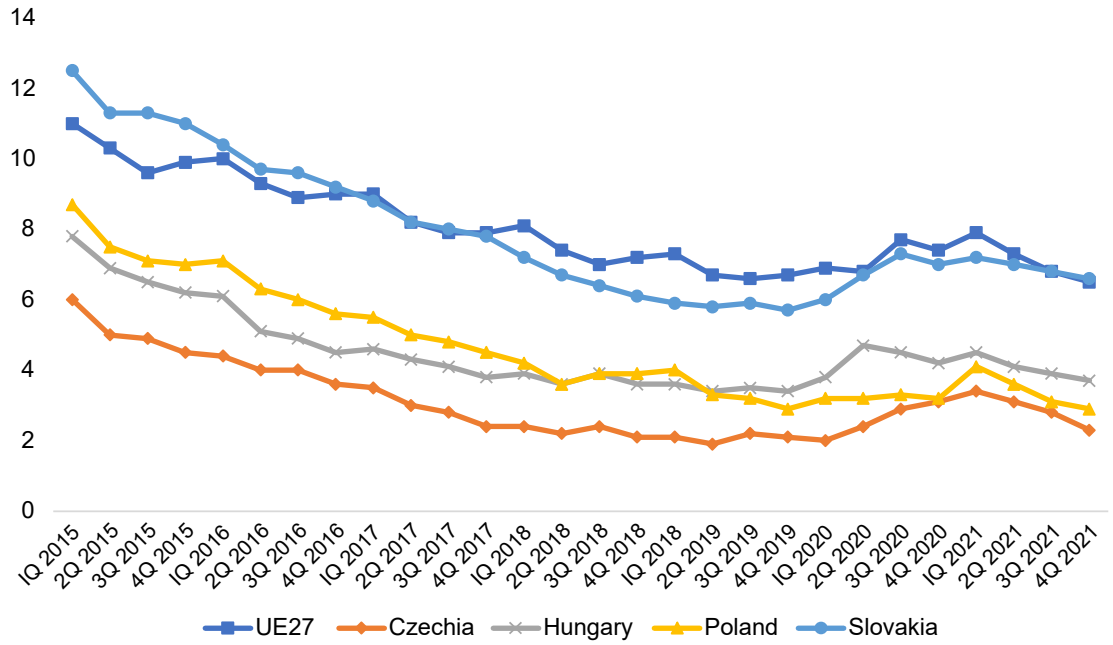

Figure 2. V4 countries' unemployment rates, 2015–2021 (quarterly data, %)

Source: own elaboration based on Eurostat 2023d.

It is notable that the gap between the V4 countries with the highest and lowest unemployment rates decreased from 6.5 p.p. in 2015 to 4.3 p.p. in 2021. This suggests that the V4 labour markets stabilised in that period and points to a relationship between the unemployment rate and fluctuations in the economic cycle, which collapsed in 2020 in the wake of the COVID–19 pandemic.

The model and results of econometric analysis

The econometric analysis sought to determine the labour market situations of population groups in the V4 countries from 2015 to 2020. Czechia, Slovakia, and Hungary were studied using LFS individual data from the sample years provided by Eurostat. As Eurostat's Polish data on occupations and professions did not have four-digit codes, LFS individual data from 2016–2020 released by Statistics Poland were used[3].

3 LFS individual data with four-digit codes were not available for Poland for 2015 and the first three quarters of 2016; therefore, annual data from 2017–2020 and the 4th quarter of 2016 were used.

In order to estimate the probabilities of individuals transitioning from one labour market state to another (unemployment, employment, and outside the labour force (economic inactivity)), a panel of annual observations was constructed. Transitions between labour market states in a given quarter were compared with transitions in the same quarter of the previous year.

The econometric analysis was performed using a polynomial logit model, which assessed the probability of transitions in discrete time. The probability of individual i experiencing event j (a transition from unemployment into employment or outside the labour force) can be described with the following formula (Chow 1995; Wiśniowski 2012; Cameron and Trivedi 2015):

$$P_{ij} = \frac{e^{\beta' z_{ji}}}{\sum_{k=1}^{J} e^{\beta' z_{ji}}}, \tag{1}$$

where: $i = 1, \ldots, J$; P_{ij} – the probability of transitioning, for instance, from unemployment to employment or economic inactivity; and z_{ji} – a vector containing explanatory variables that represent the labour market participants' characteristics (such as age, gender, level of education, place of residence, and occupational group), and a dummy variable, 'pandemic', which takes a value of 1 for 2020 and 0 for the other years.

Two variants of the polynomial logit model were used. Their parameters were estimated to determine: 1) the probability of an individual transitioning from employment to unemployment or economic inactivity and 2) the probability of an individual transitioning from unemployment to one of the other two labour market states. In both variants and for each V4 country, the same explanatory variables were used.

Table 2 contains the estimates of relative risk ratios[4] (RRR) for transitioning from employment to unemployment and outside the labour force. They were calculated taking into account the individuals' age, education, gender, place of residence, and occupational (task-content) group. Below, the conclusions drawn from the analysis of the estimates are presented.

A variable that significantly determined the probability of moving from employment to unemployment or economic inactivity was the person's age. In all four countries, 15–24-year-olds were the most likely of all age groups to lose their jobs compared with the base category. The risk of redundancy was the smallest for people in the oldest age

4 RRR values were interpreted as follows: a value greater than 1 meant that individuals in the occupational group under consideration were more likely to transition to another labour market state than those representing the base category; a value smaller than 1 indicated that the probability was lower. For the sake of illustration, the members of an occupational group with an RRR of 2.5 meant that they were 150% more likely to transition between labour market states compared with the base category.

group, who were also the most likely to move from employment to economic inactivity compared with the group 35–44 years. In Czechia, Poland, Slovakia and Hungary, the probability of 15–24-year-olds being terminated and unemployed was greater compared with the base category by 140.6%, 187.1%, 126.9%, and 136%, respectively.

In each country, the risk of unemployment compared with the base category was lowest for people aged 45–54 years. They were also the least likely to transition from employment to economic inactivity.

Educational attainment also significantly determined the labour market situation. In all four countries, tertiary graduates were the least at risk of unemployment, with the probability of unemployment being the lowest compared with the base category for tertiary graduates in Hungary (by 66.1%).

In Czechia and Slovakia, gender was also significantly related to the risk of redundancy and unemployment. In both countries, the risk was greater for women than for men, by 31.8% and 26%, respectively. At the same time, however, women in all four countries were more likely to transition from unemployment to economic inactivity.

Table 2. The estimates of relative risk ratios for transitioning from employment to unemployment and outside the labour force in the Visegrád Group countries, 2015–2020[5]

Explanatory variable	Czechia	Poland	Slovakia	Hungary
To employment				
Age (base category age 35–44)				
15–24	2.406*	2.871*	2.269*	2.360*
25–34	1.646*	1.628*	1.496*	1.487*
45–54	0.834*	0.733*	0.943*	0.838*
55 and more	0.924	0.565*	0.783*	0.645*
Education (base category: Less than primary, primary and lower secondary education (levels 0–2))				
Tertiary (levels 5–8)	0.303*	0.623*	0.299*	0.239*
Upper secondary and post-secondary non-tertiary education (levels 3–4)	0.325*	0.747*	0.373*	0.359*
Gender (base category: men)				
Women	1.318*	1.052	1.260*	1.027
Place of residence (base category: rural area)				
Urban area	1.318*	1.471*	1.046	0.980
Occupation (base category: non-routine manual)				

5 For Poland, from IV Q 2016 to 2020.

Explanatory variable	Czechia	Poland	Slovakia	Hungary
Non-routine analytic	0.391*	0.379*	0.505*	0.525*
Non-routine interactive	0.591*	0.468*	0.638*	0.736*
Routine cognitive	0.484*	0.597*	0.589*	0.523*
Routine manual	1.434*	0.968	1.060	1.439*
Pandemic (base category: years 2015–2019)				
Pandemic	1.256*	1.073*	1.371*	1.354*
To inactivity				
Age (base category age 35–44)				
15–24	2.621*	2.544*	2.151*	2.515*
25–34	3.281*	1.509*	2.201*	2.126*
45–54	0.576*	0.856*	0.571*	0.686*
55 and more	8.888*	5.918*	6.787*	4.138*
Education (base category: Less than primary, primary and lower secondary education (levels 0–2))				
Tertiary (levels 5–8)	0.585*	0.695*	0.654*	0.444*
Upper secondary and post-secondary non-tertiary education (levels 3–4)	0.591*	0.905*	0.485*	0.489*
Gender (base category: men)				
Women	2.010*	2.000*	1.387*	2.384*
Place of residence (base category: rural area)				
Urban area	0.892*	1.324*	0.886*	0.767*
Occupation (base category: non-routine manual)				
Non-routine analytic	0.763*	0.585*	0.184*	0.814*
Non-routine interactive	0.747*	0.603*	0.183*	0.766*
Routine cognitive	0.877	0.773*	0.254*	0.669*
Routine manual	1.237*	0.841*	0.361*	0.984
Pandemic (base category: years 2015–2019)				
Pandemic	1.005	1.029	1.093*	1.411*
Number of observations	104,932	463,343	209,478	529,755
Log-likelihood	– 23,246.4	– 86,786.6	– 46,203.9	– 122,191.2
Pseudo R^2	0.1	0.08	0.09	0.08

* Significant at up to 5%.
Source: own elaboration based on Eurostat LFS microdata provided by EUROSTAT and Statistics Poland within the project "Technical change and polarisation of labour markets in the 'old' and 'new' EU Member States" conducted at the Faculty of Economics and Sociology, University of Lodz.

According to the RRR estimates, place of residence significantly influenced the probability of transitioning from employment to unemployment in Czechia and Poland. In Poland, the risk of redundancy and unemployment was 47.1% higher for towns and cities than for rural areas. Urban residents in Czechia, Slovakia, and Hungary were less at risk of moving from employment to economic inactivity. The lower probability of employed urban residents in Poland moving to economic inactivity can be explained by the reinstatement of the previous retirement ages on 1 October 2017.

In all V4 countries, the risk of redundancy was significantly related to the task content of jobs. People in non-routine analytic and non-routine interactive jobs were less threatened by job loss than those comprising the base category. The least at risk of unemployment were the best-qualified employees (in non-routine analytic jobs). This is because the demand for their services increases as the technological revolution moves forward, and when employers must reduce their workforce in periods of economic downturn, they shed the lowest-skilled workers first.

In Poland and Slovakia, workers doing manual routine jobs were less at risk of transitioning to unemployment than the lowest-skilled workers. Only in Czechia were they more exposed to the risk of unemployment than the base category.

The members of the three occupational groups were also the least likely to transition from employment to economic inactivity.

The crisis triggered by COVID–19 significantly changed the risk of becoming unemployed in all V4 countries. In 2020, it increased the most compared with the pre-pandemic years in Slovakia and Hungary, and the least in Poland. Slovakia and Hungary were also where the pandemic statistically significantly increased the probability of transitioning from employment to economic inactivity in 2020.

The estimates of relative risk ratios for transitioning from unemployment to employment and economic inactivity in the V4 countries are summarised below (Table 3).

Table 3. The estimates of relative risk ratios for transitioning from unemployment into employment and outside the labour force in the Visegrád Group countries, 2015–2020[6]

Explanatory variable	Czechia	Poland	Slovakia	Hungary
To employment				
Age (base category age 35–44)				
15–24	3.004*	1.209*	2.043*	1.542*
25–34	1.633	1.093*	1.313*	1.118*

6 For Poland, from IV Q 2016 to 2020.

Explanatory variable	Czechia	Poland	Slovakia	Hungary
45–54	0.743*	0.818*	0.821*	0.869*
55 and more	0.402*	0.641*	0.669*	0.722*
Education (base category: Less than primary, primary and lower secondary education (levels 0–2))				
Tertiary (levels 5–8)	4.241*	1.170*	2.425*	1.981*
Upper secondary and post-secondary non-tertiary education (levels 3–4)	2.977*	1.158*	0.806*	1.228*
Gender (base category: men)				
Women	1.183*	0.961	1.226*	1.239*
Place of residence (base category: rural area)				
Urban area	0.885	0.976	0.984	0.582*
Occupation (base category: non-routine manual)				
Non-routine analytic	3.869*	1.411*	6.760*	2.922*
Non-routine interactive	4.630*	2.083*	7.088*	5.201*
Routine cognitive	6.280*	2.206*	9.242*	5.751*
Routine manual	5.064*	1.930*	13.762*	6.119*
Pandemic (base category: years 2015–2019)				
Pandemic	1.008	1.002	0.748*	0.905*
To inactivity				
Age (base category age 35–44)				
15–24	1.155	0.695*	1.206*	0.965
25–34	1.013	0.815*	0.915	0.894*
45–54	0.937	1.228*	1.216*	1.178*
55 and more	2.372*	2.634*	2.637*	2.462*
Education (base category: Less than primary, primary and lower secondary education (levels 0–2))				
Tertiary (levels 5–8)	0.669*	0.723*	0.761*	0.535*
Upper secondary and post-secondary non-tertiary education (levels 3–4)	0.867*	0.906*	0.655*	0.708*
Gender (base category: men)				
Women	0.931*	1.679*	1.377*	1.283*
Place of residence (base category: rural area)				
Urban area	1.047	0.894*	1.036	0.655*
Occupation (base category: non-routine manual)				
Non-routine analytic	0.538	1.010	0.781	0.646*
Non-routine interactive	0.607**	0.839*	0.859	0.620*

Explanatory variable	Czechia	Poland	Slovakia	Hungary
Routine cognitive	0.504*	0.917	1.196	0.791*
Routine manual	0.486*	0.758*	0.707*	0.613*
Pandemic (base category: years 2015–2019)				
Pandemic	1.320**	1.266*	1.640*	1.471*
Number of observations	4384	31493	30017	50790
Log-likelihood	–4,031.8	–31,809.5	26,840.3	–50,151.2
Pseudo R^2	0.13	0.06	0.14	0.09

*, ** Significant up to 5% and 10%.
Source: own elaboration based on Eurostat LFS microdata provided by EUROSTAT and Statistics Poland within the project "Technical change and polarisation of labour markets in the 'old' and 'new' EU Member States" conducted at the Faculty of Economics and Sociology, University of Lodz.

The labour market situation of V4 residents was also significantly determined by their age. Compared with the base category, unemployed 15–24 year olds (the most mobile age group on the labour market) had the best prospects of all age groups to find employment. By contrast, unemployed people aged 55 years and over were the least likely to be re-employed and the most likely to leave the labour force.

The significance of the level of education for the re-employment prospects of unemployed individuals in the V4 countries was ascertained. Tertiary graduates were more likely to find a job than people with the lowest educational attainment, which shows that although higher education does not shield individuals from unemployment, it considerably increases their chances for re-employment. Tertiary graduates in Poland, Hungary, and Czechia were also less likely to transition from unemployment to economic inactivity, meaning that even failed job searches do not make them consider transitioning to economic inactivity.

Unemployed Czech, Slovak, and Hungarian women were more likely to exit unemployment and find employment than unemployed men. The RRR estimates for Poland were statistically not significant.

Hungary proved to be the only country where the place of residence was significant for the probability of exiting unemployment into employment. The unemployed living in Hungary's towns and cities were 41.8% less likely to find a job than unemployed rural residents. At the same time, the urban unemployed in Poland and Hungary were less likely to transition from unemployment to economic inactivity.

In all four countries, the level of qualifications was significantly associated with the probability of unemployed people finding new jobs. Interestingly, relatively high chances

to shift from unemployment to employment were recorded for individuals performing routine cognitive jobs. This points to the still high demand for such candidates in these countries, which may be linked to offshoring: V4 countries are perceived as good locations for Business Processes Outsourcing (BPO) centres, in which routine cognitive tasks dominate (Arendt et al. 2023).

The COVID–19 pandemic reduced unemployed people's chances to return to the workforce in Slovakia and Hungary. However, it increased the probability of transitioning from unemployment to economic inactivity in all four countries as the economic crisis paused recruitment.

Conclusions

This study assessed the labour market situation of selected social groups in the Visegrád Group countries by analysing the likelihood of transitioning between employment, unemployment and economic inactivity, and thus people's employability potential. The findings point to many similarities across the V4 countries. Firstly, it was revealed that educational attainment is a significant driver of an individual's situation in the labour market, i.e., tertiary graduates were the most likely to transition from unemployment to employment and the least likely to lose their jobs compared with the least-educated people. Of all V4 countries, the labour market position of tertiary graduates was the most favourable in Czechia.

Secondly, being under 24 years of age was associated with the most uncertain position in the labour market. This age group faced the highest risk of redundancy compared with people aged 35–44 years, which confirms that the youth are still a disadvantaged group in the V4 labour markets. The COVID–19 pandemic exacerbated this unfavourable situation. A relatively difficult labour market situation across the four countries was also faced by people aged 55 years and over. They were less at risk of unemployment than the 35–44-year-old group, although they had poorer prospects of transitioning from unemployment into employment. This qualifies them as a stagnant segment of labour markets in the V4 countries. In each country, the oldest age group was the most likely to exit employment or unemployment and transition to economic inactivity. This points to the need for targeted support for these two age groups to enhance their employability prospects.

Thirdly, COVID–19 increased the probability of transitioning from employment to unemployment across the group of countries. However, Slovakia and Hungary were the only countries where the likelihood of exiting unemployment into employment was lower than in the pre-pandemic years.

Analysing the situation in the labour market by task-content of jobs is the value added of this study, as to the best of our knowledge, no such analysis has yet been conducted.

This approach is important, considering the dynamic changes in digitalisation and automation, which pose new challenges to both employers and employees, leading to shifts in the required skills mix. The study showed that individuals who perform non-routine analytical jobs had the best prospects of finding a job and were the least threatened by redundancy and unemployment compared with those who perform non-routine manual jobs. This clearly indicates that the technical change in V4 countries largely follows a pattern that is characteristic of more developed economies, where individuals who perform non-routine analytical and interactive tasks are less at risk of losing their jobs than people who perform other tasks (especially routine manual).

The labour markets in the V4 countries still offer relatively good prospects for individuals who perform routine cognitive tasks. However, this may change due to an increase in relative wages in the V4, leading to shifts in labour demand and, thus, a deterioration of the employability prospects of this group of individuals.

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Sytuacja na rynku pracy grup ludności w krajach Grupy Wyszehradzkiej

W artykule przedstawiono wyniki analizy sytuacji wybranych grup ludności na rynkach pracy krajów Grupy Wyszehradzkiej (V4) w latach 2015–2020. Badanie pozwala na określenie względnej sytuacji tych grup, z uwzględnieniem profili kwalifikacyjnych pracowników. Innymi słowy, w badaniu identyfikowane są grupy o relatywnie najlepszych i najgorszych perspektywach zatrudnienia na rynkach pracy V4. W tym celu oszacowano parametry wielomianowego modelu logitowego (reprezentującego względne współczynniki ryzyka odpływu z zatrudnienia oraz z bezrobocia). Z przeprowadzonych analiz wynika, że we wszystkich krajach V4 najlepszą pozycję na rynku pracy mieli absolwenci szkół wyższych. Największe szanse na znalezienie pracy mieli specjaliści o najwyższych kwalifikacjach i w najmniejszym stopniu byli zagrożeni jej utratą. Najbardziej niepewna sytuacja na rynku pracy dotyczyła osób w wieku do 24 lat, osób najsłabiej wykształconych i o niskich kwalifikacjach oraz osób w wieku 55 lat i więcej. Wskazuje to na potrzebę zapewnienia programów wsparcia skierowanych do tych grup społecznych, realizowanych w ramach polityk publicznych – polityki rynku pracy i edukacji, ze szczególnym uwzględnieniem systemu uczenia się dorosłych. Główną wartością dodaną badania jest uwzględnienie podejścia zadaniowego w analizie perspektyw zatrudnienia na rynkach pracy Grupy Wyszehradzkiej.

Słowa kluczowe: bezrobocie, zatrudnienie, sytuacja grup ludności na rynku pracy

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.31

Does Governance Matter for Outward FDI? Evidence from the European Union Member States

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Abstract

Our principal aim is to assess the role of governance companies' active internationalisation. We first measured and compared the degree of institutional quality among the 28 European Union Member States (EU–28) between 2004 and 2021 using the authorship synthetic index of governance quality (SIGQ) values. In the second step, we assessed outward foreign direct investment (OFDI) projects measured by their relative value to the GDP per capita in each member state. Finally, we correlated the overall quality of governance (GQ) and its six dimensions with OFDI in the EU–28 (including the UK). We employed numerous statistical tools, i.e., hierarchical cluster analysis, contingency analysis, synthetic index values, and descriptive statistics. We used the Worldwide Governance Index (WGI) to assess the GQ in the EU–28 for 2004–2021. The statistical analysis results revealed a positive relationship between the quality of governance and the OFDI. The most important of the partial variables was the rule of law, which reflects perceptions of the degree to which individuals and actors trust and adhere to social rules. Our research demonstrates that policymakers should consider the importance of institutional quality indicators in supporting domestic companies "to go abroad". The primary input delivered by the study to the current body of knowledge about OFDI involves identifying the relationship between GQ in all the EU–28 ("old" and "new") using the SIGQ index.

Received: 27.02.2024. Verified: 17.04.2024. Accepted: 24.09.2024

Keywords: quality of governance, internationalisation, outward FDI, the EU Member States

JEL: F21, F23

Introduction

Internationalisation is one of the most critical processes in the contemporary global economy. It involves creating and developing various forms of transnational relations between enterprises, from relatively simple ones, such as exports, to much more advanced ones. The advanced ones include foreign direct investment (FDI), a common phenomenon of multinational enterprises (MNEs). Multinationals seek the optimal location in almost all politically and economically secure countries and regions worldwide. This is because foreign investors are primarily interested in a specific place to carry out their projects.

If we recognise that the internationalisation of indigenous companies benefits the economy of the capital's country of origin, we can create space for research into the determinants of companies' foreign activity in the form of FDI. The rationale for domestic companies' active internationalisation has a long history in economics and management research, including international economics and international business. In the last few years, the focus of research on FDI in Poland has also shifted towards outward investment projects. We still need to understand the factors that characterise the domestic economy that may favour or inhibit international entrepreneurial activity. Our study focuses on institutional factors that, according to our previous research, were statistically significant for investment location (Dobrowolska, Dorożyński, and Kuna-Marszałek 2023). This time, we examine the issue from the economic perspective of the capital's country of origin. Hence, we formulated the following research questions:

Can the quality of governance in home countries be a stimulant in making capital expansion abroad?

What is the role of governance in stimulating outward foreign direct investment (OFDI) from the perspective of the EU–28?

Which of the six dimensions of governance quality impacts FDI outward in the EU–28 the most?

Potential answers to these questions, as well as an in-depth study of the link between governance and OFDI, are beneficial for formulating effective industrial policies to accelerate the pace of foreign expansion of the EU companies, especially those from countries still classified as emerging markets, such as Bulgaria, Hungary, Poland, and Romania (IMF 2023).

Hence, the principal goal of our study is to evaluate the quality of governance in the EU–28 and to examine the relationship between governance and FDI outward stock as a % of GDP. The central hypothesis states that a positive relationship exists between the quality of governance and the value of FDI outward stock as a % of GDP. We used various statistical methods to achieve our goal, i.e., hierarchical cluster analysis, contingency analysis, synthetic index values, and descriptive statistics. We employed the Worldwide Governance Index (WGI) to assess the GQ in the EU–28 for 2004–2021.

Literature review

The literature provides various answers as to why a company expands abroad through FDI. According to the neoclassical school of thought, which assumes that markets are completely free, owners are only interested in maximising the value of their holdings. Thus, it does not matter where companies invest their capital in production facilities: at home or abroad (Dunning and Lundan 2008). However, reality shows that markets do not provide an optimal allocation of resources, so several additional circumstances that influence the decision on capital investment can be considered. Market imperfections are why the taxonomy of motives followed by enterprises involved in FDI is so rich (Belniak 2015; Cuervo-Cazzura and Narula 2015; Wach 2016; Zasadzki and Opalach 2021). The motives for foreign expansion can vary greatly depending on the industry in which a company operates, its structure, experience in operating in foreign markets, the strategy adopted, the level of maturity, the institutional quality in the home or host country, and how capital is invested (Gorynia 2007). Hence, it is hard to disagree with Cuervo-Cazzura and Narula (2015), who claim that FDI motives may not only be approached in a variety of ways but, first of all, "are always evolving, like strategies, because they are aspiration-driven, and when they fail to produce the desired outcome, require a revision in motivation, if not also in strategy."

The literature most often refers to Dunning's (1993) four motives for FDI: resource-seeking, market-seeking, efficiency-seeking, and strategic asset-seeking. The first two are most often evoked in the literature, particularly regarding international trade models that try to formalise the OLI paradigm and define them as vertical and horizontal FDI (Franco, Rentocchini, and Vittucci 2008). However, these FDI motives are believed to have changed with the growing importance of knowledge and cooperation between companies under increasing global economic integration (Danes et al. 2023).

The motives for conducting FDI also vary depending on whether capital comes from developed, emerging or developing countries (Arslan, Tarba, and Larimo 2015; Pananond 2015; Ahammad et al. 2017; Filippaios et al. 2019). These motives include institutions and good governance. For instance, according to Child and Marinova (2014) and Stoian and Mohr (2016), MNEs from emerging countries decide to invest abroad

to overcome institutional constraints in their home markets. Some researchers also point out that democratic governments can stimulate FDI while policy changes in authoritarian countries discourage it (Jin and Huang 2023).

Good governance is the foundation on which everything else in the economy evolves (UNDP 2011; OECD 2016); it covers all aspects of how a country is governed, including economic policies, the regulatory framework, and adherence to the rule of law. Thus, good governance is a process which ensures transparent operations and accountability of institutions, boosts institutional effectiveness, helps to foster the economic competitiveness of the country, and builds trust in the business community (Dobrowolska, Dorożyński, and Kuna-Marszałek 2023). That primarily relates to public administration and its capacity to provide public services (World Bank 1994; 1997; 2002; Lateef 2016).

As argued by many authors, governance is thus equated with institutional quality. For instance, according to Huther and Shah (1999), governance encompasses "all aspects of the exercise of authority through formal and informal institutions in the management of the resource endowment of a state". Similar conclusions were reached by Kaufmann, Kraay, and Zoido-Lobatón (1999), Kaufmann, Kraay, and Mastruzzi (2003), and Zhuang, de Dios, and Lagman-Martin (2010). For example, Kaufmann, Kraay, and Zoido-Lobatón (1999) defined governance as "the traditions and institutions by which the authority in a country is exercised". Kaufmann and Kraay (2007) use the terms "governance", "institutions", and "institutional quality" interchangeably throughout their paper. On the other hand, some believe that this is the correct way to approach them (Alonso and Garcimartín 2018; Dobrowolska, Dorożyński, and Kuna-Marszałek 2021; 2023), and "governance indicators can be based on criteria related to institutional quality, adapting them to the different functions of the state" (Alonso and Garcimartín 2018).

The quality of institutions enhances productivity and economic stability by attracting and enhancing foreign investment (Hayat 2019). Many studies have demonstrated that solid institutions in host countries attract more FDI (Sabir, Rafique, and Abbas 2019; Belfqi, Qafas, and Jerry 2021; Khan, Weili, and Khan 2022). Researchers far less often investigate the impact of good governance on FDI outflows, yet the policies of the home country government can influence companies' decisions on where to locate their investments (Gaur, Ma, and Ding 2018; Luo, Tung 2018), mainly if the government owns and controls the company (Buckley et al. 2018). Such MNEs may take more risks when engaging in overseas operations.

In turn, Fon and Alon (2022) identified a link between China's OFDI of state-owned enterprises in Africa and the financial assistance that the Chinese government provides to African countries hosting Chinese investments in the form of loans or credit. The example of Chinese OFDI is relatively well described in the literature, and researchers agree that the decisions made by Chinese companies to engage in FDI are strongly

influenced by their domestic market institutions (Li et al. 2018; Ramamurti and Hillemann 2018; Christofi, Vrontis, and Makrides 2022). According to Lu, Liu, and Wright (2014), home country government support plays a more decisive role in determining prior experience when firms enter developing countries.

Stoian (2013) studied OFDI from 20 Central and Eastern European countries. The results showed the importance of home country institutional factors when examining the determinants of OFDI. She highlighted that including institutional variables increased the explanatory power of the models and that competition policy and general institutional reforms played a crucial role in explaining OFDI from CEE countries. Meanwhile, Stoian and Mohr (2016) showed that multinational firms from developing and emerging economies may engage in FDI to overcome competitive disadvantages arising from "home country institutional voids" related to underdeveloped capital markets, regulatory systems, contract enforcement mechanisms, and infrastructure. Institutional theory maintains that firms' strategies are embedded in the institutional context of their home country and are therefore influenced by the rules of the game, which are enforced by institutions themselves (Stoian 2013).

The quality of governance in the EU Member States

The first step in our study is to measure and compare the degree of governance quality among EU countries. Based on the results of studies that assessed GQ in the 28 EU Member States (EU–28) published in the WGI reports, we used hierarchical cluster analysis methodology[1] to identify countries that represent similar GQ. Using Ward's method[2], we obtained a dendrogram that shows the hierarchical structure of the components in the set (see Figure 1).

1 Hierarchical cluster analysis is used to identify homogenous groups of elements based on selected characteristics in a given set of data (Lasek 2002; James et al. 2014).

2 Ward's method is one of the agglomeration methods used in hierarchical cluster analysis.

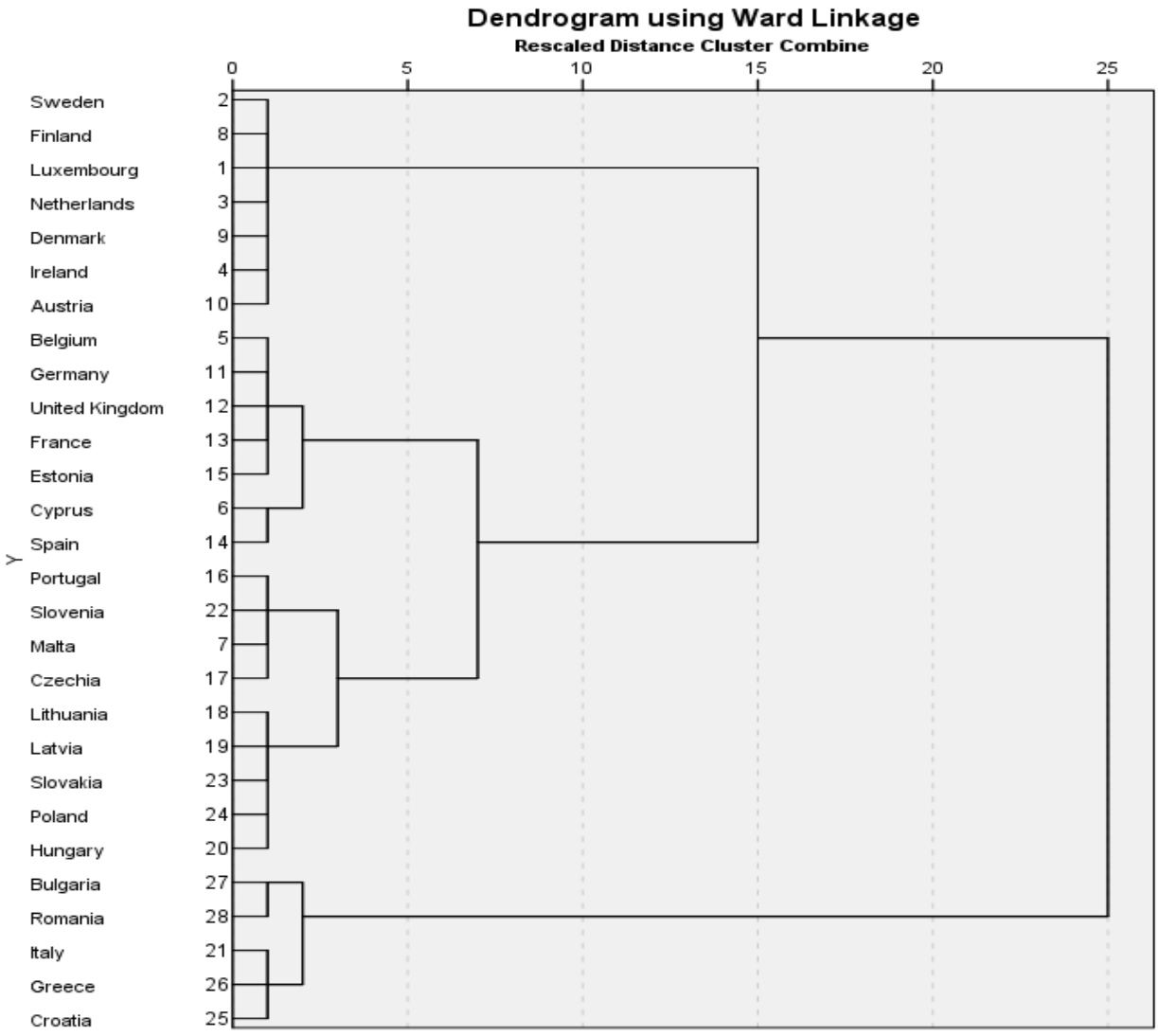


Figure 1. The dendrogram for the EU–28 based on Ward's linkage method

Source: own compilation using PS IMAGO.

Based on cluster analysis, we divided EU–28 into groups representing similar levels of GQ. They are as follows:

Group 1$_{gov}$: Denmark, Netherlands, Austria, Ireland, Finland, Sweden, Luxembourg;

Group 2$_{gov}$: Cyprus, Spain, Estonia, France, Belgium, Germany, United Kingdom;

Group 3$_{gov}$: Hungary, Poland, Slovakia, Latvia, Lithuania, Portugal, Slovenia, Czechia, Malta;

Group 4$_{gov}$: Bulgaria, Romania, Greece, Italy, Croatia.

Although hierarchical cluster analysis helped us distinguish four groups of countries with comparable GQ, it failed to identify which group performs better than the others. Hence, we compared the GQ among the preselected groups of countries with Ward's

linkage method. To achieve this goal, we constructed **a synthetic index of governance quality** values (SIGQ) for each country based on data from 2004–2021. This measure is a sum of percentile ranks for the countries published by the WGI for six governance dimensions over the investigated period. The ranking of the EU–28 based on the SIGQ is presented in Table 1.

Table 1. Ranking by the SIGQ of the EU–28, 2004–2021

Ranking	Country	SIGQ value
1	Finland	10,544.31
2	Luxembourg	10,392.65
3	Sweden	10,370.22
4	Denmark	10,335.80
5	Netherlands	10,154.60
6	Austria	10,022.84
7	Ireland	9,843.93
8	Germany	9,701.45
9	United Kingdom	9,463.23
10	Belgium	9,356.24
11	Malta	9,097.44
12	France	9,022.08
13	Estonia	8,984.90
14	Portugal	8,840.16
15	Slovenia	8,604.12
16	Czechia	8,536.47
17	Cyprus	8,470.27
18	Spain	8,229.51
19	Lithuania	8,174.19
20	Slovakia	7,920.46
21	Latvia	7,827.04
22	Poland	7,797.32
23	Hungary	7,757.90
24	Italy	7,423.57
25	Croatia	7,013.34

Ranking	Country	SIGQ value
26	Greece	6,979.88
27	Bulgaria	6,284.34
28	Romania	6,173.44

Source: own compilation using PS IMAGO.

Using the synthetic governance quality index, we calculated the index's mean value for the four groups of countries (see Figure 2).

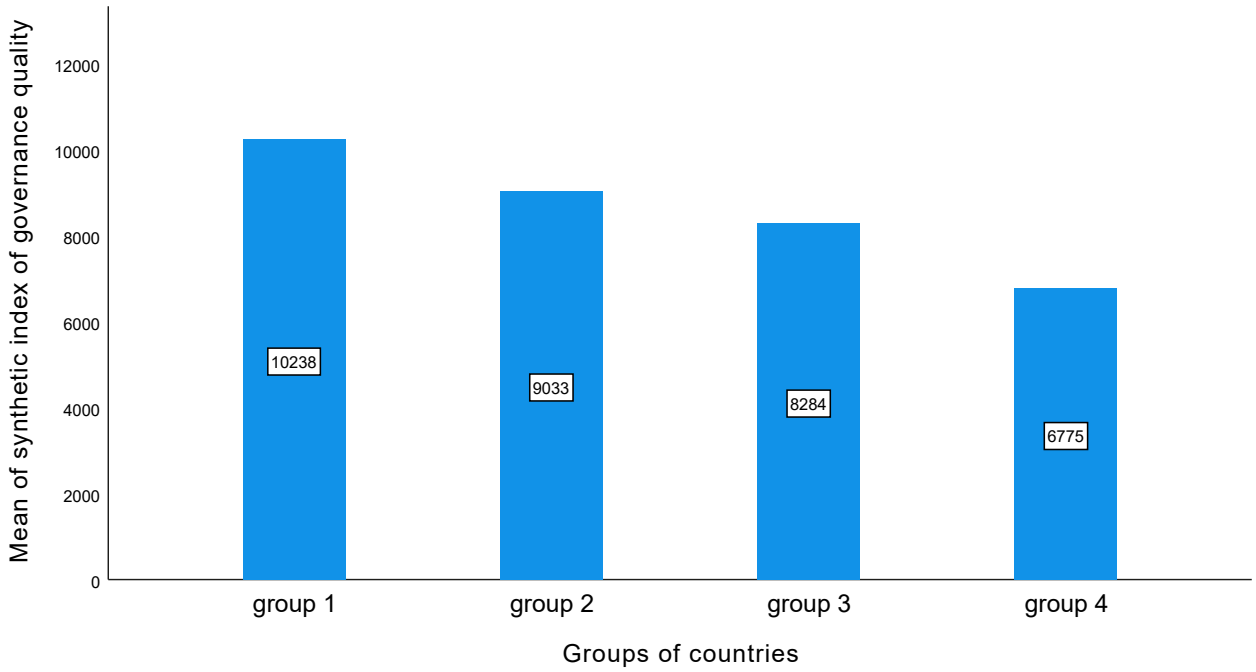


Figure 2. The mean value of the SIGQ for the EU–28, 2004–2021

Source: own compilation using PS IMAGO.

The ranking confirmed that the highest GQ was reported by countries from Group 1_{gov}, i.e. Finland, Sweden, Luxembourg, Denmark, Netherlands, Austria and Ireland. At the other extreme is Group 4_{gov}, with Bulgaria, Romania, Greece, Italy, and Croatia, where potential investors can expect the lowest level of governance quality.

We then extended our research to include partial rankings that showed the index values for six dimensions of governance quality (see Figure 3). Finland leads in three of the six partial rankings and is second in two. Sweden, Luxembourg and Denmark also perform relatively well. In almost all subcategories, the weakest performers are new Member States, Romania and Bulgaria, which joined the EU in 2007. Greece, which has membership experience of over 40 years, is also included. Significant differences exist between the countries, with the best and worst results almost double in the sub-ranking. This

applies to four of the following six sub-rankings: (1) political stability and absence of violence, (2) government effectiveness, (3) rule of law, and (4) control of corruption.

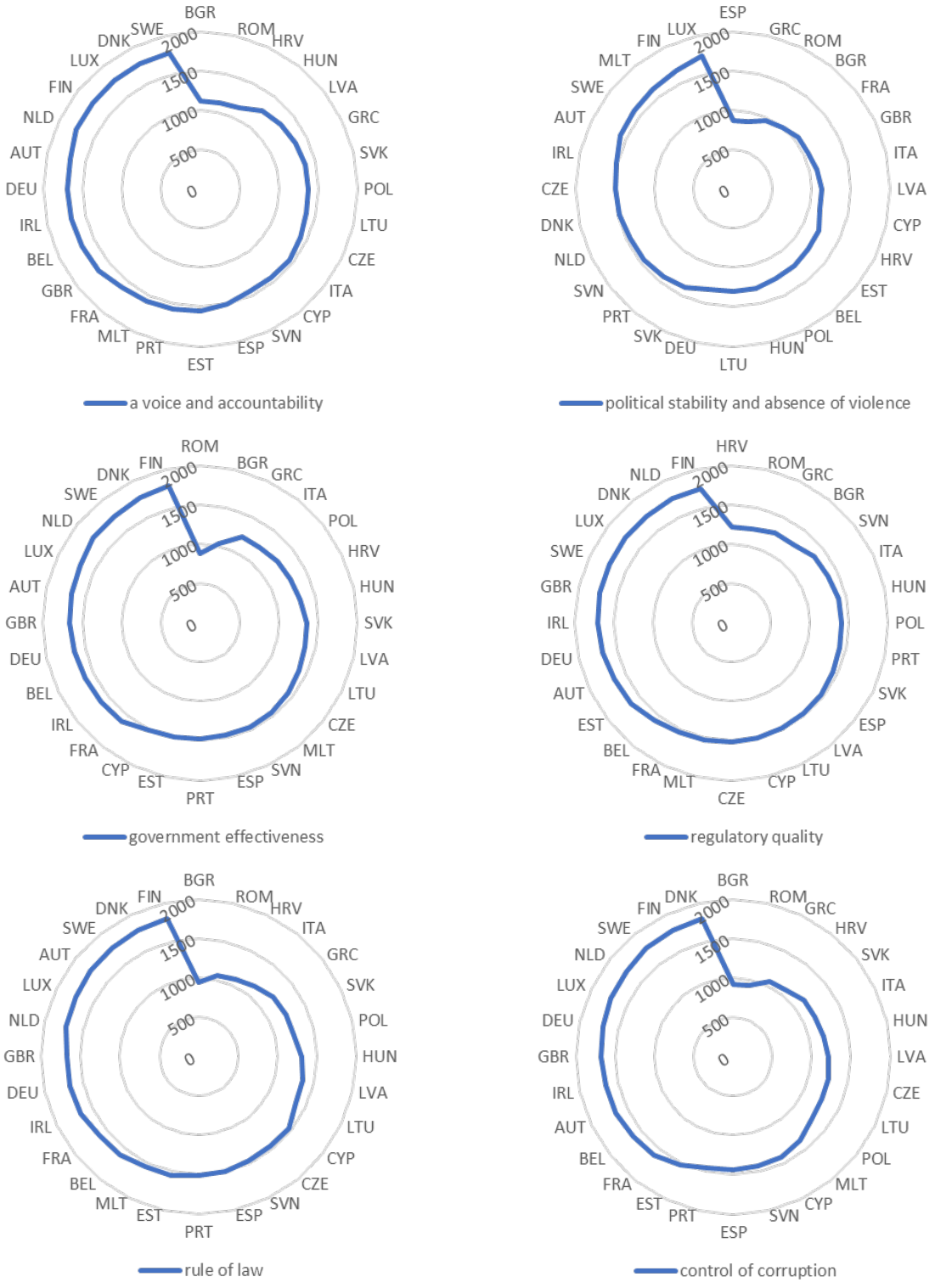


Figure 3. Individual rankings of the six dimensions of GQ in the EU–28, 2004–2021

Source: own compilation using PS IMAGO.

The OFDI from the EU–28 Member States

In the next stage, we looked into the OFDI from the EU–28. Based on the descriptive statistics in Table 2, we can conclude that OFDI stock as a % of GDP for the EU–28 at the end of 2021 is remarkably differentiated, highly skewed, and with high kurtosis. The 5% trimmed mean and M-estimators differ significantly from the mean, providing evidence of the absence of homogeneity in the examined population.

Table 2. Statistics describing OFDI stock as a % of GDP in the EU 2021

Descriptives	Statistics	Std. Error
Mean	171.62	74.26
95% Confidence Interval for Mean – Lower Bound	19.25	
95% Confidence Interval for Mean – Upper Bound	323.99	
5% Trimmed Mean	105.82	
Variance	154 402.61	
Std. Deviation	392.94	
Minimum	0.95	
Maximum	1 537.05	
Range	1 536.10	
Interquartile Range	56.82	
Skewness	3.17	0.44
Kurtosis	9.41	0.86
Percentiles 25	14.63	
Percentiles 50	39.24	
Percentiles 75	70.32	
M-Estimators		
Huber's M-Estimator[a]	40.34	
Tukey's Biweight[b]	30.71	
Hampel's M-Estimator[c]	32.23	
Andrews' Wave[d]	30.72	

[a] The weighting constant is 1.339.

[b] The weighting constant is 4.685.

[c] The weighting constants are 1.700, 3.400, and 8.500.

[d] The weighting constant is 1.340*pi.

Source: own compilation made in PS IMAGO.

We divided the EU–28 into four groups arranged in ascending order of OFDI stock as a % of GDP based on position measures such as quartiles. We transformed the OFDI

stock as a % of the GDP variable measured on a numerical scale into an ordinal scale variable. As a result, we produced the following groups of countries:

Group 1$_{fdi}$: Cyprus, Luxembourg, Malta, Netherlands, Ireland, Belgium, Sweden;

Group 2$_{fdi}$: Denmark, United Kingdom, France, Austria, Germany, Finland, Spain;

Group 3$_{fdi}$: Estonia, Italy, Portugal, Hungary, Czechia, Lithuania, Latvia;

Group 4$_{fdi}$: Slovenia, Croatia, Greece, Slovakia, Poland, Bulgaria, Romania.

A detailed ranking of OFDI stock as a % of GDP (as of the end of 2021) is presented in Figure 4.

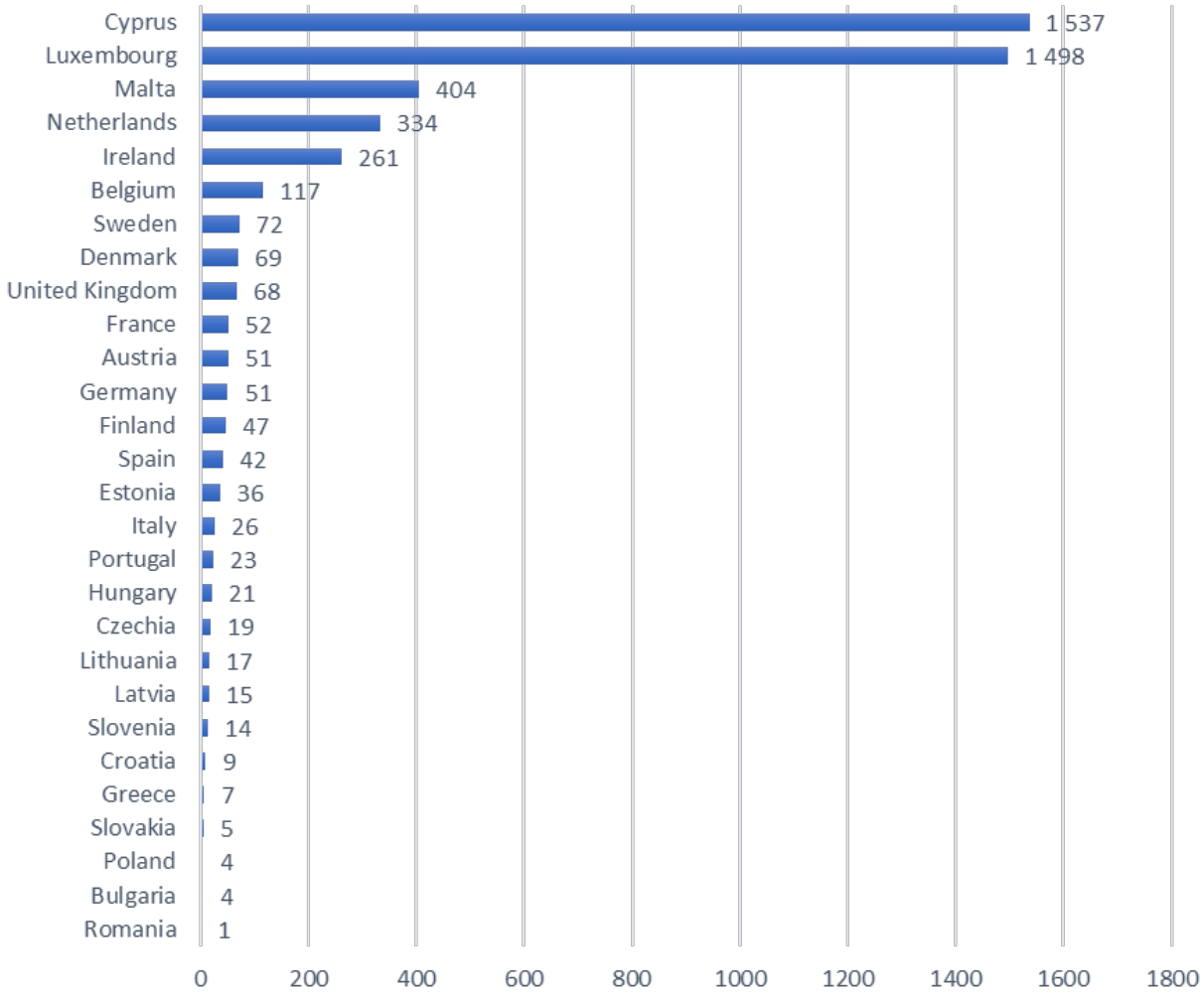


Figure 4. OFDI stock as a % of GDP as of the end of 2021

Source: own compilation based on UNCTADSTAT.

The relationship between GQ and OFDI

In the next stage of this study, we assessed the relationship between the GQ in the EU–28 between 2004 and 2021 and OFDI stock as a % of GDP as of the end of 2021. The correlation analysis started with drafting the correlation diagram for the variables (Figure 5).

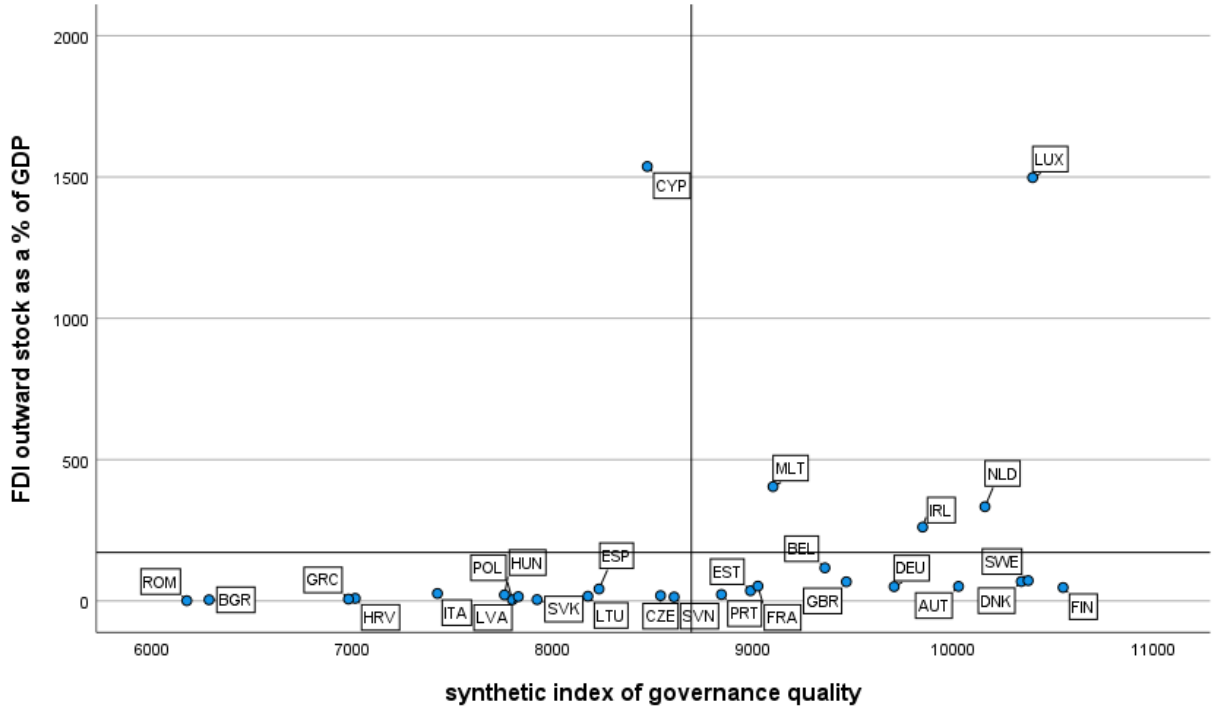


Figure 5. Correlation diagram for the SIGQ and FDI outward stock as a % of GDP

Source: own compilation using PS IMAGO.

The correlation diagram verifies the conclusions drawn in the previous step, suggesting massive differentiation of the OFDI stock as a % of GDP among the EU–28, mainly due to the values of this variable for Cyprus, Malta, and Luxembourg. To understand this further, we will now assess how much the synthetic index of governance quality differs across the four groups of member states arranged in ascending order of OFDI as a % of GDP based on the measures of position such as quartiles (see Figure 6).

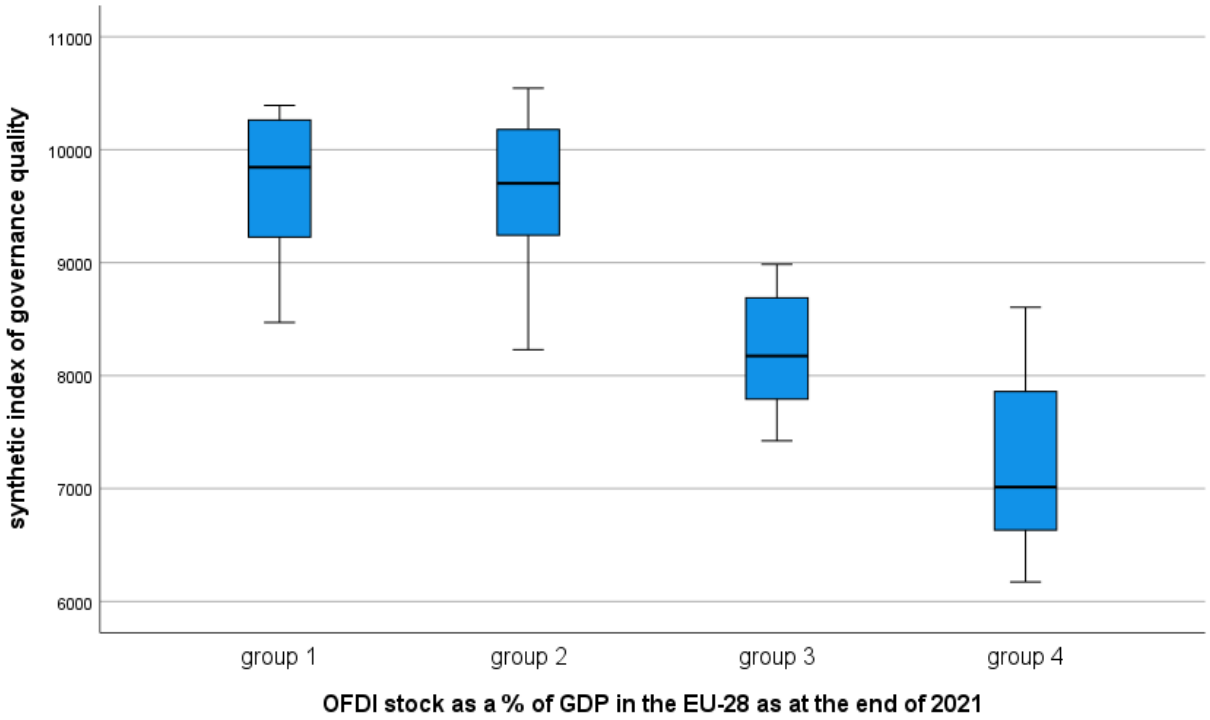
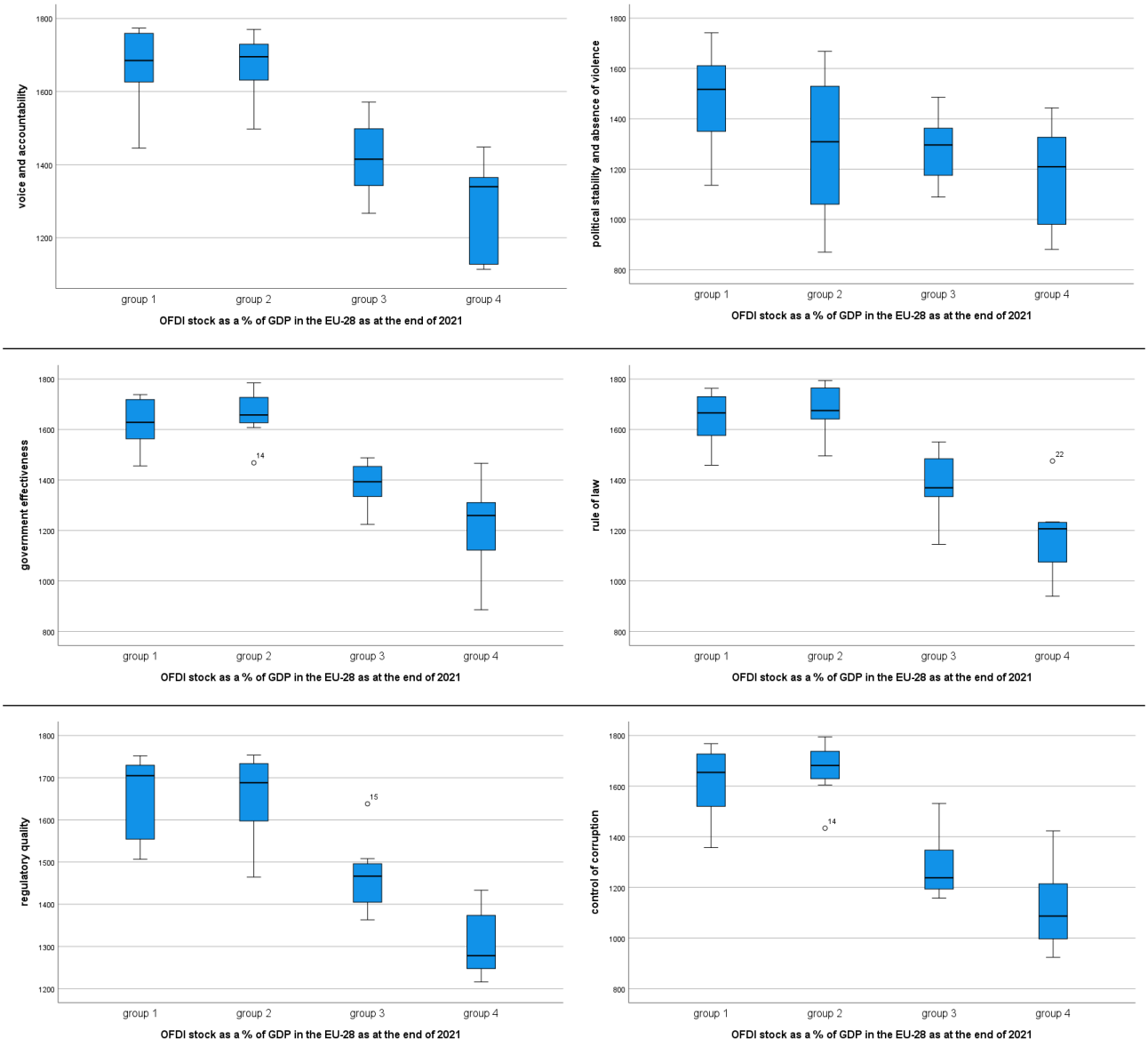


Figure 6. Box-whisker for the SIGQ in 4 groups of countries based on the OFDI stock as a % of GDP in the EU–28 as of the end of 2021

Source: own compilation using PS IMAGO.

The highest median values of the SIGQ among the EU–28 were reported for Group 1_{fdi}, which means that the most significant FDI outward stock as a % of GDP is characterised by countries offering the highest institutional quality to potential investors. The median values of the synthetic governance quality index are slightly lower in Group 2_{fdi} compared to Group 1_{fdi}. The median values of the SIGQ are much lower in Group 3_{fdi} and Group 4_{fdi}, bringing together countries reporting the lower levels of OFDI stock as a % of GDP and the SIGQ values.



° Number 22 – Slovenia, number 15 – Estonia, number 14 – Spain.

Figure 7. Box-whisker for six dimensions of governance quality in groups of countries distinguished based on OFDI stock as a % of GDP

Source: own compilation based on PS IMAGO.

In the next step, we verified the relevance of the six dimensions of GQ for OFDI, and the results are presented in Figure 7. The distribution of median values in all areas covered by the study is consistent with the distribution of the synthetic measure. Notably, however, the most significant differences were found in the three dimensions of GQ, i.e. rule of law, regulatory quality, and government effectiveness.

Table 3. Contingency matrix for groups of the EU–28 for GQ and OFDI stock as a % of GDP

Groups of countries with similar levels of OFDI stock as a % of GDP	Groups of countries with similar quality of governance				Total
	Group 1_{gov} Denmark, Netherlands, Austria, Ireland, Finland, Sweden, Luxembourg	Group 2_{gov} Cyprus, Spain, Estonia, France, Belgium, Germany, United Kingdom	Group 3_{gov} Hungary, Poland, Slovakia, Latvia, Lithuania, Portugal, Slovenia, Czechia, Malta	Group 4_{gov} Bulgaria, Romania, Greece, Italy, Croatia	
Group 1_{fdi} Cyprus, Luxembourg, Malta, Netherlands, Ireland, Belgium, Sweden	4	2	1	0	7
Group 2_{fdi} Denmark, United Kingdom, France, Austria, Germany, Finland, Spain	3	4	0	0	7
Group 3_{fdi} Estonia, Italy, Portugal, Hungary, Czechia, Lithuania, Latvia	0	1	5	1	7
Group 4_{fdi} Slovenia, Croatia, Greece, Slovakia, Poland, Bulgaria, Romania	0	0	3	4	7

Source: own compilation is done using PS IMAGO.

We grouped the countries in ascending order of FDI as a % of GDP based on quartiles, as well as governance quality. This allowed us to construct a contingency matrix table (Table 3). By examining the data from Table 3, it can be assumed that countries with higher GQ tend to record a higher share of OFDI in relation to GDP, as exemplified in our study by the Netherlands, Luxembourg, Sweden, and Ireland.

Table 4. Contingency coefficients between six dimensions of governance and FDI outward stock as a % of GDP in the EU–28

	Dimensions of governance	Contingency coefficient
1	Voice and accountability	0.656
2	Political stability and absence of violence	0.548
3	Government effectiveness	0.656
4	Regulatory quality	0.657

Dimensions of governance		Contingency coefficient
5	Rule of law	0.707
6	Control of corruption	0.666
Six dimensions of governance / overall value (SIGQ)		**0.704**

Source: own compilation is done using PS IMAGO.

We used the contingency coefficient to assess the strength of the correlation between GQ and OFDI stock as a % of GDP (Table 4). Its value for the six dimensions of governance quality for the EU–28 was 0.704, which shows a significant, positive[3] correlation between GQ and OFDI stock as a % of GDP. By ensuring an appropriate quality of governance, the EU–28 increase OFDI as a % of GDP. The contingency coefficients between the six dimensions of governance and OFDI as a % of GDP suggest that the rule of law has, relatively speaking, the most significant impact on OFDI.

Conclusions

The principal goal of the article was to evaluate the quality of governance in the EU–28 and to examine the relationship between governance and OFDI stock as a % of GDP. From our research, the following conclusions can be obtained:

1. The overall quality of governance, as measured by the WGI and its six key components, differs significantly across the EU Member States. At the same time, it was found that the analysed countries can be grouped into groups, indicating a similar quality of governance.
2. We used hierarchical cluster analysis to split the EU–28 into four groups with similar characteristics, i.e. political stability, rule of law, and corruption control. Finland, Sweden, Luxembourg, Denmark, Netherlands, Austria, and Ireland comprise the best group. Finland is, without a doubt, the leader. In turn, the weakest performers tended to be Romania and Bulgaria, which joined the EU in 2007, as well as Greece, which has been a member of the EU for more than four decades.
3. The statistical analysis revealed a positive correlation between governance quality and the OFDI. The rule of law is the most essential of the partial variables, as it captures perceptions of the extent to which agents have confidence in and abide by societal rules.

3 Direction of the relationship was assessed based on the distribution of data in the contingency table (Table 4) and the ranking of variables describing quality of governance in the EU Member States (Figures 2 and 3).

4. The other correlation results support the idea that all factors determining the governance quality positively impact OFDI projects.

Our study has some limitations. No distinction was made between different entry modes of OFDI or specific motivations that drive OFDI. Such an investigation would be interesting, especially in the context of EU countries, which differ regarding economic and social development and membership experience. Future studies could be oriented towards investigating differences in the quality of governance and OFDI between developed and emerging economies. Central and Eastern European countries are an exciting research group, as they have carried out many reforms over the last three decades that have considerably affected their institutional environment. Moreover, MNEs from these countries differ from those in other regions because they have different motives and starting points for the internationalisation process.

The study has specific implications for research and practice. Given the positive relationship between GQ and OFDI, policymakers should consider the importance of institutional quality indicators in supporting domestic companies "to go abroad". A good governance profile of the home country encourages local businesses to invest internationally in the most sophisticated way, e.g., in greenfield projects. Thus, governments should implement institutional reforms to implement OFDI investment incentive schemes. Our research demonstrates that government policies should also focus on improving specific dimensions of governance quality, such as the rule of law. The results show that this dimension of governance has been the most relevant for OFDI in the EU–28.

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Czy jakość rządzenia w kraju pochodzenia kapitału wpływa na zagraniczne inwestycje bezpośrednie? Badanie porównawcze państw członkowskich UE

Głównym celem badania jest wpływ jakości rządzenia na aktywną internacjonalizację przedsiębiorstw w Unii Europejskiej. Najpierw zmierzyliśmy i porównaliśmy poziom jakości instytucjonalnej w państwach członkowskich UE w latach 2004–2021, wykorzystując autorski syntetyczny indeks jakości rządzenia (SIGQ). Następnie porównaliśmy wartość zagranicznych inwestycji bezpośrednich wychodzących (OFDI) w relacji do PKB na mieszkańca w każdym państwie członkowskim UE. Na koniec skorelowaliśmy ogólną jakość rządzenia (GQ) i jej sześć wymiarów z OFDI w państwach członkowskich UE–28 (w tym w Wielkiej Brytanii). Zastosowaliśmy metody statystyczne, m.in. hierarchiczną analizę skupień, analizę kontyngencji, syntetyczne wartości indeksu i statystyki opisowe. Wyniki analizy statystycznej potwierdziły pozytywny związek między jakością rządzenia a OFDI. Najważniejszą ze zmiennych cząstkowych okazał się współczynnik określający rządy prawa (*rule of law*), to znaczy postrzeganie stopnia, w jakim jednostki i podmioty przestrzegają zasad społecznych w danym kraju. Nasze badania pokazują, że decydenci polityczni powinni rozważyć znaczenie wskaźników jakości instytucjonalnej we wspieraniu krajowych firm w wychodzeniu za granicę. Głównym wkładem w obecny stan wiedzy na temat OFDI jest próba zidentyfikowania ich związku z GQ we wszystkich państwach członkowskich Unii Europejskiej („starych” i „nowych”) przy użyciu indeksu SIGQ.

Słowa kluczowe: jakość rządzenia, umiędzynarodowienie, zagraniczne inwestycje bezpośrednie, państwa członkowskie UE

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.32

Exploring Income Convergence for Central and South Asia

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Abstract

Income convergence refers to the idea that poor countries grow more quickly than rich ones and catch up in terms of per capita income; as a result, the per capita income of integrated nations eventually converges. Beta convergence suggests that less developed nations grow more quickly than more developed ones and reach their average per capita income level by growing more quickly. Meanwhile, sigma convergence suggests that the per capita income disparity among the countries in a regional block narrows over time.

The objective of this study is to test income convergence through beta and sigma convergence for Central and South Asia integration using data from 1990 to 2022. Sigma convergence is

Received: 21.01.2024. Verified: 14.02.2024. Accepted: 27.09.2024

tested through the standard deviation and coefficient of variation of average per capita income, while beta convergence is tested using panel unit root tests. The results of the study confirm the beta convergence and sigma convergence, which implies income convergence for the integration of Central and South Asia.
The implications of this study are manifold. It recommends that Central and South Asian countries ensure economic, political and social cooperation with one another. This is possible by eliminating trade restrictions and decreasing import taxes to increase free trade. Additionally, ensuring free labor, capital, and technology movement between Central and South Asia will be beneficial for ensuring economic integration, facilitating income convergence, and reducing income inequality between these regions. This study contributes to the income convergence literature by focusing on integration between Central Asia and South Asia.

Keywords: income convergence, economic integration, Central Asia, South Asia

JEL: F15, F43, O4, O47

Introduction

The world is gradually turning into a global village. One of the most prominent effects of globalization is the incredible degree of regional integration among the nations (Singer 2016). The interaction between the nations of the world takes many different forms, including the cross-border movement of people and ideas, as well as the cross-border trade of products and services (Rodrik 2008). Convergence is a term used in economics that can refer to social, technological, real, nominal, and income convergence, among other concepts (Islam 2003). Sala-i-Martin (1996) introduced the concepts of economic convergence and divergence. The process of eliminating disparities in real income and economic growth between economies is known as income convergence. Real convergence occurs when poorer economies or areas overtake wealthy ones, and the gap between their real incomes narrows. By contrast, income divergence occurs when the gap between their real incomes widens.

Income convergence can be gauged through beta convergence and sigma convergence. Beta convergence, which is a prerequisite for income convergence, explains that less developed nations grow more quickly than more developed ones, converging towards distinct steady-states. Meanwhile, sigma convergence suggests that the per capita income disparity among the countries in a regional block narrows over time (Sala-i-Martin 1996).

Convergence testing for economies is an ongoing topic in economics. However, after the 2008 financial crisis, it gained more prominence as a result of heated political debate for convergence clubs or specific regions, like the European Union (EU), where the process of convergence stopped and divergence in per capita real income took place. Since the 1990s, developing countries have experienced greater financial and trade globalization than developed countries. Although many economic associations are in place,

questions remain about the costs and benefits of economic associations, as well as who will win and lose from these associations in the form of trade agreements, customs unions, and other forms of integration schemes already in place (Fedajev et al. 2022).

Due to a rise in globalization and international competition, regional integration among nations has expanded almost everywhere in the world during the past nearly 50 years. Import substitution policies have changed to trade openness policies, resulting in increasing commerce with neighbors and participation in regional integration. Due to a reduction in trade restrictions on international trade and an increase in nation-to-nation integration, protectionism policies were replaced with policies of trade openness, and trade openness has since become the benchmark for measuring and realizing economic growth and well-being.

Political and economic factors have stimulated regional integration. Nations have shifted toward economic integration to expand markets, opportunities, and production rivalry in local markets. Additionally, as economies have become more intertwined, there has been a rise in social and economic integration, which has led to a more stable trading climate and fewer disputes among countries. The previous agreement, the General Agreement on Tariffs and Trade (GATT), paved the way for the creation of the World Trade Organization (WTO) and stoked national excitement for increased trade openness. The countries that joined the WTO abolished trade restrictions and participated more in international trade, which grew more quickly than in those countries with trade restrictions. Due to this increase in trade openness, economic integration started in the shape of regional trade arrangements, including custom unions, preferential trading arrangements (PTAs), common markets, and single markets or monetary unions all over the world. Almost all nations today are members of one or more regional organizations (Kheyfets and Chernova 2021).

Regional economic cooperation among nations or regions accelerates economic development in the member nations and makes them more competitive in the international market. It leads to the establishment of mutually compatible economic policies, which increase the volume of trade through better use of economies of scale. This has a long-lasting, favorable impact on economic development, increases income levels, and decreases income inequalities (Dey and Neogi 2015). Regional economic integration lowers obstacles to international labor movement and can help to enhance job possibilities. It is crucial for emerging countries because it accelerates their rates of development. These regional economic agreements facilitate trade and capital development by reducing barriers and lowering or eliminating tariffs, lowering the cost of goods for consumers in the associated nations. It minimizes earnings disparities in the area.

These regional associations have given nations more power to focus on issues relevant to their economic growth stages and to speed up trade among their neighbors. Political

cooperation among the member countries is facilitated by regional commonalities and understanding (Gammadigbe 2021).

Regional economic integration may be important for development for a variety of reasons. Initially, economic integration encourages capital and labor movement in the region, which can boost labor productivity. Second, trade arrangements benefit all countries while boosting the volume of commodities exchanged in the region, like customs unions or free trade agreements. Lastly, regional economic integration encourages the adoption of cutting-edge technologies that improve the quality of a product and lower domestic production costs by encouraging the exchange of ideas, products, and expertise among regional businesses (Gul, Haq, and Khan 2022).

Central Asia consists of Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan, and Uzbekistan. In the early 1990s, the nations of Central Asia gained independence from the USSR and moved towards free market economies. These nations are bringing reforms for modernization and to raise living standards. They have abundant natural resources, rich cultures, an educated labor force, and strategic positions, in particular, their proximity to China. This may give them an excellent opportunity for economic expansion. Many factors may stimulate development, the most significant of which is foreign trade because these nations heavily depend upon it. Due to limited access to the global markets, intra-regional trade is very vital for these nations. In the last two decades or so, Tajikistan and the other countries of Central Asia gained significant advantages from the improved regional integration in the global economy. The growth in international trade is regarded as the engine for the economic development of the region as it reduces poverty, decreases income inequality through income convergence, and brings prosperity (Gul, Haq, and Khan 2022).

The economies of the Central Asian states are well-established, and there is enormous room for expansion. The entire GDP of Central Asia reached $347 billion in 2021, having increased more than sevenfold over the last two decades. Since 2000, the population of Central Asia has grown by 1.4 times, creating a sizable sales market and a growing supply of labor resources. The demographics of the region favor economic growth, with the existing age distribution predicting an increase in labor resources in the future. Over the last 20 years, Central Asia's average annual economic growth rate has been 6.2%, compared to 5.3% in developing nations and a global average of 2.6%.

The increase in exports, workers' remittances, and foreign direct investment all helped to lower poverty and raise income. Exports from the area in 2021 reached $165.5 billion, a sixfold rise over the last two decades. The amount of FDI coming into Central Asia has climbed more than seventeen times in the last two decades, reaching $211 billion in 2021. Although FDI is increasing in the region, its structure, which is country- and sector-specific, shows some difficulties. International investors' perceptions of the region are still influenced by the lack of openness, their distance from important economic

hubs, and the fact that they lack access to the ocean. The region is underinvested, as evidenced by the fact that the ratio of FDI to GDP, excluding investment in the commodity industries, is lower than the global average (Kim, Mariano, and Abesamis 2022).

Central Asian nations may overcome their structural development challenges with a coordinated effort. There is no choice but to cooperate in the areas of water and energy due to increased energy demand during a time of rapid economic growth and the fact that the nations share river basins. Coordination of initiatives to build transportation infrastructure and reduce climate risk is also crucial. Infrastructure bottlenecks must be removed to increase economic productivity, commerce, and economic alliances with neighboring nations; they must also diversify production and exports (Cheong and Turakulov 2022).

The GDP growth rates of Central Asian countries from 1991 to 2022 are shown in Figure 1. The initial per capita growth rates of all the member countries were negative, but they soon started to become positive and increase quickly. This clearly demonstrates that the per capita income of all countries rises with time; the average per capita growth rate of the regional block converges, indicating income convergence among the member countries.

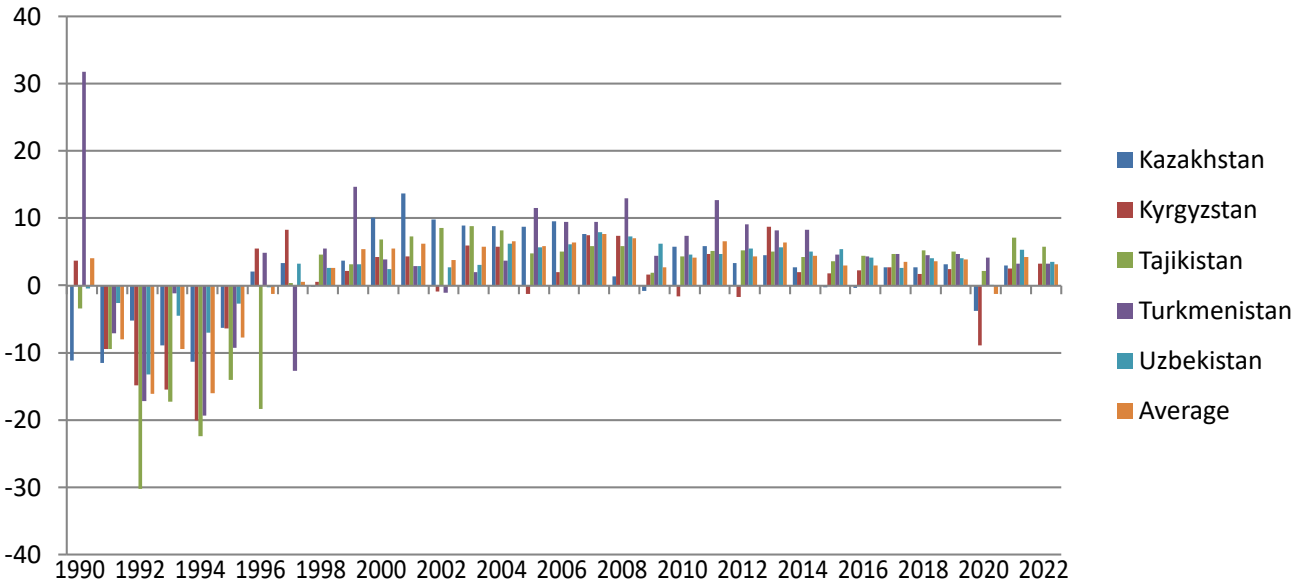

Figure 1. Annual GDP per capita growth rates of Central Asia

Source: World Bank n.d.

The South Asian Association for Regional Cooperation (SAARC) is the intergovernmental and geopolitical union of the countries in South Asia. It has eight permanent member nations, including Afghanistan, Bhutan, Bangladesh, India, the Maldives, Nepal, Pakistan, and Sri Lanka. SAARC was established on 8th December 1985 in Dhaka, Bangladesh, to raise the well-being of the people of South Asia. SAARC

supports collaboration in diverse fields and maintains and encourages cooperation with regional and international organizations for economic integration and development. In 2021, it covered three percent of the world's land mass (5,099,611 square km, or 1,968,971 square miles), twenty-one percent of the world's population, and 5.22% (US$4.47 trillion) of the global economy. In 2021, the GDP (PPP) was US$14.85 trillion, while the GDP (nominal) in the same period was $4.47 trillion (Bishwakarma and Hu 2022).

SAAR Cestablished the South Asia Free Trade Area (SAFTA) in 2006, which was the first step in moving towards the second step, a Customs Union, the third step, a Common Market, and finally, an Economic (Monetary) Union. SAFTA was expected to steadily move towards the customs union of South Asia, but unfortunately, investment among member nations is currently very low and not very encouraging of trade relations; it seems the targets they set will not be easy to reach. The share of trade among the member nations of SAARC is only 5% of the total share of regional trade. FDI is also very low because the flow of intra-regional FDI is about 4% of the overall FDI. According to an Asian Development Bank (ADB) report, trade among SAARC members could raise their agricultural exports by US$15 billion annually, from the present US$8 billion to US$23 billion (Islam 2022).

Long-term prosperity and peace in the region have been elusive. The political discourse is frequently discussed in SAARC meetings, emphasizing the need to refrain from interfering in member nations' internal issues. At the twelfth and thirteenth SAARC summits, significant emphasis was placed on enhancing cooperation among the member nations to combat terrorism.

Figure 2 shows the GDP growth rates of SAARC countries from 1991 to 2022. In the initial year, we can see that this rate is lower in all the countries and very far away from the average value of the block. Then, it started to increase in all the economies, and the gap from the average value was minimized in the last years, which clearly shows that income disparity is decreasing over time in the block.

Countries and regional blocks are usually interested in forming a forum for mutual socio-economic benefits. The countries Central Asia and South Asia also formed such a forum which is called Subregional Economic Cooperation in South and Central Asia. The purpose of this forum is basically to cooperate in trade and infrastructure (energy and transport) and to connect the people of the two regions for mutual interests. Likewise, the countries of both regions are also members of other forums and try to enhance economic cooperation. Therefore, this study was conducted in this context and its main objective is to explore income convergence for Central and South Asian countries.

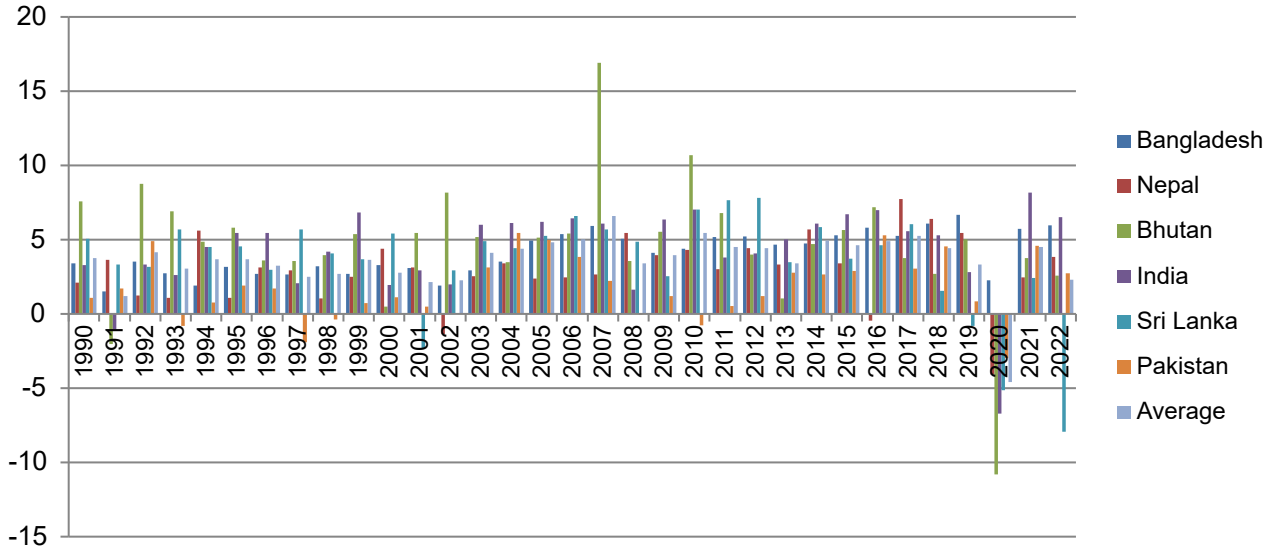

Figure 2. Annual GDP per capita growth rates of SAARC

Source: World Bank n.d.

Literature review

The first empirical work on income convergence started with Baumol (1986), and since then, it has been explored by numerous researchers. Initial research included cross-sectional studies, like Sala-i-Martin (1996) and Barro (1991), which confirmed the presence of cross-sectional income convergence. Later on, however, economists challenged the results and focused on time series studies (e.g., Bernard and Durlauf 1995; Strazicich, Lee, and Day 2004; Dawson and Strazicich 2010). Time series work has been done mostly for developed nations and most concluded that income convergence occurred for these nations. Few empirical works exist for developing nations, with only a few studies exploring intra-group income convergence using the panel technique.

The basic neoclassical model of economic growth (initially presented by Solow (1956) and Swan (1956) and consequently refined by Koopmans (1963), Cass (1965) and Mankiw, Romer, and Weil (1992) became the basis for many empirical research studies to test income convergence among nations and regions. Solow (1956) suggested that as an economy transitions to its long-term level of steady state, the initial per capita GDP growth rate is inversely associated with its subsequent per capita GDP growth rate. It means that rich nations, which initially have a higher per capita GDP growth rate and grow slower than poor nations have low per capita GDP growth rates. As a result, both rich and poor nations will converge to a similar level of per capita GDP in the long term. Therefore, there will be income convergence

among poor and rich nations. This was suggested by Solow, considering the diminishing returns to factors of production and constant return to output with no government intervention and a closed economy. Sala-i-Martin (2002) and Islam (2003) found the presence of conditional income convergence based on the neoclassical growth model.

Haider, Hameed, and Wajid (2010) conducted a comparative study of the founding nations of Association of Southeast Asian Nations (ASEAN) and selected SAARC nations by employing the beta and sigma convergence tests for the period 1984–2012. They found divergence between these two regional blocs. Their results also revealed conditional income convergence for ASEAN and South Asia. Dey and Neogi (2015) examined per capita income unconditional convergences for seven SAARC member nations by employing the beta convergence and sigma convergence tests for the period 1970–2011. The results showed the presence of per capita income unconditional convergences for SAARC nations.

Moreover, per capita income unconditional convergence was tested for the integration of China with SAARC to test whether there is an opportunity for a wider range of economic cooperation in the region. The results of beta convergence and sigma convergence tests revealed unconditional convergence after the integration of China with SAARC. In addition, with the inclusion of China, the convergence rate is also greater than before. It is suggested that there is immense opportunity in the area for further regional economic collaboration to increase trade, transfer modern technology, permit the free movement of people and capital across borders, reduce income disparity, and increase living standards.

Khan and Daly (2018) tested the income convergence for selected SAARC nations between 1960 and 2017, employing the panel unit root technique in the context of monetary union for the SAARC. Despite accounting for structural breaks, the results revealed little support for per capita income convergence. As suggested by Enders and Lee (2004), the study also employed two other techniques to test income convergence, which consider the smoothly evolving trend in per capita income rather than a possible linear trend. This study also adopted a technique developed by Phillips and Sul (2007), which allows for the examination of per capita earnings convergence within sub-groups. However, these techniques yielded minimal evidence of per capita income convergence for all the nations in the group.

In addition, their study suggested classifying SAARC nations into two non-overlapping per capita income convergence clubs, with Sri Lanka and India exhibiting an encouraging growth path. These findings raised the question about the feasibility of a monetary union for the member nations of SAARC. Conversely, Ahmed and Hussain (2019) have conducted a study for the European Union (EU) in the context of drawing lessons for SAARC nations. They argued that intra-regional trade and economic cooperation among SAARC nations is limited due to the long-standing bilateral disputes. This study

covered 1950 to 2016 (including Brexit) to find a promising lesson for SAARC by employing Gürler's model of economic integration. They concluded that a revived SAARC is nevertheless an appropriate vehicle for following a steady course of regional economic cooperation in South Asia. It could eventually lead to economic integration and resolve political disputes between nations.

Zia (2019) examined intra-group income convergence for SAARC between 1999 and 2015 by employing the typical techniques of beta convergence and sigma convergence. This study investigates income convergence among the nations of SAARC in the presence of FDI, trade liberalization, government effectiveness, and modern technology transfer. The panel technique is applied to test income convergence, taking into account the regional heterogeneity. The study concludes that there is income divergence among the nations of SAARC and argues that they would not benefit from the regional economic association after signing SAFTA and SAPTA. Furthermore, it is concluded that SAARC is not as effective as it should be. Safdar and Nawaz (2020) also explored income convergence in SAARC for selected countries using the Solow–Swan (1956) growth model for the period 1972 to 2012. Their results did not conclude that there is betaconvergence or sigmaconvergence for the specified period, nor are they consistent with the Solow–Swan growth model.

Gammadigbe (2021) asserted that regional trade agreements (RTAs) stimulate economic growth in nations that participate in these agreements through trade, transfer of knowledge and technology, and economies of scale. He carried out the study to explore how regional trade integration contributed to economic growth and income convergence in Africa. The findings reveal that regional trade integration encourages economic growth in Africa. They also support the African Continental Free Trade Area (ACFTA) project, which aims to reduce non-tariff restrictions on trade and improve infrastructure to maximize the impacts on growth in all African nations that participate in the RTAs.

Kheyfets and Chernova (2021) investigated income convergence for the Eurasian Economic Union (EAEU) nations. They concluded that the rate of income convergence for the associated nations decreased. However, they concluded that China and its Belt and Road Initiative (BRI) program paved the way for integration into this union. The EAEU member nations are leaning towards China due to its financial support.

Likewise, Alinsato (2022) analyzed the nature of West African Economic and Monetary Union (WAEMU) relations from 1995 to 2015 using beta convergence techniques and the spatial competition model of Dendrinos and Sonis (1990). He concluded that there was divergence in standards of living. In addition to this, the study also revealed very poor integration among the countries in the region, and they have competitive relationships with each other. The study suggested that it is necessary to increase the rate of regional economic integration in WAEMU, bearing in mind the comparative advantage of every nation in the region.

Hu et al. (2022) investigated the impact of China's BRI economic development project on fostering regional economic integration. China adopted a policy of openness that encouraged globalization. Thus, this study determined income convergence across the periods 1960 to 2016 and 1979 to 2016. They contend that the BRI countries that exhibit income convergence towards China in their income convergence testing typically already had a close economic link with China. In contrast, nations with relatively limited economic ties with China typically do not demonstrate convergence. Thus, they argued that the BRI may allow them to catch up with China. They also concluded that China contributes to greater regional integration and income convergence.

Korwatanasakul (2022) comprehensively reviewed the progress of "Asian" economic integration, which covers the main Asian regional economic blocs. The study argued that continent-wide and comprehensive regional economic integration in the Asian region is not likely to happen because the integration practice has been generally limited to the countries of East and Southeast Asia, as other Asian regions are less globalized and integrated. Furthermore, it was suggested that the gradual integration process would be jointly beneficial for every nation of the economic association by improving technology, increasing the labor force, building capacity, and increasing the market with the upcoming accomplishment of the ASEAN single market and ample regional economic cooperation.

For the Central Asian nations, Gul, Haq, and Khan (2022) investigated income convergence. Using beta and sigma convergence, they examined the income convergence between 2003 and 2019. Both sigma and beta convergence tests confirmed income convergence in Central Asian nations. They concluded that economic integration is beneficial for Central Asia and suggested that these countries should maintain economic cooperation with one another by reducing trade barriers and import duties. Additionally, it will be beneficial to ensure labor force mobility freely throughout the Central Asian nations since it will support economic integration and reduce regional income inequality.

The literature reviewed here shows that several studies examined income convergence for various regional blocks using various methods;in most cases, they concluded that income convergence existed. Some studies confirmed intra-group income convergence for SAARC, like Dey and Neogi (2015), Zia (2019) and Safdar and Nawaz (2020). By contrast, Gul, Haq, and Khan (2022, pp. 448–461) conducted an intra-group income convergence for the Central Asian countries and concluded that there was income convergence. We found no study in the literature that tested inter-group income convergence in SAARC and Central Asia. As a result, this study fills the research gap in the literature by exploring inter-group income convergence in SAARC and Central Asia.

Research methodology

This is a panel data study for testing inter-group income convergence for Central Asia and South Asia for the period 1990–2022.Data on per capita income measured in USD were collected from the World Bank online database. Central Asian countries are Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, while Bangladesh, Bhutan, India, Pakistan, Sri Lanka, and Nepal are selected countries from South Asia. To examine income convergence, we use panel unit root tests like Levin-Lin-Chu (LLC), introduced by Levin, Lin, and Chu (2002), Im-Pesaran-Shin (IPS), developed by Im, Pesaran, and Shin (2003), and the PP-Fisher Chi-square and ADF-Fisher Chi-square tests, introduced by Choi (2001). The panel unit root tests are tested based on the following equation (1):

$$y_{it} = \alpha + \beta y_{it-1} + \varepsilon_{it}. \quad (1)$$

To avoid the unit root problem, extra lags can be included, and the above equation (1) can be written as follows:

$$\Delta y_{it} = \alpha + \rho y_{it-1} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{it-j} + \varepsilon_{it}, \quad (2)$$

where Y_{it} denotes the average per capita income of the countries selected for the analysis. The negative value of ρ in the LLC and IPS tests will indicate income convergence, as positive values represent income divergence. Sigma convergence tests whether there is a decline or not in differences in per capita amongst the nations or in regions over time. To explore the sigma convergence, Standard deviation (SD) and the coefficient of variation (CV) are employed.The following formula is employed:

$$CV = SD / AM \times 100, \quad (3)$$

where SD is standard deviation, and AM is arithmetic mean. If the value declines over time, it shows that the gaps in per capita earnings among the economies have decreased, so there is sigma convergence.

Results and discussion

As discussed earlier, the beta convergence for the integration of Central Asia and South Asia is tested through panel unit root tests. The results of these panel unit root tests are given in Table 1. The result of the LLC test is significant,

witha negative coefficient (–18.88). The result of the IPS test also shows a significant result with a negative coefficient (–10.28). The result of the PP-Fisher Chi-square test shows a significant result with a positive coefficient (316.82). The result of the ADF-Fisher Chi-square test shows a significant result with a positive coefficient (567.13). The results of these tests show that income per capita converges when Central Asia and South Asia integrate; thus, these results confirm beta convergence.

Table 1. Results of Beta convergence when Central Asia integrates with SAARC

LLC		IPS		PP-Fisher Chi-square		ADF Fisher Chi-square	
Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
–18.88*	< 0.01	–10.28*	< 0.01	316.82*	< 0.01	567.13*	< 0.01

Source: author's estimation.

Sigma convergence is tested through the SD and CV of average per capita income. Table 2 showsthe results of the SD and CV, while Figure 3 shows the CV over time. The SD and CV of the average per capita income for Central Asia and South Asia between 1990 and 2022 show a downward trend. The declining trend of CV can be witnessed between 1990 and 1998. However, it started an upward trend in 1999, reaching 96.68 in 2007. There is not much change in the CV between 2009 and 2014. However, the CV value decreased from 88.64 in 2015 to 80.66 in 2022. The CV value for the whole period decreased, which demonstrates that the variation in per capita income decreased over time. This confirms the presence of sigma convergence when Central Asia integrates with South Asia. The results of the beta convergence and sigma convergence confirm income convergence when Central Asia integrates with South Asia.

Table 2. Results of Sigma convergence when Central Asia integrates with SAARC

Year	Bang	Nepal	Bhutan	India	Sri Lanka	Pak	Kazak	Kyrgyz	Tajik	Turkmen	Uzbek	CV
1990	493.10	420.74	747.23	534.48	1320.63	956.99	5831.07	1203.48	1308.32	3533.60	1565.56	91.46
1991	500.49	436.10	732.03	528.89	1364.53	973.46	5156.94	1089.90	1185.14	3281.34	1524.99	85.91
1992	518.11	441.48	796.24	546.44	1407.77	1021.31	4887.37	928.31	826.59	2715.93	1322.82	85.55
1993	532.25	446.29	851.20	560.79	1487.92	1013.01	4453.56	784.57	683.58	2684.65	1263.35	82.06
1994	542.45	471.27	892.63	586.17	1555.01	1020.79	3949.04	627.21	529.99	2165.77	1174.38	77.08
1995	559.69	476.45	944.40	618.14	1625.57	1040.28	3700.75	587.30	455.38	1965.33	1142.97	73.58
1996	574.84	491.30	978.49	651.95	1673.99	1057.98	3776.08	619.67	371.83	2060.70	1140.38	74.22
1997	590.00	505.77	1013.49	665.46	1768.99	1037.74	3901.33	671.25	373.04	1799.60	1177.27	74.55
1998	609.01	511.05	1053.54	693.40	1840.96	1033.88	3893.93	675.06	390.32	1897.86	1208.29	73.08
1999	625.36	523.88	1110.06	740.91	1908.86	1041.52	4037.45	689.41	402.62	2176.84	1246.73	73.24
2000	646.04	546.93	1115.62	755.48	2011.98	1053.00	4446.45	718.33	430.34	2261.70	1276.76	76.77
2001	666.07	564.07	1176.65	777.73	1965.82	1058.22	5055.31	749.41	461.57	2326.36	1313.19	82.31
2002	678.87	556.36	1272.63	793.10	2023.39	1058.78	5550.50	742.44	501.03	2300.63	1348.76	86.56
2003	698.73	570.41	1338.50	840.81	2122.21	1091.80	6046.32	786.35	545.25	2345.87	1389.58	89.28
2004	723.23	589.75	1385.39	892.38	2216.27	1151.28	6580.88	831.48	590.03	2432.10	1475.97	91.63
2005	758.89	603.75	1456.48	947.76	2332.65	1208.68	7155.34	820.71	617.93	2711.98	1560.29	93.92
2006	799.78	618.56	1535.42	1008.67	2486.64	1255.20	7837.62	837.13	649.17	2968.11	1656.22	96.47
2007	847.28	635.00	1795.07	1070.13	2628.15	1283.22	8438.10	900.02	687.06	3249.87	1787.49	96.68
2008	890.29	669.55	1859.07	1087.58	2756.12	1282.18	8554.82	966.41	727.55	3672.65	1917.84	94.30
2009	927.02	696.14	1961.93	1156.88	2826.23	1297.46	8487.54	982.37	741.35	3835.86	2037.58	91.42

Year	Bang	Nepal	Bhutan	India	Sri Lanka	Pak	Kazak	Kyrgyz	Tajik	Turkmen	Uzbek	CV
2010	967.56	726.05	2171.91	1238.01	3025.30	1287.61	8979.33	966.15	773.67	4119.57	2131.35	91.97
2011	1017.63	748.01	2319.59	1285.28	3257.44	1294.51	9506.73	1011.32	813.52	4643.31	2231.05	92.42
2012	1070.60	781.10	2411.89	1337.47	3512.13	1309.93	9823.69	993.73	855.68	5066.23	2354.59	91.93
2013	1120.69	807.13	2436.86	1404.54	3634.61	1346.28	10264.30	1080.54	898.64	5481.15	2487.24	92.06
2014	1173.89	853.14	2551.48	1490.02	3846.82	1382.09	10539.04	1101.70	937.00	5935.69	2613.74	91.06
2015	1236.00	882.30	2695.63	1590.17	3990.35	1421.83	10510.77	1121.08	970.36	6208.29	2753.97	88.64
2016	1307.73	878.15	2889.49	1701.18	4174.63	1497.16	10476.35	1146.10	1013.31	6478.47	2867.05	86.11
2017	1376.60	946.04	2998.47	1795.91	4427.54	1542.90	10758.52	1177.43	1060.91	6784.17	2943.09	85.31
2018	1460.30	1006.60	3079.14	1891.13	4495.71	1612.83	11053.36	1197.611	1116.29	7089.94	3062.48	84.72
2019	1557.96	1061.48	3233.59	1944.31	4458.43	1626.74	11402.76	1226.82	1172.07	7422.36	3185.33	84.68
2020	1593.35	1018.10	2884.20	1813.53	4229.75	1578.43	10974.24	1117.70	1197.21	7064.44	3187.04	84.77
2021	1684.43	1042.97	2992.43	1961.96	4331.47	1650.69	11298.36	1145.56	1281.96	7275.93	3356.03	83.83
2022	1784.74	1083.03	3468.95	2089.73	4488.08	1695.95	11290.90	1182.91	1356.31	7297.31	3473.36	80.66

Source: author's estimation based on World Bank Data n.d.

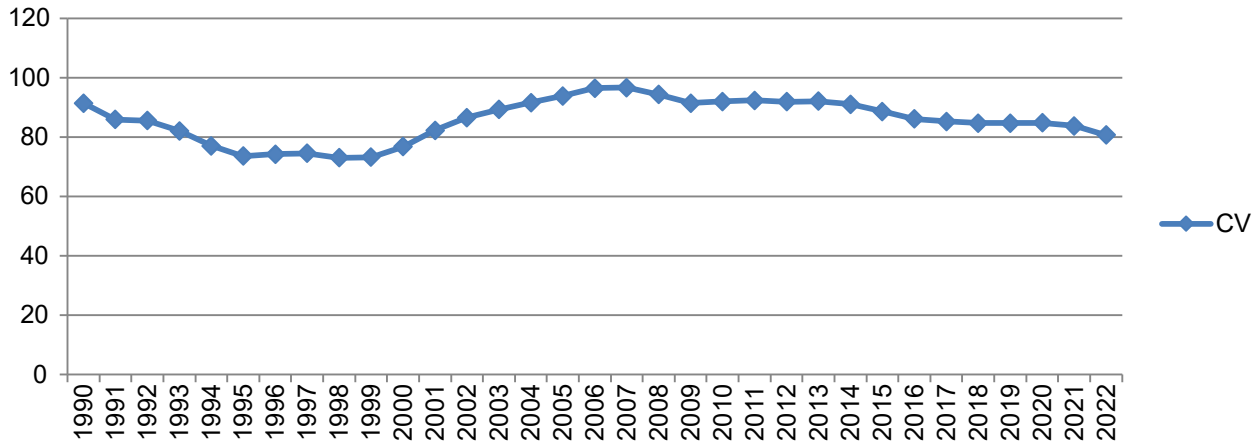

Figure 3. Results of CV when Central Asia integrates with South Asia

Source: author's estimation based on World Bank Data n.d.

Conclusion

Income convergence is the concept that poor countries grow more quickly than rich ones, and that they catch up in terms of per capita income; as a result, the per capita incomes of all nations eventually converge. The possibility for developing countries to have quicker growth than developed countries is assumed to be due to the application of diminishing returns to capital in developed countries, while developing countries have the potential for faster growth than developed countries. Additionally, developing nations may copy and duplicate the institutions, technologies, and methods of production used by developed nations.

Different regions of the world engage in integration. Thus, it is important to test whether income converges or not after their integration. The objective of this study was to determine inter-group income convergence for Central Asia and South Asia. Beta convergence was investigated to determine whether countries with lower initial growth rates experience faster growth than those with higher initial growth rates. Panel unit root tests were used, revealing beta convergence for the inter-group of Central Asia and South Asia. The sigma convergence was also tested. When there is a decline in the difference in income levels among the countries, it is known as "sigma convergence." The results confirmed sigma convergence for the inter-group of Central Asia and South Asia. The beta and sigma convergence tests indicate income convergence for Central and South Asia integration,thereby achieving the objective of the study.

The results of the study suggest that economic integration is beneficial for both SAARC and Central Asian economies; therefore, it is recommended that these economies and blocks ensure economic integration among themselves by eliminating

trade barriers and reducing taxes on imports. SAARC members have already signed a free trade agreement, but unfortunately, it is not very effective. Therefore, it is recommended that it should be implemented in the true sense and efforts be made for the next stage of economic integration, the "Customs Union", where member nations not only allow free trade among themselves but also formulate similar policies for non-member nations for trade.

Central Asian nations are working for free trade agreements, and the leaders of all these nations have agreed to launch a free trade agreement for member nations to increase trade. Central Asian nations are land-locked countries without access to deep harbors in the region, relying on roads and railways for trade. Therefore, Central Asia must launch a free trade agreement among member nations and with other nations in the region to increase the volume of trade, fostering income convergence in the region.

Free trade among nations is crucial for the income convergence of nations or regions. It encourages innovations and boosts investment in human capital, improves marketing channels, increases management expertise, and promotes economic development. Economists believe that financial assets should be free to move across national borders to maximize the return on investment. In the local input markets, competition increases due to international trade. Through a variety of ways, international trade helps to promote capital development and economic growth in the host country. It is beneficial during times of financial difficulty, encouraging the transfer of advanced technology and increasing labor productivity while lowering labor costs. The development of underdeveloped areas is possible with an increase in trade. It is vital for Central and South Asia to reduce trade restrictions, and policies should be adopted that increase international trade, which is very significant for reducing income inequality and helping income convergence. This study contributes the case of integration of Central Asia and South Asia to the income convergence literature. The limitation of the study is that this study is limited to income convergence. Future researchers could also examine the determinants of income convergence.

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Badanie konwergencji dochodów w Azji Środkowej i Południowej

Konwergencja dochodowa odnosi się do idei, że kraje ubogie rozwijają się szybciej niż kraje bogate i nadrabiają zaległości pod względem dochodu na mieszkańca. W rezultacie dochód na mieszkańca krajów zintegrowanych ulega zbliżeniu. Konwergencja beta sugeruje, że kraje słabiej rozwinięte osiągają swój średni poziom dochodu na mieszkańca poprzez szybszy wzrost. Tymczasem zbieżność sigma sugeruje, że dysproporcja dochodów *per capita* między krajami w bloku regionalnym zmniejsza się w czasie.

Celem tego badania jest przetestowanie konwergencji dochodów poprzez konwergencję beta i sigma dla integracji krajów Azji Środkowej i Południowej na podstawie danych z lat 1990–2022. Konwergencja sigma jest testowana za pomocą odchylenia standardowego i współczynnika zmienności średniego dochodu na mieszkańca, podczas gdy konwergencja beta jest testowana za pomocą testów panelowych pierwiastka jednostkowego. Wyniki badania potwierdzają konwergencję beta i sigma, co implikuje konwergencję dochodów krajów Azji Środkowej i Południowej.

Konsekwencje tego badania są wielorakie. Zaleca się, aby kraje Azji Środkowej i Południowej rozwijały współpracę gospodarczą, polityczną i społeczną. Jest to możliwe dzięki wyeliminowaniu ograniczeń handlowych i zmniejszeniu podatków importowych w celu zwiększenia swobodnego

handlu. Ponadto zapewnienie swobodnego przepływu siły roboczej, kapitału i technologii między Azją Środkową a Południową będzie korzystne dla zapewnienia integracji gospodarczej, ułatwienia konwergencji dochodów i zmniejszenia nierówności dochodowych między tymi regionami. Niniejsze badanie wnosi wkład w literaturę dotyczącą konwergencji dochodów, koncentrując się na integracji między Azją Środkową a Azją Południową.

Słowa kluczowe: konwergencja dochodów, integracja gospodarcza, Azja Środkowa, Azja Południowa

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.33

Labor Market Slack in the EU during the COVID–19 Crisis

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Abstract

The general aim of the article is to verify the extent of labor market slack at three moments considered crucial when analyzing labor market changes caused by the COVID–19 pandemic. The main goal is to identify similarities and differences between EU countries grouped into clusters identified during the research.

The study uses cluster analysis to classify the EU members into groups of similar countries according to the labor market slack variables observed before (2019) and during the pandemic (2020, 2021). A two-stage approach was selected. In the first stage, hierarchical analysis was used to determine the initial number of groups, while in the second stage, the proper classification of objects was made using the k-means method.

A comparison of changes taking place in the labor markets of the analyzed countries allows us to select four homogeneous clusters of countries in all periods under study. The results also show that the labor market slack in most EU countries did not change over the analyzed period, although some countries improved (like Ireland, France, and Cyprus). The reason could be the effectiveness of measures that support labor markets that were implemented during the pandemic. The country where the labor market slack situation worsened is Italy.

It would be valuable to analyze in more detail the effectiveness of labor market policies and programs from countries in the identified clusters because they contributed to a relatively stable labor market slack situation. Future research should also be directed towards analyzing changes on the side of employment, including a sectoral analysis, which would expand

Received: 19.01.2024. Verified: 15.03.2024. Accepted: 24.09.2024

the knowledge of the labor market during the COVID–19 crisis. Moreover, to deepen the analysis of labor market slack, the demographic structure could be included.
Analysis of the labor market based solely on the unemployment rate is insufficient, which is even more visible in the face of the consequences caused by the COVID–19 pandemic as that measure does not include the "discouraged worker effect". For the EU, there is a research gap regarding this effect, which can be gleaned from the labor market slack statistics. This article, therefore, fills the gap.

Keywords: labor market slack, unemployment, COVID–19, anti-crisis policy, cluster analysis

JEL: J01, J08, J21

Introduction

Labor market slack is a key concept in understanding labor market equilibrium. It refers to the gap between the amount of work that workers desire and the amount of work that is actually available. Labor market slack goes beyond the unemployment rate by summing unemployment, underemployment (individuals who work part-time and claim they want a full-time job), people seeking a job but not currently available, and people not seeking a job but available to work. Those final two groups create unemployment "halos" (de la Fuente 2011). Individuals who are seeking but not available and not seeking but available for work are excluded from the labor force and are considered inactive. Labor market slack is therefore expressed as the sum of all unmet labor supply among the four groups as a percentage of the extended labor force (ELF = the labor force + the two groups not counted as part of the labor force – called the potential additional labor force) (Gros and Ounnas 2021).

Analyses of the labor market based solely on the unemployment rate are insufficient (Fontaine 2016), which is even more visible in the face of the consequences caused by the COVID–19 pandemic. Although the components of labor market slack have been published by Eurostat for many years, they have become more important. Taking them into account gives a more complete picture of the labor market, which allows for a better understanding of the market, especially during the pandemic (Statistics Poland 2020). In particular, in the first phase of the crisis, the implementation of active measures to reduce job losses more often led to absenteeism than to dismissal, and people were unable to look for work or were unavailable due to restrictive measures. Therefore, they were not counted as unemployed.

Unemployed people have, on average, the largest share of the labor market slack in the European Union (EU). However, in Italy in 2021, for example, the largest share constituted people available to work but not seeking it. Unemployment rates can hide the "discouraged worker effect", that is, potential workers who stopped looking for jobs

to wait for conditions to improve and economic sectors to reopen. Research shows that this phenomenon most likely took place in the US during the pandemic (Coibion, Gorodnichenko, and Weber 2020). For the EU, there is limited research into this effect (Gros and Ounnas 2021). On the other hand, some studies indicate this effect may also be present in Europe, e.g., in Norway from 1988 to 2008 (Dagsvik, Kornstad, and Skjerpen 2013).

Despite this, it is reasonable to conclude that the economic shocks caused by the pandemic have put the labor market into a transitional phase as it seeks a new equilibrium. Given the distinct sources of shock compared to previous events, such as the Global Financial Crisis, economies have responded differently (Ando et al. 2022). Interestingly, unlike other pandemics, COVID–19 also had an unprecedented impact on the labor market (Li et al. 2022).

The starting point for explaining the current state of the labor market involves the policies adopted by individual countries during the pandemic. While they led to lockdowns, these policies were largely responsible for the relatively quick and significant revival of the labor market, although they had an asymmetric impact on various sectors of the economy (Verick, Schmidt-Klau, and Lee 2022). In the EU, holiday and short-term work programs were the most important. In addition, Zinecker et al. (2021) also noted that the Small and Medium Enterprise (SME) sector had been backed by funds that allowed the implementation of part-time work schemes. Thanks to this solution, it was possible to maintain many jobs, and the unemployment rate increased only moderately. At the same time, while studying the other components of labor market slack, it can be seen that in Poland, for example, the partial or complete closure of businesses led to a decline in employment with a simultaneous increase in underemployment and only a slight increase in unemployment (thanks to the government, which temporarily took over the burden of maintaining employment).

In line with the above statements, the aim of the article is to verify the extent of labor market slack at three moments that are considered crucial when analyzing changes in the labor market caused by the pandemic. The main goal is to identify similarities and differences between EU countries. This will allow us to group them into clusters identified during the research. Cluster analysis was used for this purpose. The components of labor market slack were used to group all EU countries into separate clusters except for the United Kingdom, as it left the EU during the study period (hereinafter: the EU–27). Taking into consideration the characteristics of some periods (justified later in this paper), the data were taken for the second quarters of 2019, 2020 and 2021.

The two research hypotheses were set out, which were verified in the research process:

H1: Labor market slack in the EU deteriorated during the COVID–19 crisis.

H2: The COVID–19 crisis reduced the differences in labor market slack between the EU–27 countries.

The rest of this paper is organized as follows. In the first part, an in-depth review of the literature on labor market slack is conducted. Following this, in the second section, the method used to verify the hypotheses was developed. In the third part, considerations and analyses are carried out, and then the results are presented. The fourth section compares the results with those of other authors. Finally, the last part presents the conclusion of the research.

Theoretical background

Research on labor market slack is conducted from various perspectives. First of all, labor market researchers increasingly emphasize that due to the characteristics of the COVID–19 crisis and the dynamics of changes, conducting analysis based on annual data or the unemployment rate indicator is not only insufficient but also leads to erroneous conclusions (Lee, Schmidt-Klau, and Verick 2020). The unemployment rate may not be an accurate measure of labor market slack when analyzing countries with large-scale labor market programs, e.g., an Active Labor Market Policy (Pannenberg and Schwarze 1998). Additionally, there are also drawbacks to the earlier focus on the unemployment rate as the main measure of underutilization of the labor market. These drawbacks include the inability to take into account the behavior of the employed in the unemployment rate or the failure to include all people who represent underutilization of the labor market in the unemployment rate (Faberman et al. 2020).

Szörfi and Tóth (2018) noted a better reflection of the labor market situation (especially during the Global Financial Crisis and the recovery) thanks to an approach based on a broad measure of labor underutilization. According to Blanchflower and Levin (2015), in the face of a deep recession and slow recovery, labor market slack cannot be measured solely by a conventional measure of the unemployment rate. Employment gap assessments should reflect the prevalence of underemployment and the extent of hidden unemployment. Moreover, each of these forms of labor market slack puts significant pressure on lower nominal wages. Research confirming the importance of underemployment in changes in the level of wages was carried out by, among others, Bell and Blanchflower (2018).

Bonam, de Haan, and van Limbergen (2021) compared the Phillips wage curve to alternative measures for labor market slack for the five biggest Eurozone countries. They concluded that the unemployment gap was unable to adequately capture the persistence in additional labor market slack, which may, therefore, lead to an overly optimistic view of the situation in the labor market (after the recent financial crisis and perhaps also

after the crisis caused by the pandemic). Byrne and Zekaite (2020) analyzed the sensitivity of wage growth depending on the labor market situation in terms of tightness and slack in the eurozone in the period Q1 1999 – Q2 2018. They argued that the Phillips wage curve in the euro area is convex. They concluded that when the labor market slack was high, wage growth did not respond to the changing labor market conditions. Therefore, their results indicate the negative impact of underemployment on wage growth and explain the "missing wage growth" phenomenon witnessed during high levels of labor market slack. A change in wages depends not only on the labor market slack; another important determinant is inflation (Donayre and Panovska 2018).

Some researchers, wishing to eliminate the disadvantages associated with relying only on the unemployment rate, explore alternative measures of labor market slack. For example, Berger and Vierke (2017) created a multivariate unobserved-components model using information on GDP, inflation, and hours worked. By formally comparing models, they contend that the estimated hourly gap exceeds the conventional measures of the unemployment gap in the Taylor rule. They demonstrated that labor force participation and hours worked play important roles in the adjustment process, including that additional information, other than the unemployment rate, can help in a more accurate assessment of the state of the labor market. While their observations pertain to the Global Financial Crisis, particularly in Germany, the methodologies applied (e.g., short-term and part-time work programs) suggest potential applicability to the COVID–19 crisis.

Conversely, Gallant et al. (2020) propose considering the distinction between temporary and permanent unemployment, the share of the temporary unemployed who actively seek employment, and the differentiation between short-term and long-term unemployment rather than focusing solely on the unemployment rate. Their model incorporates the job separation rate, the recall rate of workers on temporary layoff, and vacancy rates. They argue that this approach will be useful in forecasting the dynamics of the labor market as a result of the COVID–19 recession.

Important research trends include analyses of labor market slack in selected countries or areas (e.g., the EU). Table 1 below summarizes notable research on labor market slack.

When analyzing the pandemic period, the situation in the United States and in the EU is often contrasted. In particular, the rapid impact of COVID–19 on the rise in unemployment rates in individual US states is noted, in contrast to a much weaker rise in unemployment and its gradual adjustment in Europe. This is partly explained by the differences in the labor markets and in the implemented anti-crisis programs (Adams-Prassl et al. 2020).

Table 1. Selected papers on labor market slack

Researchers	Focus
MacKay and Davies (2008)	Labor market slack in the United Kingdom
Hurley and Patrini (2017)	Labor market slack in the EU
Ellul (2019)	Labor market slack in Malta
Martins and Seward (2020)	Measuring labor market slack in Portugal
Galasso and Foucault (2020)	The impact of the COVID–19 pandemic on the labor market in 12 countries
Ens et al. (2021)	The importance and unevenness of COVID–19's impact on the Canadian labor market, highlighting the need for a broader approach than traditional measures

Source: own elaboration.

Research on labor market slack also concerns the issue of differentiating the credibility of the unemployment rate indicator depending on the labor market of individual social groups. For example, Komlos (2019) demonstrated that in the United States, the position of the most vulnerable groups of society, i.e., minorities, youth, and the less educated, is better reflected by labor market slack and its components. These conclusions were confirmed by Pouliakas and Branka (2020) and Fana et al. (2020), according to whom the segments of the workforce most likely to be impacted by social distancing measures and practices due to the COVID–19 pandemic are also the most vulnerable groups, such as women, non-natives, those with non-standard contracts (e.g., the self-employed and temporary workers), the lower educated, those employed in micro-sized workplaces and low-wage workers. In line with these findings, Palomino, Rodríguez, and Sebastián (2020) demonstrated that the crisis increased inequality and poverty in all EU–27 countries.

Research methodology

The research analyzes the impact of COVID–19 on labor market slack in the EU–27 in the second quarters of 2019, 2020, and 2021. The second quarter of 2019 represented the period before the COVID–19 crisis, while in the second quarter of 2020, the influence of the pandemic on the labor market was already noticeable; however, the prevention policies had not yet been implemented. The second quarter of 2021 marked a period of the development of the pandemic with a simultaneous implementation of prevention policies in the EU–27 countries.

The quarterly data come from Eurostat and refer to all EU–27 countries at the country level. Labor market slack was analyzed using four variables:

X_1 – unemployed as a percentage of the extended labor force,

X_2 – people available to work but not seeking employment as a percentage of the extended labor force,

X_3 – people seeking work but not immediately available as a percentage of the extended labor force,

X_4 – underemployed people working part-time as a percentage of the extended labor force.

Cluster analysis was used to classify the EU–27 into groups of similar countries according to labor market slack variables observed before the pandemic (2019) and during the pandemic (2020, 2021). Cluster analysis is a very popular multidimensional statistical method with a fundamental aim of classifying (observing) objects into groups (clusters), and it has been used for the clustering of labor markets (Rollnik-Sadowska and Dąbrowska 2018; Dmytrów and Bieszk-Stolorz 2021).

Cluster analysis as a grouping method allows for the identification of clusters that contain similar objects (Tryon 1939). Clustering techniques are applied in various research fields, as highlighted by Hartigan (1975), who summarized many studies that describe the results of cluster analysis. This method represents interdependence analysis, where all variables in the analysis are treated as interdependent without distinguishing between dependent (effects) and independent variables (causes). In such cases, the analysis is usually aimed at identifying the structure of the examined sets of variables or objects. Cluster analysis, as a grouping method, makes it possible to identify internally consistent groups of objects. The research is conducted in four main phases: (I) selecting variables and adopting a method for determining similarities between objects, (II) choosing the manner of designating data objects into homogeneous groups, (III) selecting the number of identified clusters, and (IV) interpreting and profiling the obtained clusters.

The literature offers two basic approaches to clustering: hierarchical and non-hierarchical. In the former, a hierarchical structure of similarities among objects is represented as a dendrogram (Ward 1963). Among the non-hierarchical approaches, the k-means method stands out, as it allows for faster and more efficient grouping of cases. It is an iterative method that is conducive to grouping sets of objects, whether they contain just a few observations or several thousand. However, in this method, the researcher must specify the number of clusters in advance. Therefore, a two-stage approach is quite commonly used in research, as was the case in this study. In the first stage, hierarchical analysis is used to determine the initial number of groups, while in the second stage, proper classification of objects is performed using the k-means method.

The k-means method divides the entire set of cases into k different, possibly distinct clusters. The algorithm of this method involves transferring objects between the specified number of clusters to minimize variation within clusters and maximize the variation

between clusters. When analyzing the results of the clustering, the averages for each cluster are examined in every dimension to assess the extent of differentiation among the distinguished k clusters. The k-means method relies on estimating the distance between clusters and objects (MacQueen 1967).

Research results

In the first stage of the research, cluster analysis was conducted to verify the research hypotheses. To ensure comparability of the results, variable standardization of X_1, X_2, X_3, and X_4 was performed before conducting the cluster analysis. Each standardized variable has a mean of 0 and a standard deviation of 1. The subsequent figures (Figure 1–3) depict the standardized values of the variables.

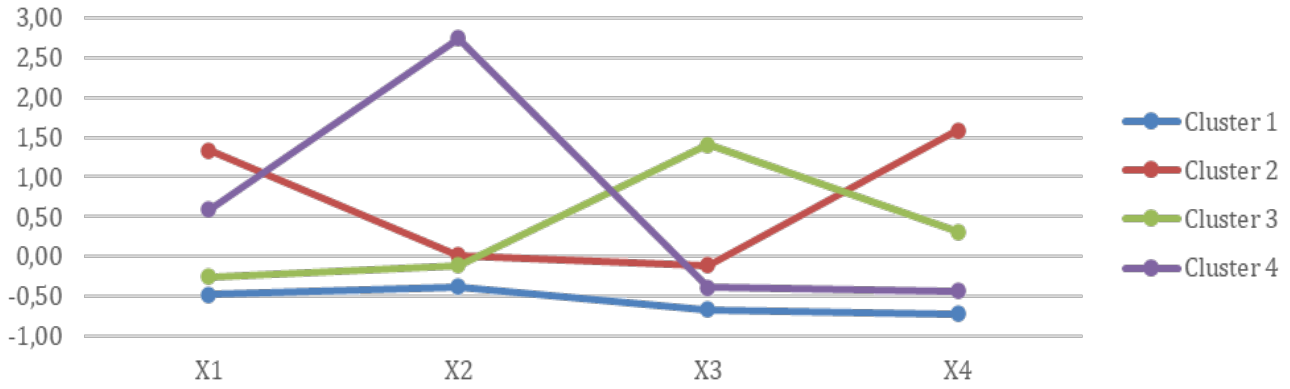
Before the pandemic, in the second quarter of 2019, the following four clusters of EU countries were identified (Figure 1):

Cluster 1. Variables below the average level

Cluster 2. Very high unemployment, average professional inactivity, very high underemployment

Cluster 3. Low unemployment, average availability but not seeking, high seeking but not available, above-average underemployment

Cluster 4. Above-average unemployment, very high availability but not seeking, below-average seeking but not available, below-average underemployment.



X_1 – unemployed as a percentage of the extended labor force, X_2 – available but not seeking as a percentage of the extended labor force, X_3 – seeking but not available as a percentage of the extended labor force, X_4 – underemployed part-time workers as a percentage of the extended labor force.

* Standardized variables.

Figure 1. The clusters of labor market slack in the EU–27, Q2 2019

Source: own calculations based on Eurostat 2021.

Table 2 presents the means for variables X_1–X_4 achieved in each of the clusters of labor market slack in the second quarter of 2019. Before the pandemic, the first cluster, which groups countries with variables below the average level, mainly comprised Central and Eastern European (CEE) countries such as Bulgaria, Czechia, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia, although it also included Germany, Malta and Portugal. This is the largest cluster. The values of all variables were the lowest among those achieved in all clusters in this period. The average value for X_1 in this cluster was 4.3, while the total mean for all countries was 5.8. Czechia had the lowest level of the X_1 variable, at only 2.0. It was also the lowest value among all countries in all three quarters included in the analysis. Similarly, the lowest values in all three analyzed periods were reached in Q2 2019, both in terms of cluster means and overall means. Again, Czechia had the lowest value of the X_4 variable at 0.3, and this value remained at the same level in all analyzed quarters. The mean for the entire cluster in Q2 2019 was 1.3 and was almost twice lower than the mean for all countries. The average in the cluster for variable X_3 was also twice lower than the mean for all countries and reached a very low level of 0.4. In the case of variable X_2, four countries from the cluster (Bulgaria, Estonia, Latvia, and Portugal) achieved values above the mean for all analyzed countries in this period.

The second cluster, which is characterized by very high unemployment and underemployment, and average professional inactivity, included Ireland, Greece, Spain, France and Cyprus. It is a cluster with an average X_1 level of 10.1, which is more than twice as high as the average for the first cluster and twice as high as the third cluster. It includes the only two countries where the X_1 variable reached a double-digit value – Spain (13.5) and Greece (16.9). In turn, the average value of the X_4 variable in this cluster is practically twice as high as the mean calculated for all analyzed countries and amounts to 4.7. For comparison, it is more than three times the analogous mean from the first cluster. It is noteworthy that the X_4 level was the highest in all three analyzed quarters. The average values of variables X_2 and X_3 were equal to the corresponding means calculated for all countries in Q2 2019.

The third cluster was described by low unemployment, average availability but not seeking, high seeking but not available, above above-average underemployment. It includes the Scandinavian countries, as well as Belgium, Luxembourg, the Netherlands and Austria. In this cluster, the average level of the X_3 variable, which was 1.8, is the most noteworthy. This value was more than twice as high as the mean calculated for all countries and even more than four times higher than the corresponding value in the first cluster. Particularly high values were achieved in Finland and Sweden (2.2 and 2.3, respectively), which were the same two countries where variables X_1 and X_4 were higher than average (both for the cluster and in total).

The fourth cluster, characterized by above-average unemployment, very high availability but not seeking, below-average seeking but not available, and below-average underemployment, included two countries – Croatia and Italy. The average value of the X_2 variable

here was exceptionally high, at 7.8, i.e., three times higher than the corresponding mean for all countries in this period. Compared to the other clusters, this level was three times higher or even more. Although both countries had a high level of the X_2 variable, attention is drawn to Italy, where this variable reached a value of 10.0. It was also the highest value among all the countries analyzed in Q2 2019. The level of the X_1 variable was also quite high, amounting to 7.7 (which was also largely influenced by Italy; it was 9.0).

Table 2. Clusters of labor market slack in the EU–27, Q2 2019

	Means for variables in clusters*			
Cluster	X1	X2	X3	X4
1	4.3	1.9	0.4	1.3
2	10.1	2.6	0.8	4.7
3	5.0	2.4	1.8	2.9
4	7.7	7.8	0.6	1.8
Total average**	5.8	2.6	0.8	2.4

* Variables are non-standardized.
** Average weighted by the number of countries in the cluster.
Source: own calculations based on Eurostat 2021.

In the second quarter of 2020, the following four clusters were designated with different sets of variables than the year before (Figure 2):

Cluster 1. Variables below the average level.

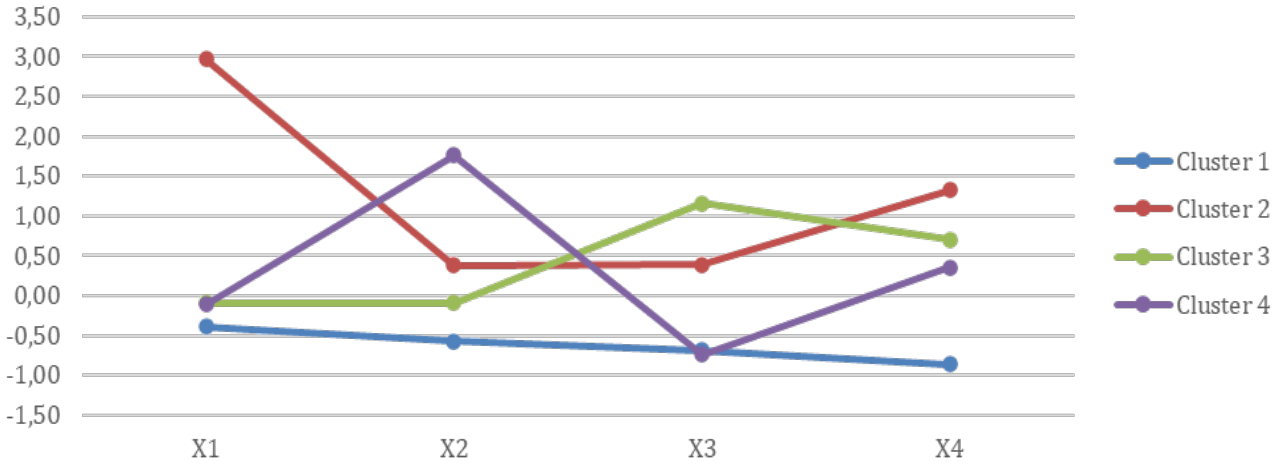
Cluster 2. Very high unemployment, above-average professional inactivity, very high underemployment.

Cluster 3. Average unemployment, average available but not seeking, very high seeking but not available, above-average underemployment.

Cluster 4. Average unemployment, very high available but not seeking, below-average seeking but not available, above-average underemployment.

As shown in Table 3, the first cluster was described by variables below the average level. This cluster includes CEE countries such as Bulgaria, Czechia, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia, as well as Germany and Malta. It was still the most numerous cluster. The composition remained unchanged compared to Q2 2019, except for Portugal, where the share of people available to work but not seeking in the extended labor force increased significantly and was included in the fourth cluster. In the first cluster, compared to Q2 2019, the average values of variables X_1, X_2 and X_3 increased, while the value of X_4 decreased to 1.1, which was more than twice lower

than the general average for all countries and more than twice lower than the average from the remaining clusters, and in the case of the second cluster, almost four times lower. In this period, although all variables for the first cluster were below the total mean for all countries, only the X_4 variable was lower each time compared to the means calculated for individual clusters for each variable.



X_1 – unemployed as a percentage of the extended labor force, X_2 – available but not seeking as a percentage of the extended labor force, X_3 – seeking but not available as a percentage of the extended labor force, X_4 – underemployed part-time workers as a percentage of the extended labor force.
* Standardized variables.

Figure 2. Clusters of labor market slack in the EU–27, Q2 2020

Source: own calculations based on Eurostat 2021.

Based on the data, it can be concluded that if countries did not implement countermeasures at the onset of the pandemic, the consequences became visible in Q2 2020. The second cluster, characterized by very high unemployment, above-average professional inactivity and very high underemployment, took into account two countries – Greece and Spain. In this cluster, the mean calculated for variable X_1 was 15.3, and it was the highest share of the unemployed in the extended labor force in all clusters in all three periods. Interestingly, in Greece, the value of X_1 remained very high, but it decreased compared to Q2 2019. In Spain, on the other hand, the level of X_2 increased significantly compared to Q2 2019, almost doubling the average value of this variable calculated for X_2 in terms of Q2 2020 vs Q2 2019. The average level of variable X_4 was higher than in the other clusters (4.3), which was almost four times the analogous mean for the first cluster.

The third cluster was characterized by average unemployment, average available but not seeking, very high seeking but not available, and above-average underemployment, and it included the Scandinavian countries as well as Belgium, Luxembourg, the Netherlands, Austria, France, and Cyprus. Both France and Cyprus had been in the second cluster in Q2 2019. The average value for variable X_3 was 1.6, which was basically

four times higher than the corresponding value calculated for the first and fourth clusters. Such a high level was mainly due to the share of people seeking work but not immediately available in the extended labor force in Luxemburg (2.2), but also in Austria and the Scandinavian countries. On the other hand, the higher-than-average level of X_4 was mainly influenced by the situation in France, Cyprus, and the Netherlands.

The fourth cluster included countries with average unemployment, very high available but not seeking, below-average seeking but not available, and above-average underemployment. It included Ireland, Croatia, Italy, and Portugal. The average level of the X_2 variable is noteworthy in this cluster. At 8.8, it was the highest of all clusters in all three periods. The share of people available to work but not seeking in the extended labor force in Italy had the greatest impact here, where it reached 13.0. In turn, the mean calculated for variable X_3 in the fourth cluster was the lowest among all clusters in Q2 2020, at only 0.4. It was slightly more than twice lower than the mean calculated for all countries in this period. What is also worth noting is that each country in this cluster recorded a comparable value of this variable.

Table 3. Clusters of labor market slack in the EU–27, Q2 2020

	Means for variables in clusters*			
Cluster	X1	X2	X3	X4
1	5.3	2.3	0.5	1.1
2	15.3	5.0	1.1	4.3
3	6.1	3.6	1.6	3.4
4	6.1	8.8	0.4	2.9
Total average**	6.4	3.9	0.9	2.4

* Variables are non-standardized.
** Average weighted by the number of countries in the cluster.
Source: own calculations based on Eurostat 2021.

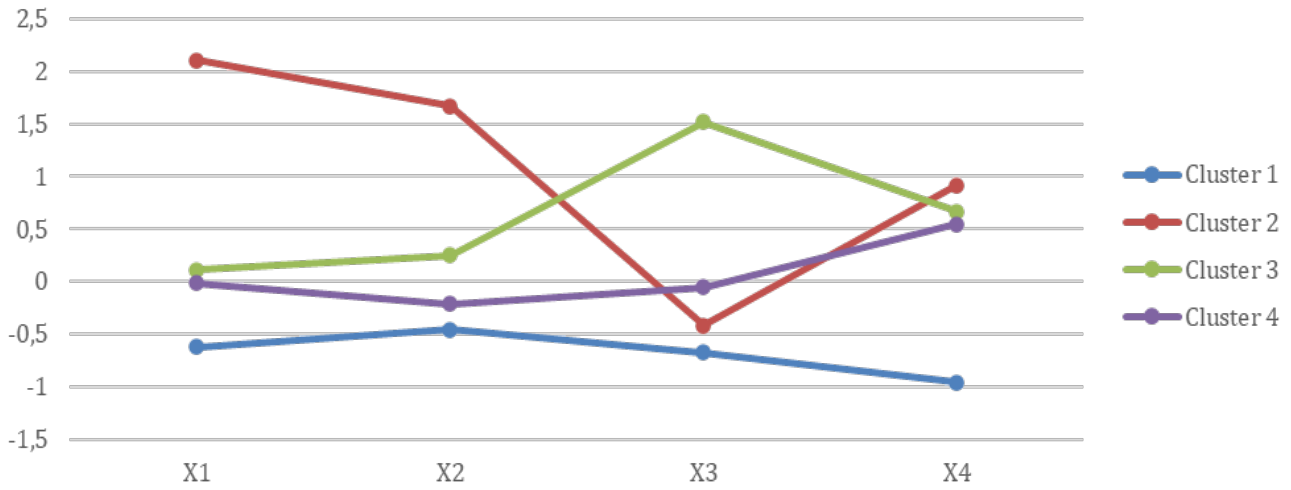
In the second quarter of 2021, the following four clusters were distinguished (Figure 3):

Cluster 1. Variables below the average level.

Cluster 2. Very high unemployment, very high available but not seeking, below-average seeking but not available, above-average underemployment.

Cluster 3. Average unemployment and availability but not seeking, high seeking but not available, above-average underemployment.

Cluster 4. Below-average unemployment and inactivity, above-average underemployment.



X_1 – unemployed as a percentage of the extended labor force, X_2 – available but not seeking as a percentage of the extended labor force, X_3 – seeking but not available as a percentage of the extended labor force, X_4 – underemployed part-time workers as a percentage of the extended labor force.
* Standardized variables.

Figure 3. Clusters of labor market slack in the EU–27, Q2 2021

Source: own calculations based on Eurostat 2021.

The first cluster, characterized by below-average variables (Table 4) included CEE countries, such as Bulgaria, Czechia, Estonia, Lithuania, Hungary, Poland, Romania, Slovenia, and Slovakia, as well as Germany and Malta. In Q2 2021, Portugal and Latvia were absent from the first cluster, both of which had migrated to the fourth cluster. The means for all variables in this cluster were the lowest compared to those of the other clusters in the same period. The average value of variable X_1 decreased compared to the average recorded in Q2 2020, although the corresponding average for all countries increased in relation to Q2 2020. In turn, the mean for this cluster calculated for variable X_4 was two and a half times lower than the total mean calculated for all countries, at 1.0. In addition, the share of underemployed people working part-time in the extended labor force in this cluster was the lowest in this period from all analyzed periods.

In the second quarter of 2021, when the EU–27 implemented measures to mitigate the pandemic, the second cluster included countries with very high unemployment, very high available but not seeking, below-average seeking but not available, and above-average underemployment – Greece, Spain, and Italy. The average level for variable X_1 was about twice the mean for all countries and amounted to 13.0. The average value of X_4 was higher than the corresponding means in the other clusters in this period, at 4.0. Both means (for X_1 and X_4) were lower in this cluster than the values obtained in Q2 2020, while the means for all countries in Q2 2021 were higher for X_1 and X_4 than in Q2 2020. The average value for variable X_2 for this

cluster was the highest among the averages for X_2 from the other clusters, with a value that was more than twice as high as the total mean for all countries.

The third cluster was characterized by average unemployment and availability but not seeking, high seeking but not available, and above-average underemployment, and it included Ireland, France, Luxembourg, Austria, Finland, and Sweden. In this cluster, the average value for variable X_1 stood at 7.1, slightly exceeding the mean for all countries and influenced mainly by the level of this variable in Sweden, France, and Finland. It was also the highest value for this cluster from all three analyzed periods. It was similar for the mean calculated for variable X_4. The mean for X_2 remained at the same level both in Q2 2020 and in Q2 2021. What is also noteworthy is the high level of the mean calculated for X_3, which is more than twice the corresponding mean calculated for all countries, over four times the corresponding value in the first cluster, and even more than three times the value in the second cluster.

The fourth cluster, characterized by average unemployment, below-average inactivity, and above-average underemployment, consisted of Belgium, Denmark, Croatia, Cyprus, Latvia, the Netherlands and Portugal. The average for variable X_1 is slightly higher than in Q2 2020 but lower than in Q2 2019. On the other hand, the average value of variable X_2 dropped sharply, primarily influenced by the levels of this variable in Denmark, the Netherlands and Belgium. Compared to Q2 2020, it decreased in this cluster more than three times, reaching 2.6. Meanwhile, the average value for variable X_4 increased, which was significantly influenced by the value of this variable recorded in the Netherlands and Cyprus. It is important to note that the composition of the cluster changed in terms of the countries it encompasses.

Table 4. Clusters of labor market slack in the EU countries, Q2 2021

	Means for variables in clusters*			
Cluster	X1	X2	X3	X4
1	4.9	2.1	0.4	1.0
2	13.0	6.4	0.5	4.0
3	7.1	3.6	1.7	3.6
4	6.7	2.6	0.8	3.4
Total average**	6.7	3.0	0.8	2.5

* Variables are non-standardized.
** Average weighted by the number of countries in the cluster.
Source: own calculations based on Eurostat 2021.

Three clusters can be distinguished with a similar set of variables, which were identified before the pandemic in Q2 2019 as well as during the pandemic – in Q2 2020

and Q2 2021 (Table 5). The first cluster comprises countries where the level of variables was below average. Interestingly, this cluster was characterized by a relative constancy of members and was composed mainly of CEE countries, along with Germany and Malta. In 2019, Portugal was also included. However, in 2020, it moved to the cluster that included countries with average unemployment, very high available but not seeking, below-average seeking but not available, and above-average underemployment. In Q2 2020, both the unemployment rate and the share of underemployed part-time workers in the extended labor force fell in comparison to Q2 2019. By contrast, there was significant growth in the share of people available to work but not seeking as a percentage of the extended labor force (from 3.2% to 6%). However, there was no change in terms of the share of people seeking work but not immediately available in the extended labor force. This indicator includes, among others, discouraged jobseekers and people prevented from job-seeking due to personal or family circumstances (Eurostat).

Table 5. Clusters of labor market slack changes in the EU countries, Q2 2019, Q2 2020, Q2 2021

Cluster	2019 Q2	2020 Q2	2021 Q2
Cluster 1: Variables below the average level	Bulgaria	Bulgaria	Bulgaria
	Czechia	Czechia	Czechia
	Germany	Germany	Germany
	Estonia	Estonia	Estonia
	Latvia	**Latvia**	Lithuania
	Lithuania	Lithuania	Hungary
	Hungary	Hungary	Malta
	Malta	Malta	Poland
	Poland	Poland	Romania
	Portugal	Romania	Slovenia
	Romania	Slovenia	Slovakia
	Slovenia	Slovakia	
	Slovakia		
Cluster 2: Very high unemployment, average/above-average professional inactivity, very high underemployment	**Ireland**	Greece	Greece
	Greece	Spain	Spain
	Spain		**Italy**
	France		
	Cyprus		

Cluster	2019 Q2	2020 Q2	2021 Q2
Cluster 3: Low/average unemployment, average availability but not seeking, high seeking but not available, above-average underemployment	Belgium	Belgium	**Ireland**
	Denmark	Denmark	**France**
	Luxembourg	**France**	Luxembourg
	Netherlands	**Cyprus**	Austria
	Austria	Luxembourg	Finland
	Finland	Netherlands	Sweden
	Sweden	Austria	
		Finland	
		Sweden	

Source: own calculations based on Eurostat 2021.

In 2021, Latvia left the below-average cluster. In that year, both Latvia and Portugal moved to the group of countries with below-average unemployment and inactivity and above-average underemployment.

The next set of variables included very high unemployment, average/above-average professional inactivity, and very high underemployment in one cluster over the analyzed period. Both Spain and Greece were permanent members of this cluster, while other members changed. During the pandemic, in 2020, Ireland, France, and Cyprus left, which seemed to improve their situation regarding labor market slack. They developed a rolling series of measures to support the labor market (Brioscú, O'Reilly, and Coates 2021). In 2021, Italy joined that cluster.

The third cluster that was typical for all the analyzed periods was characterized by low/average unemployment, average availability but not seeking, high seeking but not available, and above-average underemployment. It was composed of the Nordic countries (Denmark left in 2021), Belgium, Luxembourg, Austria, and the Netherlands (which also left in 2021).

The analysis shows that during the analyzed period, labor market slack in most countries did not change. Some improved their situation (like Ireland, France, and Cyprus), which may be due to the effectiveness of measures they implemented to support labor markets. Therefore, hypothesis H1 has only been partially confirmed. The country where the labor market slack worsened was Italy.

One argument for the continued differentiation of countries is that comparing changes in the labor markets leads to the same four homogeneous clusters in all the analyzed periods. However, it is worth noting that some countries do migrate between these clusters over time, albeit relatively few. Nonetheless, four clusters are still created that differ from

each other in terms of the analyzed criteria included in the labor market slack. Additional information in this area is also provided by the analysis of data for individual countries and within individual clusters. Thus, the H2 hypothesis cannot be confirmed.

Discussion

The crisis related to the COVID–19 pandemic posed a challenge to the economies and livelihoods in each of the analyzed countries. The shock to the economy was greater in Southern Europe than in Eastern and Northern Europe. In order to protect jobs and employees, special programs were implemented, the effectiveness of which was also reflected in the level of labor market slack. At the same time, their diversity should be emphasized, especially in terms of the scale of aid, the conditions for obtaining it and its duration. This diversity was caused primarily by the economic situation of the country before the pandemic and the structure of the economy, existing anti-crisis programs, and to a lesser extent, political and even cultural conditions.

A review of the available information on aid programs shows that while in Germany and Czechia, for example, various types of subsidies played an important role, in Sweden and the Netherlands, subsidies and loans were crucial. In Italy and Spain, the multitude of solutions in the field of tax policy is noteworthy, while Spain, along with Sweden, also had extensive employee support programs. Less emphasis was placed on employee support programs in Hungary, Slovakia and the Netherlands. Important tools used to fight the pandemic included instruments that supported the labor market, which helped to maintain employment or subsidized wages.

The use of job retention schemes (Müller, Schulten, and Drahokoupil 2022; Lam and Solovyeva 2023) in a range of anti-crisis solutions should be mentioned. Ebbinghaus and Lehner (2022) showed that almost half of the 25 European countries, they investigated, introduced new schemes (nine without a prior scheme and three added a new scheme to an existing scheme), while a group of 14 countries relied on existing schemes but often improved their conditions. Continental, Mediterranean and Nordic countries often used existing instruments that were adapted, while most liberal market economies and CEE countries had to establish new job retention schemes. As shown by Corti, Ounnas, and Ruiz De La Ossa (2023), countries where the system was already in place permanently (i.e., Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Portugal, and Spain) immediately launched solutions, extending the scope and duration of interventions. Some of the countries that temporarily introduced job retention programs during the global finance crisis reintroduced these programs (i.e., Slovakia and Slovenia) while relaxing the eligibility criteria and extending the duration. Other countries introduced new schemes (e.g., Ireland) or more than one job retention scheme (i.e., Bulgaria, Czechia and Hungary). In turn, all countries that did not have

exemplary solutions for protecting jobs before (i.e., Croatia, Cyprus, Estonia, Greece, Latvia, Malta and Romania) introduced at least temporary measures for the duration of the pandemic.

The use of job retention schemes across the EU–27 helped prevent widespread job losses and stabilize household incomes. However, other studies also indicate that, overall, European labor markets were surprisingly resilient: employment fell slightly in the face of the pandemic recession, which was of an unprecedented magnitude (Gros and Ounnas 2021). That tendency also applies to changes in unemployment and inactivity. According to D'Amuri et al. (2022), the unemployment rate changed very little in the euro area from what would have happened if there had not been a decline in labor activity. Using the example of Italy, they indicate that in order to understand what happened during the pandemic, it is crucial to use models that consider not only flows into and out of employment but also into and out of the labor force. An interesting approach was used by Forsythe et al. (2020), who provided a taxonomy of the non-employed that makes it possible to divide non-employed individuals into three groups and distinguish people actively seeking new employment. They recognized that in relation to the pandemic, the unemployment of jobseekers should be measured in a way that takes into account the atypical composition of the unemployed population (e.g., due to the rising importance of temporary layoffs and recalls).

Hensvik, Le Barbanchon, and Rathelot (2021) described the Swedish context, where the anti-pandemic policy can be defined as a system of recommendations based on the voluntary compliance of citizens. They showed a correlation between the decreasing intensity of job searches by users of Sweden's largest online job board and the decrease in the number of job vacancies at the beginning of the pandemic. Expanding the topic of labor market flows to the Dutch market, Balgová et al. (2022) showed different job search behaviors depended on individuals' expectations regarding the duration and severity of the impact of the pandemic on the labor market. They also demonstrated that workers affected by changes in the number of hours worked and those in the hardest-hit sectors look for jobs differently than in a "normal" recession. In addition, they indicated differences (e.g., due to increased childcare burdens due to school closures) in job searches during the recession caused by COVID–19 compared to "normal" recessions and to normal times. In conclusion, they pointed out the risk of amplifying detachment from the labor market during the pandemic due to the atypically low search effort of the unemployed during the COVID–19 recession.

Baert (2021) demonstrated that unemployment-to-population and inactivity-to-population ratios in most European countries did not receive a huge blow from COVID–19 in 2020. He also observed important differences between countries: inactivity rose more sharply in Southern Europe, while unemployment increased dynamically in the Baltic States. Fana, Torrejón Pérez, and Fernández-Macías (2020) demonstrated that the employment

impact is asymmetric within and between countries. For example, southern countries (such as Spain or Italy), due to their productive specialization and labor market institutions, were most affected by pandemic restrictions. Their labor markets could also be described as more vulnerable even before the crisis.

A slight increase in the EU unemployment rate translates into a much smaller decrease in employment overall. The dynamics of unemployment rates appear to be driven mostly by the economic shock affecting supply and demand in the EU (Smith 2020). The widespread use of short-term work provisions isolated the European labor market from large swings in output (Gros and Ounnas 2021). Merkl and Weber (2020) drew attention to the shortening of working time in order to save existing jobs as part of the policies to counteract the pandemic crisis. However, they were not enough to prevent a decline in the labor market.

Conclusion

The value added of the study is the identification of changes in the labor market slack of the EU–27 during the COVID–19 pandemic. The results of the analysis show that during the analyzed period, the labor market slack in the majority of countries did not change. Some improved their situation (like Ireland, France, and Cyprus). In Ireland, the large-scale implementation of working from home allowed inactivity and unemployment to decrease (Stefaniec et al. 2022). In France, the measures were quite effective at dampening the impact of the lockdown on employment and the income of households and firms (Cahuc 2022). Cyprus noticed significant GDP growth in 2021, which positively influenced the labor market situation (Eures 2022). The country where the labor market slack deteriorated was Italy, which may be because of strict lockdown policy influenced the decrease in economic activity (Fiaschi and Tealdi 2022). Thus, the first research hypothesis was partially confirmed.

Comparing the changes in the labor markets leads to the creation of four homogeneous clusters of countries in all the analyzed periods. The second research hypothesis that the COVID–19 crisis reduced labor market slack differences between the EU countries cannot be confirmed. CEE countries experienced the relatively best labor market slack situation between 2019 and 2021, while Greece, Spain, and Italy experienced the worst. The CEE countries, unlike the southern countries, had very low unemployment rates (Szustak, Gradoń, and Szewczyk 2021). Additionally, they recorded relatively high economic growth, which positively influenced the labor market. By contrast, the southern countries were still suffering from the consequences of the financial crisis.

The reason for a relatively stable situation of labor market slack in EU countries during the pandemic can be the effectiveness of measures for mitigating the negative

impact of the COVID–19 outbreak on the labor market. The International Labour Organization (2020) claims that labor market policies and programs have been critically important in helping workers and employers deal with redundancies, furloughs, or reduced work schedules as a result of the pandemic. The main tool to mitigate the negative impact of COVID–19 on the labor market was temporary workforce reduction programs (involving either a temporary reduction in working hours or a temporary suspension of contracts), a scheme used throughout Europe. At the end of April 2020, it is estimated that such reductions were requested for 27% of EU workers (Duarte 2020). This was key in preventing the collapse in GDP from triggering a sharp rise in unemployment.

The slight decrease in employment may have been caused by fiscal incentives implemented during the pandemic. It was an instrument that included a series of changes to income taxes (Gajewski et al. 2021). Granting them to business owners was conditional on maintaining the same level of employment as before the pandemic. In order to cushion the drops in labor incomes related to changes in employment, governments introduced a new set of policy instruments, which complemented the existing tax-benefit system. The largest and probably the most influential instrument for preserving formal employment in affected businesses was the short-time working scheme (Sologon et al. 2022).

During the COVID–19 crisis, the tax-benefit system acted as an important stabilizer, reducing losses in disposable household income and restraining an increase in inequality generated by the loss of labor market incomes. This impact was largely driven by the short-term working schemes implemented in many countries, such as Germany, Luxembourg, and Poland (Bruckmeier et al. 2021).

The limitations of this study result from the focus on examining the dynamics of changes in labor market slack without elaborating on the demographic structure of that measure (such as sex or age). Additionally, some traditional indicators do not adequately capture the pandemic context. Firstly, the lockdown made it difficult to obtain statistical data, and secondly, restrictions on activity prevented unemployed people from seeking work or being immediately available to work; hence, they were not formally considered unemployed. Moreover, some authors claim that analyzing the effects of Non-Pharmaceutical Interventions (NPIs) on additional labor market statistics during the pandemic would provide valuable insights into their full impact on labor outcomes (Gros and Ounnas 2021).

Future research will focus on analyzing employment changes, including a sectoral analysis, which will enhance knowledge of the labor market situation during the COVID–19 crisis. Moreover, incorporating the demographic structure would enrich the analysis of labor market slack.

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Niewykorzystany potencjał na rynku pracy UE w czasie kryzysu COVID–19

Celem ogólnym artykułu jest weryfikacja poziomu niewykorzystanego potencjału na rynku pracy w trzech momentach uznanych za kluczowe podczas analizy zmian spowodowanych przez pandemię. Głównym celem jest zidentyfikowanie podobieństw i różnic między krajami UE, które zostały przypisane do klastrów wyodrębnionych w procesie badawczym.

W badaniu zastosowano analizę skupień w celu klasyfikacji państw członkowskich UE do grup podobnych krajów według zmiennych niewykorzystanego potencjału na rynku pracy, obserwowanych przed pandemią (2019) oraz w jej trakcie (2020, 2021). Wybrano podejście dwuetapowe. Na pierwszym etapie zastosowano analizę hierarchiczną do określenia początkowej liczby grup, natomiast na drugim etapie dokonano właściwej klasyfikacji obiektów przy użyciu metody k-średnich.

Porównanie zmian zachodzących na rynkach pracy analizowanych krajów pozwala na wyodrębnienie czterech jednorodnych klastrów we wszystkich badanych okresach. Wyniki badania pokazują także, że w analizowanym okresie sytuacja większości krajów UE w odniesieniu do niewykorzystanego potencjału na rynku pracy się nie zmieniła. Niektóre z nich poprawiły swoją sytuację (jak Irlandia, Francja czy Cypr). Powodem takiej sytuacji może być skuteczność środków wspierających rynki pracy, które zostały wdrożone w krajach UE podczas pandemii. Krajem, w którym sytuacja w kontekście niewykorzystanego potencjału na rynku pracy pogorszyła się, są Włochy. W perspektywie dalszych badań zasadne byłoby dokonanie dokładnej analizy skuteczności polityk i programów rynku pracy stosowanych w krajach zidentyfikowanych klastrów, ponieważ przyczyniły się one do względnie stabilnej sytuacji niewykorzystanego potencjału na rynku pracy. Przyszłe badania powinny być również skierowane na analizę zmian po stronie zatrudnienia, w tym analizę sektorową, co rozszerzyłoby wiedzę na temat sytuacji na rynku pracy w czasie kryzysu COVID–19. Co więcej, aby pogłębić analizę niewykorzystanego potencjału na rynku pracy, można włączyć perspektywę struktury demograficznej populacji.

Analizy rynku pracy oparte wyłącznie na stopie bezrobocia są niewystarczające, co jest szczególnie widoczne w obliczu konsekwencji spowodowanych przez pandemię COVID–19, ponieważ ta miara nie uwzględnia „efektu zniechęconego pracownika". Dla UE istnieje luka badawcza w tym zakresie, co można wywnioskować ze statystyk niewykorzystanego potencjału na rynku pracy. Artykuł ten wypełnił więc wskazaną lukę.

Słowa kluczowe: niewykorzystany potencjał na rynku pracy, bezrobocie, COVID–19, polityka antykryzysowa, analiza skupień

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.34

Interest Rate Pass-through and Monetary Policy Transmission in SADC and EAC Countries: Implications for Monetary Union

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Abstract

Southern African Development Community (SADC) and East African Community (EAC) countries are exploring the feasibility of establishing a monetary union. This study assesses the economic integration in the two blocs, using the interest rate pass-through mechanism to determine the convergence of interest rates in the two regions. This study evaluates the potential for forming a monetary union using the panel autoregressive distributive lag model (PARDL) with monthly data from January 2000 to December 2022, including central bank and retail bank interest rates. The dynamic common correlated effects (DCCE) results suggest that the complete interest pass-through to retail bank rates does not hold for the two blocs. Secondly, there are varying speeds of adjustment for banking rates in response to changes in policy rates. In addition, the incomplete interest-rate pass-through for the two blocs indicates the presence of banking market imperfections, weak banking asset quality, and information asymmetries, which are more pronounced in the EAC. Monetary policymakers should implement measures

Received: 25.01.2024. Verified: 14.03.2024. Accepted: 25.09.2024

to enhance the efficiency and competitiveness of their financial systems to minimise these imperfections.

Keywords: interest rate pass-through, financial integration, monetary union, SADC, EAC

JEL: F02, F15, F45

Introduction

Many African countries have been working on establishing regional economic communities and trade blocs (Redda 2021). Notable examples include the Southern African Development Community (SADC) and the East African Community (EAC). These groups are working towards economic integration to support the grand continental objective of a monetary union in the near future (McCarthy 2008; Redda 2021). The study aims to investigate the interest pass-through within SADC and the EAC as a step towards achieving economic integration.

One of the criteria for attaining economic integration is economic convergence among bloc members (Henning 1996). For instance, a member country's interest rates should not exceed far more than 2 percent of the highest three performing member states in the bloc (Henning 1996). Nonetheless, the member countries have significant differences. For instance, SADC is the largest trading bloc in Africa, consisting of 16 member countries: Angola, Botswana, Comoros, the Democratic Republic of Congo (DRC), Eswati[1], Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, and Zimbabwe. Within this bloc, South Africa has the largest economy. It plays a dominant role, with its GDP alone greater than the combined GDPs of the other 14 SADC member countries (Redda 2021). Therefore, South Africa is likely to have a major influence should a monetary union take place in the region. The EAC is a much smaller grouping than the SADC, comprising of eight-member countries. Members include Burundi, DRC, Kenya, Rwanda, Somalia, South Sudan, Tanzania, Uganda, and, Jobarteh (2023). For the EAC bloc, the economy in this region is dominated by Kenya and Uganda, while, and Burundi and Tanzania have much smaller economies.

The effectiveness of economic integration depends on factors such as macroeconomic conditions, financial market structure, and regulatory framework (Gigineishvili 2011). Therefore, a comprehensive economic and financial integration analysis must be conducted to establish whether interest rates (repo rate, deposit, and lending rate) move in the same direction before embarking on such economic integration. This paper contributes to the debate on whether the economic union between the SADC and EAC is as desirable as envisaged in their programs by establishing the interest rate pass-through mechanism in both regions.

1 Eswatini was previously known as Swaziland. It changed its name to Eswatini in 2018.

The empirical literature

Interest rate transmission in an economy is regarded as one of the most important monetary policy transmission mechanisms. It is closely associated with the effectiveness of monetary policy and is also critical for communicating central banks' policy stance to market participants (Liu 2019; Li, Si, and Ge 2021). Gigineishvili (2011) notes that several studies have examined the heterogeneity of interest rate pass-through in several countries and markets. However, the analysis of the structural determinants of these differences has received considerably less attention, possibly because of the difficulties in compiling consistent cross-country series of macroeconomic and structural variables. Based on the pioneering work of Cottarelli and Kourelis (1994), this study attempts to determine the level of economic integration in the two blocs through interest rate pass-through analysis. Interest rate pass-through refers to the process by which changes in the central bank's policy interest rate (repo rates) are transmitted, or "passed through", to the interest rates set by financial institutions, such as commercial banks, in the broader economy (Li, Si, and Ge 2021).

Interest rate pass-through analysis can reveal the degree and speed of monetary policy changes pass-through to the retail banking rates (Tai, Sek, and Har 2012). Sander and Kleimeier (2006) state that, within the context of economic integration, the monetary transmission process can easily be investigated through interest rate pass-through analysis, revealing how fast and complete changes in monetary policy rates are passed onto bank lending and deposit rates. Liu (2019) examined the determinants of interest rate pass-through to lending rates in China. The study found that commercial banks' asset quality influences interest pass-through to lending rate.

Hofmann (2002), Sander and Kleimeier (2006), and Aydin (2007) argue that the nature of interest rate pass-through reveals the degree of competitiveness and the soundness of the financial system. Sander and Kleimeier (2006) further assert that the pass-through's speed and size (completeness) depend upon the banking market structure and potential information asymmetries in the markets. A quicker, symmetric, complete interest rate pass-through indicates a well-functioning, competitive, and efficient financial system (Tai, Sek, and Har 2012). Such a financial system is essential to forming a well-functioning monetary union (Henning 1996).

While Hofmann (2002) and Aydin (2007) focused on the degree and speed of adjustment of banking rates to changes in money market rates, lending rates, and deposit rates, other studies (e.g., Aziakpono, Kleimeier, and Sander 2012; Tai, Sek, and Har 2012) have investigated the interest pass-through of monetary policy rates into the short-term and long-term market rates.

This study uses interest rate pass-through analysis to examine the integration of central bank and retail banking rates in the SADC and EAC to assess the feasibility of a monetary union. We will determine how quickly interest rate pass-through

will affect retail banking rates. It is a tool to understand the monetary transmission process and the competitiveness of the financial system. Quicker and complete pass-through indicates a well-functioning system. The method and econometric modelling applied in the study are presented in the next section.

Methodology

Data and sampling

To investigate the interest pass-through within the SADC and EAC, we analysed the integration of central bank and retail banking interest rates in each bloc. The sample includes monthly data from January 2000 to December 2022, encompassing central bank interest rates and retail banks' interest rates, represented by lending and deposit rates, from SADC countries and EAC countries for which consistent data are available for the sample period. The data were obtained from the World Bank and the International Financial Statistics (IFS) through the IRESS databases.

Burundi, the Seychelles, Somalia, South Sudan, and Zimbabwe were dropped due to a great deal of missing data. Therefore, the final sample size consists of 12 SADC countries and four EAC countries for which consistent data are available for the entire sample period. We also sampled the original member states before any extensions. For instance, South Sudan became an EAC member in 2016, while the DRC became a full member of the EAC bloc in 2022. Therefore, these two countries were not grouped with the EAC bloc in Table 1. In addition, DRC and Tanzania are in both groups, although, for the purposes of this study, DRC will be treated only as a member of the SADC. Table 1 presents the list of countries and each country's regional blocs. Tanzania belongs to both blocs.

Table 1. Panel data of countries in the two regions

SADC	EAC
Angola	Kenya
Botswana	Rwanda
Comoros	Uganda
DRC	Tanzania
Eswatini	
Lesotho	
Mauritius	
Mozambique	
Namibia	
South Africa	

SADC	EAC
Tanzania	
Zambia	

Source: authors' elaboration.

Model specification

To model the interest rate pass-through in the regions, the following function was considered.

$$y_{it} = f\left(y_{it-1}, Repo_{rateit}\right), \tag{1}$$

where y_{it} represents bank rates in country i at time t. The bank rates proxied are the monthly lending rate and deposit rate. The lending rate is the cost of obtaining a loan from the bank. The deposit rate is the savings rate on monies kept with the bank. $Repo\_rate_{it}$ is the monthly central bank rates for each country in the study.

Estimation techniques

To estimate the function in Equation 1, this study adopted the panel autoregressive distributed lag (PARDL) model. The PARDL is selected because it can simultaneously estimate short- and long-run dynamics while accommodating different lags on each variable (Muzindutsi and Mposelwa 2021). The PARDL equation:

$$Lending\_rate_{it} = \alpha_i + \sum_{j=1}^{p} \lambda_{ij} Lending\_rate_{i,t-j} + \sum_{j=0}^{q} \delta_{1,ij} Repo\_rate_{i,t-j} + \varepsilon_{it}, \tag{2}$$

$$Deposit\_rate_{it} = \alpha_i + \sum_{j=1}^{p} \lambda_{ij} Deposit\_rate_{i,t-j} + \sum_{j=0}^{q} \delta_{1,ij} Repo\_rate_{i,t-j} + \varepsilon_{it}. \tag{3}$$

The reparameterisation of Equations 2 and 3 is estimated as:

$$\begin{aligned} \Delta y_{it} = \alpha_i + \phi_i y_{i,t-1} + \beta_{1i}^{'} Repo\_rate_{it-1} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-j} + \\ + \sum_{j=0}^{q-1} \delta_{2,ij}^{*'} \Delta Repo\_rate_{i,t-j} + \varepsilon_{it}. \end{aligned} \tag{4}$$

In terms of the econometric properties of Equation 4, the coefficients β and δ capture the interest rate pass-through to y. It also captures the impact of the specified

explanatory variable on the bank rates. ε_{it} is the error term for country i in year t. It captures the speed of adjustment of repo rate pass-through towards long-run equilibrium.

Results and discussion

Descriptive analysis

Table 2.1 presents summary statistics for the EAC bloc. The descriptive statistics of interest rate variables for the EAC show that the repo rate is 11.84, the deposit rate is 8.46, and the lending rate is 17.51. Table 2.2 presents summary statistics for the SADC bloc. The results show that SADC has the highest repo rate but the lowest deposit rate, while the EAC has the highest lending rate. Although the official central bank rate (repo rate) is higher for the SADC, the spread between the repo rate and lending rate is low at 3.51 compared to 5.67 for the EAC. This shows that lending to customers is cheaper in the SADC than in the EAC.

Nevertheless, the lending rate is double-digit for the two blocs, making loans expensive to bank customers in African countries. One of the criteria for economic integration is that there must be economic convergence, where the cost of lending should not be significantly different between the two blocs (Henning 1996). However, achieving economic convergence in interest rates remains a distant goal, which is evidenced by the standard deviation in Table 2.1 for the EAC and Table 2.2 for the SADC. There is a wide variation in the interest rates between the two blocs.

Table 2.1. Summary statistics of interest rates for the EAC countries

Variable	Obs	Mean	Std. dev.	Min	Max	Variance	Skewness	Kurtosis
Repo_rate	598	11.84	4.39	5.75	29	19.29	1.38	5.08
Deposit_rate	596	8.46	2.6	3.54	23.85	6.75	1.76	9.14
Lending_rate	598	17.51	3.27	11.75	27.58	10.72	.61	3.17

Source: authors' elaboration.

Table 2.2. Summary statistics of interest rates for the SADC countries

Variable	Obs	Mean	Std. dev.	Min	Max	Variance	Skewness	Kurtosis
Repo_rate	2,922	13.1	20.07	.92	150	396.1	5.44	35.56
Deposit_rate	2,913	6.94	6.13	0	65.58	37.26	4.01	27.62
Lending_rate	2,926	16.61	14.66	5.25	125.97	210.66	3.94	20.87

Source: authors' elaboration.

Table 3 summarises the country-specific descriptive statistics. The result shows that there are high variations in interest rates among individual member countries, which may hinder economic convergence and progress towards a monetary union. All the countries, excluding Mauritius, have an average double-digit lending rate. We have not established a steady similar spread between the repo rate and lending rate across countries SADC bloc, which may suggest an incomplete convergence of monetary and banking market integration among the SADC countries. According to Ndou and Mokoena (2019), persistently high lending rates are driven by economic policy uncertainty shocks, where the actual rise of the lending rate exceeds the counter effect of the repo rate adjustment. This is further supported by Liu (2019), who found that the quality of financial institutions in countries with high lending rates is weak.

Table 3. Country-specific descriptive statistics

Countries	Repo_rate	Deposit_rate	Lending_rate
	%	%	%
Angola	36.77	12.82	46.7
Botswana	9.84	5.51	11.46
Comoros	2.75	2.24	10.47
DRC	19.08	7.77	32.65
Eswatini	7.38	4.28	10.80
Kenya	9.21	7.26	14.68
Lesotho	11.49	3.47	12.22
Mauritius	4.66	5.7	9.45
Mozambique	9.95	10.94	19.12
Namibia	7.45	5.75	10.69
Rwanda	10.44	7.92	16.65
South Africa	7.14	6.98	10.63
Tanzania	11.43	8.65	16.01
Uganda	15.95	10.23	21.21
Zambia	16.50	11.02	21.43
Total	12.88	7.2	16.76

Source: authors' elaboration.

Specification tests for repo rate and bank rates

Unit root tests and cross-dependency tests were carried out for PARDL estimations for Equation 4. Pesaran, Frees and Friedman's cross-dependency test suggests a presence of cross-dependence; therefore, the pooled mean group (PMG) estimation technique

becomes an inefficient estimator for this study. This study employs the dynamic common correlated effects (DCCE) model developed by Chudik and Pesaran (2015), which accounts for cross-sectional dependency, to achieve the study objectives.

Panel unit roots test for PARDL

The augmented Dickey–Fuller (ADF) and Phillips Perron test (PPT) unit root tests, which are appropriate for unbalanced panels, were conducted to identify whether the key variables are stationary at level. These tests established that the panel is stationary at I(1), confirming that PARDL can be used to estimate Equation 4 (see Appendix 1). Since the study employs DCCE, it allows variables to be first differenced.

The study further tests for the unit root using a second-generation panel unit root, as the first-generation unit root test in Appendix 1 assumes cross-sectional independence. Appendix 2 provides the results of the second-generation unit root test, known as the cross-sectional augmented panel unit root test (CIPS) by Pesaran (2007). The interest rate variables are stationary at levels and first difference. The repo rate is stationary at first difference, while the bank rates are stationary at level.

Interpretation and result discussion

The study applied the DCCE model to estimate equation (4), and the results are presented in Tables 4 to 6. Table 4 presents the repo rate pass-through for each bloc of EAC and SADC countries.

For the EAC countries, the short-run estimation shows the absence of short-run repo rate pass-through to the bank rates. This implies that the bank rates in the EAC bloc are slow to reflect the central bank's monetary policy changes. The lack of a significant relationship shows that the financial market does not react to changes in the repo rate. For instance, interest rates charged on loans or earned on deposits remain unchanged regardless of changes in policy rates.

For the SADC countries, in the short run, the repo rate has a positive and significant effect on deposit and lending rates at the 5 percent and 1 percent significance levels. This implies that a change in the repo rate is immediately passed through to the deposit and lending rate in the short run.

In the long run, there is no homogeneity in the repo rate pass-through to the bank rates. The result indicates a repo rate pass-through to the lending rate for the SADC bloc in the long run, while the EAC bloc shows a long-run repo rate pass-through to the deposit rate at the 1 percent significance level. This shows that, for the two blocs, the effect

of change in central bank monetary policy passed through to one type of bank rate in the long run, but not both.

There is a low and incomplete repo rate pass-through for the two blocs. The coefficient of the repo rate on bank rates is less than 1 for the EAC and SADC blocs. At 0.14 for the deposit rate and 0.29 for the lending rate, the estimates of the short-run repo rate pass-through for the SADC bloc are higher than the coefficients for the EAC bloc, at 0.021 and 0.06. The low-rate incomplete repo rate pass-through to bank rates may be interpreted as the presence of banking market imperfection (Aziakpono, Kleimeier, and Sander 2012).

Table 4. Repo rate pass-through for the EAC and SADC blocs

	EAC			SADC	
	D.Deposit_rate	D.Lending_rate		D.Deposit_rate	D.Lending_rate
SR					
D.Repo_rate	0.021	0.006		0.141**	0.291***
	(0.095)	(0.045)		(0.057)	(0.104)
ECM	−0.159***	−0.102*		−0.121***	−0.103**
	(0.033)	(0.062)		(0.036)	(0.046)
LR					
Repo_rate	0.075***	0.045		0.030	0.068***
	(0.020)	(0.033)		(0.025)	(0.021)
N	757	759		2968	2980
R-squared	0.84	0.90		0.93	0.89

Note: Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.001.
Source: authors' elaboration.

In addition, the repo rate pass-through reflects bank behaviour in response to changes in the repo rate in bank rates. Banks may not be motivated to raise interest rates too much on loans or savings. Although there is a low and incomplete repo rate pass-through, the SADC exhibits a stronger repo rate pass-through than the EAC bloc. This may be because interest rates are lower for SADC countries. Therefore, SADC banks may be more incentivised to increase loan interest charges than in EAC countries.

In contrast, the EAC countries can only marginally increase bank rates following a change in the repo rate because interest rates charged on loans are already high. Thus, bank borrowers may not be willing to accept an increase in lending rates. As a result, banks may not have an incentive to increase the lending rate. This may be the reason for incomplete repo pass-through with very low estimates of 0.06 for the lending rate.

The speed of adjustment to changes in the repo rate towards a long-run equilibrium is small, as shown by the error correction model (ECM) of –0.16 and –0.10 for the EAC bloc and –0.12 and –0.1 for the SADC bloc. This implies that with any change in the repo rate, the speed of adjustment rate towards the long-run equilibrium is in the range of 10 percent and 16 percent for the deposit rate and lending rate in both EAC and SADC, and long-run repo rate pass-through is still incomplete in the long run. The ECM is significant and negative, indicating a stable and converging long-run relationship between repo rate and bank rates. However, there is no long-run relationship between the repo rate and deposit rate for the SADC bloc. Meanwhile, the EAC bloc has no long-run relationship between the repo rate and the lending rate.

Table 5 presents the results of the full sample, providing insight into the potential for a monetary union among African countries. The results show incomplete repo pass-through to bank rates in both the short run and long run. Still, among the two bank rates, the lending rate has the highest repo pass-through by banks to their customers in the short- and long run.

The speed of adjustment to changes in the repo rate towards a long-run equilibrium is small, as shown by the ECM of –0.122 and –0.104. There is a significant and positive result for the repo rate and lending rate, which may imply the presence of a long-run relationship between the repo rate and the lending rate. This shows that the effect of change in central bank monetary policy is still passed through to the lending rate in the long run. However, there is no long-run relationship between the repo rate and the deposit rate. The results in Table 5 suggest that the SADC countries may be driving the outcome of the result, as it is similar to Table 4 for the SADC bloc.

Table 5. Repo rate pass-through, full sample

	1	2
	Deposit_rate	Lending_rate
SR		
D.Repo_rate	0.123**	0.234***
	(0.052)	(0.088)
ECM	–0.122***	–0.104**
	(0.027)	(0.044)
LR		
Repo_rate	0.030	0.068**
	(0.024)	(0.028)

	1	2
	Deposit_rate	Lending_rate
N	3561	3575
R-squared	0.93	0.89

Note: Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.001.
Source: authors' elaboration.

Table 6 shows whether any changes in bank rates influence the central bank's monetary policy. We find that both lending and deposit rates influence the repo rate in the short run. Regionally, only the lending rate positively and significantly influences the repo rate (at the 5 percent level of significance) for the EAC bloc in the short run. These findings contrast the findings in Table 4 for the EAC bloc, where the repo rate had no influence on bank rates in the short run. The findings in Table 6 for the EAC imply that bank lending rates have a significant effect on the central bank's repo rate, but this monetary policy instrument of the central bank has no significant or immediate influence on lending rates for the EAC countries. Furthermore, the lending rate pass-through to the repo rate is high at 0.17 in Table 6 compared to the repo rate pass-through to lending at 0.06 in Table 4 for the EAC countries.

Both bank rates significantly influence the repo rate for the SADC countries in the short run. Similar to the results in Table 4 for the SADC bloc, each interest rate affects the other.

Table 6. The effect of bank rates on the repo rate

	All panel	EAC	SADC
	D.Repo_rate	D.Repo_rate	D.Repo_rate
SR			
D.Deposit_rate	0.158**	0.163	0.143**
	(0.063)	(0.112)	(0.072)
D.Lending_rate	0.345***	0.177**	0.401***
	(0.092)	(0.077)	(0.108)
ECM	−0.102**	−0.067**	−0.105**
	(0.041)	(0.027)	(0.051)
LR			
Deposit_rate	0.133	0.101	0.142
	(0.124)	(0.079)	(0.157)
Lending_rate	0.073	−0.110	0.074*
	(0.054)	(0.082)	(0.043)
N	3561	757	2968
R-squared	0.90	0.83	0.90

Note: Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.001.
Source: authors' elaboration.

The three major findings are as follows: Firstly, the SADC bloc exhibits different behaviours following changes in the repo rate compared with the EAC bloc. According to Iris and Howells (2002), the first link in all monetary regimes is between central bank rates and bank rates, in particular, how banks react to the changes in the policy rates to lending and deposit rates. This study's findings establish no significant link between central bank rates and bank rates in the EAC bloc. Therefore, bank rates do not move in a similar direction following changes in the policy rate for the EAC and SADC blocs.

Secondly, there is incomplete repo rate pass-through for the two blocs; as such, there is banking market imperfection. However, the EAC bloc has more banking market imperfection, as evidenced by the very low repo rate pass-through transmission to bank rate, both in the short- and long run. In addition, according to Liu (2019) and Sander and Kleimeier (2006), incomplete repo rate pass-through suggests that the banking industry in these blocs is not very competitive, and the markets have information asymmetries.

Thirdly, SADC countries have a repo rate pass-through to bank rates immediately following changes in the repo rate in the short run, with significant market reaction.

For EAC countries, an immediate interest rate pass-through from the central bank onto bank rates could not be established in the short run. However, a long-run influence on the deposit rate was observed. The EAC countries are a small bloc compared with SADC countries, and the findings suggest that these blocs react to monetary policies differently. The possibility of a monetary union between the two blocs may not be feasible as the EAC bloc lacks an efficient, immediate monetary policy transmission to banking interest rates. Finally, the results indicate what monetary integration would look like in Eastern and Southern Africa, which would provide an indication of the ultimate goal of having a common monetary union throughout Africa.

Conclusion and recommendations

The study examined interest rate pass-through to determine the feasibility of a monetary union between SADC and EAC in the near future. Firstly, the findings suggest that the SADC and EAC blocs react to monetary policies differently following changes in the repo rate. Secondly, although there is an incomplete repo rate pass-through for the two blocs, the SADC exhibits immediate significant changes in market reactions to bank rates following monetary policy changes in the short run. Only a long-run relationship was established for the EAC bloc for the deposit rate. The possibility of a monetary union between the two blocs may not be feasible as the EAC bloc lacks an efficient, immediate transmission of monetary policy onto banking interest rates compared with the SADC bloc. The incomplete repo rate pass-through for the two blocs indicates the presence of banking market imperfection, weak banking asset quality, and information asymmetries, with the situation being more severe in the EAC.

One can conclude that given the SADC region's stronger repo rate pass-through, monetary policymakers should continue to use interest rate adjustments to influence the broader economy to achieve their macroeconomic objectives. Monetary policymakers should, therefore, work to identify these imperfections and implement measures to enhance the efficiency and competitiveness of their financial systems.

For the EAC, the low and incomplete repo rate pass-through points to potential challenges in transmitting monetary policy to bank rates such as deposit and lending rates. Monetary policymakers should investigate and address the factors that cause this inefficiency to make monetary policy instruments work effectively. In light of the findings regarding the lack of efficient, immediate transmission of monetary policy onto banking interest rates in the EAC region, the monetary union seems unfeasible. Monetary policymakers considering a monetary union in the EAC should carefully assess the readiness of the financial and banking sectors to ensure effective policy transmission across member countries before implementing any form of monetary union.

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APPENDIX

Appendix 1. Panel unit root test

Variable	ADF	PPT	Stationary
Repo_rate	0.0000	0.0000	I(1)
Deposit_rate	0.0000	0.0000	I(1)
Lending_rate	0.0000	0.0000	I(1)

Appendix 2. Second-generation panel unit root test

Variables	z-stat	Difference level
Repo_rate	– 18,935***	I(1)
Deposit_rate	– 2,597***	I(0)
Lending_rate	– 1,777***	I(0)

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

Przeniesienie stóp procentowych i transmisja polityki pieniężnej w krajach SADC i EAC: implikacje dla unii walutowej

Kraje Południowoafrykańskiej Wspólnoty Rozwoju (SADC) i Wspólnoty Wschodnioafrykańskiej (EAC) analizują możliwość ustanowienia unii walutowej. Niniejsze badanie poddaje ocenie proces integracji gospodarczej w obu blokach, wykorzystując mechanizm przenoszenia stóp procentowych w celu określenia konwergencji stóp procentowych w obu regionach. Wykorzystując dane miesięczne od stycznia 2000 r. do grudnia 2022 r., obejmujące stopy procentowe banku centralnego i banków detalicznych, niniejsze badanie ocenia możliwości stworzenia unii walutowej. Zastosowano ilościowe podejście badawcze z wykorzystaniem panelowego modelu autoregresyjnego o rozłożonych opóźnieniach (PARDL).
Wyniki uzyskane dzięki zastosowaniu *dynamic common correlated effects* (DCCE) sugerują, że w obu blokach nie występuje pełne przeniesienie stóp procentowych banku centralnego na stopy banków detalicznych. Po drugie istnieją różne prędkości dostosowań stóp bankowych w odpowiedzi na zmiany stóp procentowych banku centralnego. Ponadto niepełne przeniesienie stóp procentowych w obu blokach wskazuje na obecność niedoskonałości rynku bankowego, słabej jakości aktywów bankowych i asymetrii informacji, przy czym kwestie te są bardziej widoczne w EAC. Aby sprostać tym wyzwaniom, decydenci w obszarze polityki pieniężnej powinni wdrożyć środki mające na celu zwiększenie wydajności i konkurencyjności ich systemów finansowych w celu zminimalizowania tych niedoskonałości.

Słowa kluczowe: przeniesienie stóp procentowych, integracja finansowa, unia walutowa, SADC, EAC

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.35

The Role of the Circular Economy in Economic Development: An Empirical Investigation for Panel of Some Selected European Economies

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Abstract

This study examines the relationship between the circular economy and economic development in 14 EU countries for the period 2000–2020.
Compared to previous work, we emphasize the importance of taking into account cross-dependencies and heterogeneity between the countries making up the Panel. Furthermore, the cointegration relationship employed in this work considers structural shocks and cross-dependencies using the test of Westerlund and Edgerton. This last test made it possible to validate the long-term relationship in the model. This study used the augmentedmean group technique to overcome some economic problems. Using Kónya's bootstrap panel causality test, we found that the causal relationship is only found in a few countries.
According to the empirical analysis conducted in this work, our findings indicate that economic growth, research and development and the generation of municipal waste favor the recycling and composting of municipal waste. In the same way, the recycling of municipal waste, research and development expenditure and the Generation of municipal waste increase positively the economic growth rate.
Our empirical results provide important policy implications for 14 EU countries that need to take adequate measures to improve the recycling rate through environmentally friendly technology to achieve a level of sustainable growth and development. Compared to previous studies, this work attempts to fill a gap in current research and enrich the existing literature between the circular economy and economic development in Europe.

Received: 19.01.2024. Verified: 14.03.2024. Accepted: 25.09.2024

Keywords: circular economy, economic development, cross-section dependencies and heterogeneity, panel cointegration analysis, Augmented Mean Group, panel causality analysis

JEL: C01, F64, O44, P48

Introduction

The circular economy has become one of the themes that have received so much theoretical and empirical interest in recent years. This concept has developed to constitute a model to follow and replace the old paradigm of the so-called linear economy, by limiting the waste of resources and its effect on the environment through recycling but also by product design, thanks to eco-design, to develop objects or services designed to limit waste (Kampelmann 2016). The linear economy is considered to be a process of wealth creation based on the conversion of natural resources into waste through production (Bourdin and Maillefert 2020). This economic model is based on approach on the "take-make-dispose" and not able to maintain the balance between supply and demand in the consumption of natural resources (Ghisellini, Ripa, and Ulgiati 2018; Goyal, Esposito, and Kapoor 2018). In this sense, Andrews (2015) explains the limitations of the traditional linear economy and how the circular economy offers a more sustainable and efficient alternative. His study explores the role of designers in promoting the circular economy and highlights how design thinking can be used to create innovative solutions that support this economic model. As a result, current policies at the international level have changed direction in favor of growth models that face pollution growth by overcoming the old models based on the continuity of production and waste at all levels (Ghisellini, Cialani, and Ulgiati 2016). Sehnem et al. (2019) consider that the circular economy assumes that resources are unlimited and always available at low cost. This assumption seems unacceptable in the real world and cannot determine the long-term growth pattern.

A circular economy (CE) therefore includes, as a whole, all forms of the economy (Blomsma and Brennan 2017) built around circularity, in which materials, resources, waste, and energy are reused as much as possible to avoid waste. The idea of circular economy has two long parts, the first dealing with the movements of materials in an economy and the second involving thinking about the economic conditions that can lead to such movements (Ekins et al. 2019). The idea of reconciling economic development and ecological development dates back to the 1970s during the Stockholm conference in 1972 under the theme of eco- development. In Morocco, the circular economy is part of the strategic plan for the new development model at local, national, and global levels (Benmahane 2018). It can provide an impetus to face environmental challenges and meet the most pressing needs in the short and long term. It is supposed to be a necessary step for the achievement of the objectives of the new development model and an essential long-term milestone for sustainable development. To do this, various programs

and plans have been launched to achieve the expected objectives of sustainable development. The implementation of an energy strategy (ENR) aims to exploit new sources of energy such as the transformation of waste and it also aims to use renewable energies as much as possible. This strategy makes it possible the countries to produce energy from renewable sources in the world. As Brundtland report (*Report of the World Commission…*, 1987) has pointed out this development model must meet the needs of the present, without undermining the ability of future generations to meet theirs. Furthermore, according to Kirchherr, Reike, and Hekkert (2017), CE is considered an economic system that seeks to reduce, reuse, recycle, and recover resources (Kristensen and Mosgaard 2020) through sustainable business models. In this way, CE represents a significant opportunity for companies by forcing them to go beyond their environmental and energy efficiency objectives (Leitão 2015). In this perspective, through a certain industrial symbiosis, the collaboration between companies in the same sector or different sectors could optimize the use of resources. This may involve the exchange of by-products, the reuse of waste from one company as raw material for another, or even the pooling of infrastructures. In addition, companies can also in a continuous cycle (The value loop) design products in such a way that they can be easily repaired, remanufactured, recycled, or reused, to maximize value throughout their life cycle (Bjørnbet et al. 2021). The circular economy is often seen as an opportunity for companies to extend the economic life of goods (Gregson et al. 2015), join efforts along the supply chain and also involve consumers, seeking to recover the value of these products throughout their life cycle.

A certain industrial ecology can be developed through this interaction between companies in a given region to optimize the flow of materials and energy between economic players in the same territory, thus promoting the circular economy at the local level. By doing so, they can make significant profits and create more employment in the market. Moreover, Tonelli and Cristoni (2018) indicate that most companies consider the circular economy as a risky and expensive system rather than a source of revenue generation. As the World Economic Forum (2014) report points out, if companies set up circular supply chains to increase recycling, reuse, and remanufacturing, one billion dollars and 100,000 new jobs could be created by 2025 (Kalmykova, Sadagopan, and Rosado 2018). According to the same report, this eco-design, waste prevention and reuse can bring an estimated net savings of up to Euros 600 billion to EU businesses, while reducing greenhouse gas emissions. In addition, other measures to increase resource productivity by 30% by 2030 could increase GDP by nearly 1% and also create an additional 2 million jobs (European Commission 2014a; 2014b). Mazur-Wierzbicka (2021) points out that in the case of European countries, CE is seen as a priority for development and an important element of industrial strategy. According to this last author, his analysis of 28 European countries shows that the most advanced countries begin to feel the problems of waste generation, exhaustion of resources, environmental pollution, increasing consumerism, or unbalanced

consumption earlier than the less advanced countries. The latter, for lack of infrastructure, cannot get involved in the implementation of the EC.

The remainder of the study is organized as follows. Section 2 provides a literature review on the relationship between the circular economy and economic development. Section 3 presents econometric analysis, including the selection and analysis of the sample and model specifications, different tests of cross-sectional dependencies, cointegration, and causality with cross-sectional dependencies and heterogeneity. Finally, section 4 contains the most relevant conclusions and the most significant contributions of the study and policy implications.

Literature review

From the theoretical background, we can consider that the circular economy is a new production paradigm that can drive the economy toward long-term growth and maintain sustainable development (Korhonen et al. 2018; Arruda et al. 2021). A circular economy includes activities to reduce, reuse and recycle materials along the production chain, thereby reducing the harmful impact of economic activities on the environment (Ormazabal et al. 2018). Economic growth must be independent of environmental pressures to keep ecosystems resilient and prevent the effect on human well-being. The goal of CE is to change the status quo and inspire new business visions, and innovations that improve efficiency and competitiveness (De Jesus and Mendonça 2018). The circular economy offers potential environmental benefits, including reduced greenhouse gas emissions, energy savings, and conservation of natural resources (European Commission 2015).

Empirical investigations could assess the environmental impacts of circular economy practices and their relationship to economic development. This could involve analyzing indicators such as carbon footprints, resource productivity, and environmental certifications.

In international scientific research, there is a lot of discussion about the economy but very little attention is given to the existing link between the circular economy and economic growth (Kaivo-oja, Vehmas, and Luukkanen 2022). Dinda (2020) investigates the circular economy approach for sustainable economic development and finds that the circular economy model emphasizes the reuse of resources without degrading the environment, which is crucial for the future of our world. Using quantile regression, Horbach and Rammer (2019) find a positive relationship between CE innovation experienced by a panel of German firms in 2012 and 2014, and sales and employment growth in the case of German firms during the period 2014–2016. Simionescu (2020) used a macroeconomic approach based on panel data models (panel ARDL) from European countries (Cyprus, Latvia,

Lithuania, Hungary, Poland, Romania, Slovenia, and Slovakia) and Bayesian random linear regression models analysis over the period 2008 to 2020. The results show that gross investment in material goods and more people employed in circular economy sectors are long-run factors to sustain economic development in these countries. By estimating two fixed effects models in the case of a panel of countries composed of 23 European countries, Ferrante and Germani (2020) found that the circular economy has a significant effect on employment and poverty reduction and that there is unidirectional causality between the circular economy and employment. Škrinjarić (2020) empirically assessed CE achievements of selected European countries by applying gray relational analysis (GRA), with a robustness check via MCDM (Multiple Criteria Decision) approach over the period 2010–2016. The results indicate regional differences between European countries in terms of their involvement in the circular economy. It was noted that the countries with higher GDP per capita, good infrastructure, education, and the development of R&D (research and development) such as Germany, Netherlands, Denmark, France, and Italy perform better than less developed countries such as Romania, Greece, Cyprus, Slovakia and Bulgaria. The last countries are lower ranked concerning the indices of corruption and organizational efficiency. These results seem to be confirmed by the work of Mazur-Wierzbicka (2021). Ghazi Alajmi (2016) examines whether municipal solid waste is influenced by economic activity or not, and the Environmental Kuznets Curve (EKC) hypothesis between economic growth and MSW in Saudi Arabia lasted from 1980–2012. The results show that this EKC hypothesis is not validated over the study period using a VECM model. The study conducted by Vuţă et al. (2018) assessed the effect of the circular economy on the economic growth of EU–28 countries over the period 2005–2016. The authors conclude that a circular economy is an excellent tool to move towards more sustainability in Europe. More recently, Georgescu, Kinnunen, and Androniceanu (2022) assess the relationship between the recycling of R&D expenditure, generation of municipal waste per capita, and the recycling rate of municipal waste influence the GDP per capita in a panel of 25 European countries during the period 2000–2018. In the first equation, the authors try to test the impact of R&D expenditure, generation of municipal waste per capita and the recycling rate of municipal waste influence the GDP per capita. In a second equation, they attempt to test whether these variables affect GDP per capita. To do this, the authors use two estimation methods (a fixed effects model and a Tobit model). Their results show that the recycling rate has a positive effect on economic development and vice versa. In this study, given the positive relationship between waste generation and GDP per capita, innovative measures need to be implemented by these countries to reduce waste generation and achieve sustainable development. Gardiner and Hajek (2020) investigate the relationships between municipal waste generation, R&D intensity, and economic growth in EU regions (old and new EU regions) between 2000–2018. This study shows that there is a long-term relationship between municipal waste production and economic growth. Furthermore, this work showed a positive two-way causality between municipal waste generation and GDP was observed for regions of old EU member states, while only

a long-term one-way effect from GDP to the generation of municipal waste has been observed for the regions of the new EU Member States. In the short term, these results indicate bidirectional causality for the two categories of regions. Bianchi and Cordella (2023) examine a panel covering 28 European countries over the period 2010–2019. Their findings confirm that promoting a shift to more circular economic systems can reduce primary resource extraction. More recently, the empirical work of Feiferytė-Skirienė and Stasiškienė (2023) show the importance of structural shocks such as the global financial crisis of 2008–2009 on the durable transition. The results show that there is a short-term positive impact on environmental degradation and that economic interests prevail over environmental objectives and that following the Covid–19 crisis and the war between Russia and Ukraine, industrial behavior has shifted from sustainable to linear. The authors argue that, so far, countries' actions on sustainable transitions are insufficient and require drastic decisions and economic changes focused not only on short-term but also long-term solutions. From what has been cited above, it seems to us that the empirical work dealing with the relationship between the circular economy and economic development shows serious problems in the empirical analysis. Firstly, in the case of the panel, taking into account the dependencies between the individuals of the panel and secondly the importance of structural shocks is completely ignored. These last hypotheses can lead to a statistical bias and lead to retaining the wrong model in the analysis. To fill the gap in the literature, this paper aims to take into account all of these empirical considerations, in particular the impact of structural shocks and the hypothesis of dependencies that may exist between the countries analyzed in the panel context.

Econometric analysis

Data and models specification

This section will be devoted to the econometric examination of the relationship between the circular economy and economic development in a panel of 14 European countries (France, Germany, Spain, Netherlands, Belgium, Finland, Portugal, Czech Republic, Estonia, Cyprus, Hungary, Poland, Slovenia, and Slovakia). Our Datasets were collected from Eurostat and World Bank. This panel analysis will be based on a sample depending on the availability of data for the period 2000–2020. According to the seminal work of Georgescu, Kinnunen, and Androniceanu (2022), we will test the following two models:

The first-panel data model to be estimated has the form:

$$\ln RMU_{it} = \alpha_i + \beta_{1i}\ln GDPC + \beta_{2i}\ln RD + \beta_{3i}\ln GMW + \varepsilon_{it}. \quad (1)$$

The second-panel data model is:

The second-panel data model is:

$$\ln GDPC_{it} = \alpha_i + \varphi_{1i}\ln RMU + \varphi_{2i}\ln RD + \varphi_{3i}\ln GMW + \varepsilon_{it}, \quad (2)$$

where *RMU*, *GDPC*, *RD*, and *GMW* are respectively Recycling rate of municipal waste (% of total waste generated), GDP per capita (constant, USD 2015), Research and development expenditure (% of GDP), and Generation of municipal waste per capita (kg per capita). *t*: is the period term (2000–2020) and ε_{it}: The error term.

Unlike previous studies, in this work, we will try to test these two models by testing the presence of heterogeneity and independence for this panel composed of 14 EU. The long-term or cointegration relationship will be tested by taking into account the dependence between the individuals in the panel and the structural breaks, in particular the impact of the 2008 subprime crisis and the covid–19 crisis. According to the literature already mentioned, structural shocks can play an important role in the circular economy.

Estimation strategy

Before proceeding to the estimation of the two proposed models, we will first, test the hypothesis of independence between the countries by applying the Pesaran test (2004) and the heterogeneity hypothesis between countries (Pesaran and Yamagata 2008) will be applied. Second, we apply panel unit root and cointegration tests with dependencies and structural breaks. Finally, two tests of causality between the variables of the models will be done.

Panel independence and heterogeneity test

The test of the two hypotheses of cross-sectional dependencies and the homogeneity between the variables are important in econometric analysis. Depending on these latter assumptions, the choice of tests used in the empirical analysis, such as panel unit root tests and cointegration tests will be made. The following two tables (Tables 1 and 2) show respectively the cross-sectional dependence test and the homogeneity test in the data.

Table 1. CSD outcomes

	Eq.1	Eq.2
Breusch–Pagan LM	593.48*** (0.000)	403.85*** (0.000)
Pesaran-scaled LM	37.24*** (0.000)	23.19*** (0.000)
Pesaran CD	9.91*** (0.000)	3.74*** (0.000)

Note: (***) indicate the rejection of the null hypothesis (cross-sectional independance) at 1% level.
Source: authors' calculations.

The results of Pesaran, Ullah, and Yamagata (2008) showed that the p-value was 0.000 and therefore the null hypothesis – there is cross-sectional independence – is rejected at a significance level of 1%. We can conclude that there is a cross-sectional dependence between the series. It is worth noting here that ignoring cross-sectional dependencies introduces significant bias and scale bias (Pesaran 2006), suggesting that examining cross-sectional dependencies is a critical step in analyzing panel data. For the homogeneity test, it was analyzed using the delta tilde test and the adjusted delta tilde provided by Pesaran and Yamagata (2008). According to this test, the null hypothesis tested is the existence or not of heterogeneity in the panel. The results given in Table 2 show that the panel studied is heterogeneous because the hypothesis of homogeneity is rejected since the p-value is zero for the two types of underlying tests.

Table 2. Results of slope heterogeneity test

Eq.1	*Statistic*	*p-Value*
Δ^	7.092***	0.000
Δ^adj	7.882***	0.000
Eq.2	***Statistic***	***p-Value***
Δ^	19.143***	0.000
Δ^adj	21.276***	0.000

Note: (***) indicate the rejection of the null hypothesis (homogenous panel) at 1% level.
Source: authors' calculations.

In light of these test results, the panel unit root test and cointegration test regarding the cross-sectional dependence, accordingly, will be conducted.

Panel unit root test

Before any panel empirical estimation, it is important to test the order of integration of the series studied. In this work, we tried to use three types of test generations Breitung (2000), Choi (2002), Im, Pesaran, and Shin (2002), Levin, Lin, and Chu (2002), and Hadri test of Carrion-i-Silvestre, del Barrio-Castro, and Lopez-Bazo (2005). The results of these different tests are given in the following table (Table 3).

Table 3. Panel unit root tests

Variables	Breitung (2000) t-stat	Levin, Lin, and Chu (2002) t*-stat	Im, Pesaran, and Shin (2002) W-test	Choi (2002) Pm test	Carrion-I-Silvestre, del Barrio-Castro, and Lopez-Bazo (2005) LM(λ)-test	
					Hadri test Homogenous Panel	Heterogeneous Panel
ln*RMU*	1.30 (0.90)	**– 2.46***** (0.006)	– 0.40 (0.34)	– 0.17 (0.57)	– 1.85 (0.97) **[11.34]**	5.06 (0.000) **[37.90]**
Δ(ln*RMU*)	– 3.54** (0.000)	–	**– 8.91***** (0.000)	**21.44***** (0.000)	–	–
ln*GDPC*	4.05 (1.00)	– 0.67 (0.25)	– 1.19 (0.12)	**3.16***** (0.000)	0.932 (0.17) **[16.83]**	2.097 (0.018) **[41.01]**
Δ(ln*GDPC*)	5.24 (1.00)	– 0.13 (0.45)	**– 1.87**** (0.03)	–	–	–
ln*RD*	0.55 (0.71)	**– 2.29***** (0.01)	– 0.92 (0.18)	– 1.66 (0.95)	2.537 (0.006) **[13.07]**	20.751 (0.000) **[32.65]**
Δ(ln*RD*)	– 0.27 (0.39)	–	– 0.56 (0.28)	**14.73***** (0.000)	–	–
ln*GMW*	2.84 (0.99)	2.33 (0.99)	2.06 (0.98)	**1.58*** (0.06)	2.65 (0.004) **[12.569]**	17.553 (0.000) **[32.152]**
Δ(ln*GMW*)	0.76 (0.77)	**– 1.83**** (0.03)	– 0.93 (0.17)	**20.15***** (0.000)	–	–

Notes: For the test of Carrion-i-Silvestre, del Barrio-Castro, and Lopez-Bazo (2005), the number of breaks points has been estimated using LWZ information criteria allowing for a maximum $m^{max} = 5$ structural breaks. The long variance is estimated using the Bartlett kernel with automatic spectral window bandwidth selection as in Andrew (1991). The p-values and bootstrapped critical values are respectively in the brackets. (*), (**), (***) indicate the rejection of the null hypothesis (Unit root) respectively at 10%, 5% level and 1%.
Source: authors' calculations.

Before estimating the long-term relationship for the two models (1) and (2), we examine the stationarity of the variables. Overall, the first and second-generation tests provided respectively by Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003) give

mixed results. Moreover, when we consider the assumption of cross-sectional dependence and the heterogeneity of our panel, the series exhibit their stationarities. As Hurlin and Mignon (2005) noted, the panel is no longer a mere collection of independent individuals, but a structure that can be subject, for example, to the influence of observable or unobservable common factors. Failure to take into account these cross-sectional dependencies can easily lead to a statistical bias. After showing the stationarity of the variables, the next step will be dedicated to examining the long-term relationship for the two models in question.

Panel cointegration test

The long-term analysis is carried out by the cointegration test with cross-sectional dependencies developed by Westerlund (2008) (Cointegration test of Westerlund-Durbin-Hausman 2008) and the test with transversal dependencies and structural breaks (Cointegration tests of Westerlund and Edgerton 2008). The last test takes into account the structural shocks already mentioned previously. These shocks can have an impact on the emission of waste and therefore on the circular economy. Taking them into consideration seems important to us to verify the long- term relationship given the period of analysis which spans between 2000 and 2020 and which is made up of several shocks, in particular the subprime crisis in 2008 and the COVID–19 period. Tables 4 and 5 show the results of the two cointegration tests.

Table 4. Westerlund (2008) Durbin-Hausman Cointegration Test

	DHg group statistics	*DHp* panel statistics
Eq.1	22.850 ***	5.359***
Results	**There's co-integration**	**There's co-integration**
Eq.2	6.501***	4.946***
Results	**There's co-integration**	**There's co-integration**
Critical values		
%1	2.33	2.33
%5	1.645	1.645
%10	1.28	1.28
For group statistics		For panel statistics
H0: No cointegration		H0: No cointegration
H1: Cointegration for all panel		H1: Cointegration for some countries

Note: (***) indicate the significance level at 1% for *DHg* and *DHp tests*.
Source: authors' calculations.

The statistics given for the Durbin Hausman group and the Durbin Hausman panel statistics reported in Table 4 show that the null hypothesis of no cointegration is rejected. We, therefore, conclude that the long-term relationship holds for both equations. Now we conduct the second cointegration test taking into account structural breaks and cross-dependencies. Table 5 gives the results of Westerlund and Edgerton (2008).

Table 5. Westerlund and Edgerton (2008) cointegration tests

	$Z\tau$ (N)		$Z\varphi$ (N)	
	Value	*P-Value*	*Value*	*P-Value*
Equation 1 (with RMU)				
No break	0.223	0.558	– 1.091	0.138
Level break	– 10.644**	0.000	– 7.204**	0.000
Regime shift	– 6.269**	0.000	– 4.109**	0.000
Equation 2 (with GDPC)				
No break	0.323	0.373	– 1.236	0.108
Level break	– 3.723***	0.000	– 1.369***	0.000
Regime shift	– 7.901***	0.000	– 10.163***	0.000

Notes: The test is implemented using the Campbell and Perron (1991) automatic procedure to select the lag length. We use three breaks, which are determined by grid search at the minimum of the sum of squared residuals. The P-values are for a one-sided test based on the normal distribution. The null hypothesis of Westerlund and Edgerton test is non-Cointegration and (*), (**), (***) indicate the rejection of the null hypothesis respectively at 10%, 5% level and 1%.
Source: authors' calculations.

Westerlund and Edgerton (2008) tests clearly show the acceptance of cointegration with cross-sectional dependencies and structural breaks. Moreover, the non-cointegration is not accepted if we consider the two models without structural breaks. This test presents reliability much more than that provided by the first-generation tests which are based for the most part on critical values according to the normal law (Jabri and Brahim 2015).

The two methods of cointegration with dependencies and with dependencies and structural breaks indicate the existence of a long-term relationship between the variables. Therefore, long-term coefficients must also be obtained with the estimation of the parameters.

Estimation of the long-term relationship of the parameters

As the long-term relationship is verified, we will try to estimate the parameters of the models. For this proposal, we will estimate the two equations (1) and (2) by the AMG (Augmented Mean Group), FMLOS (Fully Modified Ordinary Least Squares), DOLS (Dynamic Ordinary Least Squares), and OLS (Ordinary Least Squares with fixed effect). We recall that the AMG method makes estimates by taking into consideration the two hypotheses the cross-sectional dependence and slope homogeneity in the panel.

Table 6. Panel long-run estimators

	AMG	FMOLS	DOLS	OLS-EGLS (fixed effects)
Equation 1 (with RMU)				
lnGDPC	2.69*** (0.000)	1.07*** (0.000)	1.05*** (0.01)	1.01*** (0.000)
lnRD	0.86*** (0.000)	0.34** (0.04)	– 1.87** (0.04)	0.26*** (0.000)
lnGMW	0.26* (0.08)	2.61*** (0.000)	2.56*** (0.002)	2.71*** (0.000)
Common Dynamic Process	0.93*** (0.000)			
Constant	– 26.67*** (0.000)			– 26.08*** (0.000)
Hausman test: p-value				19.60*** (0.000)
Equation 2 (with GDPC)				
lnRMU	0.06*** (0.000)	0.16** (0.02)	0.29*** (0.002)	0.21*** (0.000)
lnRD	0.10*** (0.000)	0.14*** (0.002)	0.15*** (0.007)	0.14*** (0.000)
lnGMW	0.18*** (0.000)	0.10*** (0.000)	0.08*** (0.000)	0.10*** (0.000)
Common Dynamic Process	1.06*** (0.00)			
Constant	9.14*** (0.000)			8.36*** (0.000)
Hausman test: p-value				(103.08)*** 0.000

Notes: Probability values are in brackets. (*), (**), (***) indicate the significance level at 10%, 5% level and 1%.
Source: authors' calculations.

The outcomes of the different estimation methods are presented in table 6. It turns out that the coefficients appear of the same sign for all the estimation techniques. Since our panel is characterized by a cross-sectional dependence and a heterogeneous panel, according to the AMG estimation method, we find that all the coefficients are statistically significant and with their expected signs. Our findings indicate that Economic growth, research and development, and the generation of municipal waste favor the recycling and composting of municipal waste. The recycling of municipal waste has a positive effect on the level of economic growth. If the recycling rate of municipal waste were to increase by 1%, GDP per capita would increase by 0.06%, and when Research and development expenditure were to increase by 1%, GDP per capita would increase by 0.10%. Regarding the Generation of municipal waste per capita (GMW), if it increases by 1%, the economic growth rate increases by 0.18% confirming previous work such as that of Razzaq et al. (2021) which highlighted that the recycling of solid waste municipalities stimulates economic growth. All of these results show that 14-EU countries must pursue their waste recycling policies to achieve economic growth and achieve a level of sustainable development. The last step of the estimation strategy consists in verifying the direction of causality between the variables. To do this, we will perform two causality tests. The first causality test is that of Dumitrescu-Hurlin (2012) between the variables for the whole panel and the second test is that of Kónya (2006) Bootstrap Panel Causality test. The Dumitrescu-Hurlin (2012) test is performed to test Granger causality for heterogeneous panel while the second Kónya (2006) test is applied to take cross-sectional dependence by country and slope heterogeneity features into account.

Panel Causality analysis

The cointegration relationship showed that there is really a long-term relationship between the variables, which also shows the possibility of the existence of a causal relationship between these variables. In this study, we will perform two causality tests: The Dumitrescu-Hurlin (2012) causality test whose null hypothesis to be tested is that of the non-causal relationship against the alternative hypothesis is that of causality between the variables. The Kónya (2006) Bootstrap Panel Causality tests consist in testing cross-section dependence and heterogeneity of the panel countries. The results are indicated respectively in the following Tables 7 and 8.

According to the results of Dumitrescu-Hurlin (2012), we find that there is a bidirectional causal relationship between the recycling rate to level to economic development and between the generation of municipal waste to recycling rate. Contrary to the work of Georgescu, Kinnunen, and Androniceanu (2022), a two-way causality is found from research and development to the recycling rate. Contrary to the work of Georgescu, Kinnunen, and Androniceanu (2022) a double causality is found from research and economic

development to the recycling rate. In addition, a one-way causality from economic development to municipal waste generation and from the level of economic development to research and development.

Table 7. Summary of the Dumitrescu-Hurlin panel causality test

Null hypothesis	Causality	W-stat	Zbar-stat	P-Value
lnRMU > lnGDPC	lnRMU > lnGDPC	1.65	1.06	0.28
lnRMU > lnRD	lnRMU >> lnRD	6.73	2.92	0.003
lnRMU > lnGMW	lnRMU >> lnGMW	2.23	2.3	0.02
lnGDPC > lnRMU	lnGDPC >> lnRMU	2.27	2.39	0.02
lnGDPC > lnRD	lnGDPC >> lnRD	10.34	6.37	0.00
lnGDPC > lnGMW	lnGDPC >> lnGMW	2.08	2.00	0.04
lnGMW > lnRMU	lnGMW >> lnRMU	1.91	1.64	0.10
lnGMW > lnGDPC	lnGMW > lnGPDC	0.57	– 1.17	0.24
lnGMW > lnRD	lnGMW >> lnRD	2.23	2.31	0.02
lnRD > lnRMU	lnRD >> lnRMU	6.20	2.42	0.01
lnRD > lnGMW	lnRD >> lnGMW	3.74	5.45	0.00
lnRD > lnGPDC	lnRD > lnGPDC	2.48	– 1.28	0.26

Notes: The null hypothesis of Dumitrescu-Hurlin test is non-Causality. Probability values are in brackets. (*), (**), (***) indicate the rejection of the null hypothesis respectively at 10%, 5% level and 1%. >: No Causality and >>: Causality).
Source: authors' calculations.

These last results can be interpreted as follows. The more economic activity there is, the more municipal waste will be generated. In turn, the level of economic development favors research and development in these countries taken as a whole. We are now trying to verify these results by country by running the Kónya test (2006). The results are reported in Table 8.

Table 8. Kónya (2006) Bootstrap Panel Causality test

Country	RMU→DPC	RMU→RD	RMU→GMW	GDPC→RMU	GDPC→RD	GDPC→GMW
France	1.22 (0.30)	2.47 (0.59)	1.20 (0.28)	2.64 (0.11)	0.67 (0.41)	0.0005 (0.98)
Germany	2.74 (0.20)	0.66 (0.46)	0.008 (0.92)	2.61 (0.13)	1.20 (0.27)	0.42 (0.52)
Spain	6.74 (0.000)	0.25 (0.59)	0.25 (0.64)	0.08 (0.77)	0.89 (0.34)	0.08 (0.77)

Country	RMU→DPC	RMU→RD	RMU→GMW	GDPC→RMU	GDPC→RD	GDPC→GMW
Nether-lands	0.04 (0.80)	0.92 (0.38)	**4.78** (0.04)	1.80 (0.19)	1.12 (0.29)	0.85 (0.36
Belgium	1.22 (0.20)	2.37 (0.16)	0.57 (0.47)	1.68 (0.19)	0.56 (0.45)	0.68 (0.41)
Finland	0.40 (0.60)	**6.32** (0.02)	0.86 (0.77)	1.25 (0.27)	1.12 (0.29)	1.04 (0.30)
Portugal	0.16 (0.50)	0.98 (0.48)	0.04 (0.84)	1.35 (0.25)	0.05 (0.87)	0.53 (0.47)
Czech Rep.	1.42 (0.50)	0.28 (0.66)	0.01 (0.91)	2.22 (0.16)	0.38 (0.53)	0.20 (0.65)
Estonia	**2.76** (0.10)	0.25 (0.63)	0.03 (0.96)	0.73 (0.40)	0.004 (0.94)	0.03 (0.85)
Cyprus	2.86 (0.10)	2.65 (0.11)	**7.90** (0.006)	0.27 (0.62)	0.002 (0.96)	1.14 (0.28)
Hungary	0.03 (0.80)	2.65 (0.27)	0.001 (0.99)	0.06 (0.80)	1.40 (0.24)	2.22 (0.14
Poland	5.70 (0.10)	**3.65** (0.06)	0.03 (0.86)	**4.47** (0.04)	**4.19** (0.04)	0.35 (0.55
Slovenia	1.18 (0.50)	1.77 (0.24)	0.82 (0.42)	1.62 (0.63)	0.43 (0.51)	0.004 (0.94)
Slovakia	5.27 (0.40)	1.19 (0.30)	**11.05** (0.02)	2.08 (0.16)	0.17 (0.68)	0.48 (0.49)

Note: (*), (**), (***) indicate the rejection of the null hypothesis (non-Causality) respectively at 10%, 5% level and 1%. →: Direction of causality.
Source: authors' calculations.

Table 8. Kónya (2006) Bootstrap Panel Causality Test Result (continued)

Country	RD→RMU	RD→GDPC	RD→GMW	GMW→RMU	GMW→GDPC	GMW→RD
France	**2.86** (0.09)	**4.47** (0.03)	1.80 (0.18)	0.62 (0.43)	1.03 (0.31)	0.13 (0.72)
Germany	**3.58** (0.06)	**11.93** (0.000)	0.03 (0.85)	2.16 (0.14)	**3.96** (0.05)	4.34 (0.04)
Spain	**9.37** (0.002)	**22.86** (0.000)	1.51 (0.22)	0.19 (0.66)	0.08 (0.77)	**14.49** (0.000)
Netherlands	2.47 (0.11)	1.30 (0.25)	**12.98** (0.000)	0.04 (0.84)	0.21 (0.65)	0.94 (0.33)
Belgium	**6.35** (0.01)	**9.08** (0.002)	0.29 (0.58)	0.32 (0.57)	0.66 (0.41)	16.44 (5.03)
Finland	1.62 (0.20)	0.69 (0.41)	1.03 (0.31)	**4.29** (0.04)	**3.53** (0.06)	**3.03** (0.08)

Country	RD→RMU	RD→GDPC	RD→GMW	GMW→RMU	GMW→GDPC	GMW→RD
Portugal	0.61 (0.44)	**6.45*** (0.01)	1.32 (0.25)	0.96 (0.33)	6.41 (0.01)	0.03 (0.86)
Czech Rep.	**3.08*** (0.08)	1.70 (0.92)	0.82 (0.36)	**4.83**** (0.03)	**7.80***** (0.005)	2.14 (0.14)
Estonia	0.96 (0.33)	0.48 (0.49)	1.50 (0.22)	0.008 (0.93)	0.03 (0.87)	1.34 (0.25)
Cyprus	0.03 (0.87)	0.70 (0.40)	0.15 (0.70)	7.77 (0.005)	0.66 (0.42)	**5.39**** (0.02)
Hungary	1.63 (0.20)	1.48 (0.22)	2.27 (0.13)	2.57 (0.11)	0.04 (0.84)	1.25 (0.26)
Poland	**5.36**** (0.02)	**19.39***** (0.000)	1.17 (0.28)	4.98 (0.02)	**3.85**** (0.05)	1.02 (0.31)
Slovenia	0.47 (0.49)	2.67 (0.10)	**4.12**** (0.04)	1.64 (1.20)	0.67 (0.41)	1.53 (0.22
Slovakia	**2.82*** (0.09)	**3.60*** (0.06)	2.22 (0.14)	0.76 (0.38)	0.20 (0.65)	0.28 (0.60)

Note: (*), (**), (***) indicate the rejection of the null hypothesis (non-Causality) respectively at 10%, 5% level and 1%.

→: Direction of causality.
Source: authors' calculations.

According to the findings presented in Table 8, the null hypothesis of non-causality from the RMU to GDPC is rejected in one country (Estonia) of the 14 EU countries in the panel. This result may suggest that the other European countries in the panel should promote the recycling rate to achieve development sustainability. When the causality is analyzed from the RMU to RD and from the RMU to GMW, the non-causality is only found in 2 and 3 countries respectively. Moreover, the causality from GDPC to RD is found in the Poland case. Furthermore, there is causality from RD to RMU in France, Germany, Czech Republic, and Slovakia at a 99% significance level and in Spain, Belgium, and Poland at a 95% significance level. This explains that spending on research and development can play an important role in improving the recycling rate in these countries. The non-causality from RD to GDPC is rejected in 7 EU and from RD to GMW is causal relationship is accepted only in 2 EU countries. Concerning the causality from GMW to RMU, it is accepted in 2 EU, and from GMW to GDPC this causality is accepted only in 4 EU countries. Finally, the non-causality from GMW to RD is rejected in 3 EU countries.

Conclusion

This study examines the relationship between the circular economy and economic development in a panel of 14 European countries over the period 2000–2020. To do this, we have tried to emphasize the importance of taking into account the features of the panel, in particular cross-sectional dependence and heterogeneity. To the authors' knowledge, this is the first research study on the relationship between the circular economy and economic development by considering these two crucial assumptions in the panel analysis. Furthermore, previous studies investigating the relationship between circular economy and economic development overlook these two important assumptions which, according to Pesaran (2006), lead to significant biases and distortions. Similarly, we have tried to consider the structural shocks that play an important role in the implementation of the circular economy in the service of economic development. According to the cointegration methods of Westerlund (2008) and Westerlund and Edgerton (2008), we have shown that there is a long-term relationship in the two models. For the entire panel and considering only the heterogeneity of the panel (Dumitrescu-Hurlin 2012), the results indicate causal relationships between the variables. Moreover, by using the causality test with cross-sectional dependencies and heterogeneity (Kónya 2006), the causal relationship between the variables is not verified for some countries. This can allow us to assume that these countries should take adequate measures to improve the rate of recycling by improving clean technologies, creating economic growth, and achieving sustainable development respectful of the environment. Using AMG estimation which takes into account cross-sectional dependence and panel heterogeneity, we found that all parameters have their expected signs. Several reasons can explain these different cross-correlations such as the omission of common factors, spatial spillovers, and interactions within socio-economic networks (Pesaran and Tosetti 2011). In comparison with the other estimation methods (FMOLS, DOLS and OLS-EGLS with fixed effects) the parameters emerge with the same expected signs. From the first equation, we find that the level of development, R&D expenditures as well as municipal waste, have a positive effect on the recycling rate. In the second equation, the rate of recycling, R&D expenditures as well as municipal waste have a positive effect on the level of economic development. From these results, it appears that technological development promotes economic growth but not the quality of the environment. As a result, the countries studied must therefore take adequate measures to accelerate the rate of waste recycling by introducing environmentally friendly technologies. The use of these technologies can reduce the generation of waste and therefore a positive effect on sustainable development.

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Rola gospodarki o obiegu zamkniętym w rozwoju gospodarczym: badanie empiryczne dla panelu wybranych gospodarek europejskich

W artykule przeanalizowano związek między gospodarką o obiegu zamkniętym a rozwojem gospodarczym w 14 krajach UE w latach 2000–2020.

W porównaniu z poprzednimi pracami autorzy podkreślają znaczenie uwzględnienia wzajemnych zależności i niejednorodności pomiędzy krajami wchodzącymi w skład panelu. Co więcej, relacja kointegracji zastosowana w tej pracy uwzględnia wstrząsy strukturalne i wzajemne zależności dzięki zastosowaniu testu Westerlunda i Edgertona. Test ten pozwolił na walidację długoterminowej zależności w modelu. W badaniu wykorzystano technikę rozszerzonej grupy średniej w celu przezwyciężenia niektórych problemów ekonomicznych. Wykorzystanie bootstrapowej panelowej analizy przyczynowości Kónya pozwoliło na stwierdzenie, że związek przyczynowo-skutkowy występuje tylko w kilku krajach.

Przeprowadzona analiza empiryczna wskazuje, że wzrost gospodarczy, badania i rozwój oraz wytwarzanie odpadów komunalnych sprzyjają recyklingowi i kompostowaniu odpadów komunalnych. W ten sam sposób recykling odpadów komunalnych, wydatki na badania i rozwój oraz wytwarzanie odpadów komunalnych pozytywnie wpływają na tempo wzrostu gospodarczego.

Uzyskane wyniki badań empirycznych mają istotne implikacje dla 14 krajów UE, które muszą podjąć odpowiednie działania w celu zwiększenia poziomu recyklingu za pomocą technologii przyjaznych dla środowiska, aby osiągnąć poziom zrównoważonego wzrostu i rozwoju. W porównaniu z poprzednimi badaniami niniejszy artykuł ma na celu wypełnienie luki w dotychczasowych badaniach i wzbogacenie istniejącej literatury na temat gospodarki o obiegu zamkniętym i jej związku z rozwojem gospodarczym w Europie.

Słowa kluczowe: gospodarka o obiegu zamkniętym, rozwój gospodarczy, zależności przekrojowe i niejednorodność, analiza panelowa kointegracji, rozszerzona grupa średnia, analiza panelowa przyczynowości

Comparative Economic Research. Central and Eastern Europe
Volume 27, Number 4, 2024
https://doi.org/10.18778/1508-2008.27.36

Alternative Fuels as a Sustainable Innovation in Vehicle Fleet Across the EU–27: Diagnosis and Prospects for Development

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Abstract

The deployment of alternatively fueled (AF) vehicles constitutes an important measure in meeting the European Union's (EU's) climate goals. The study aims to characterize and evaluate, in a comparative manner, the current stage of the adoption of AF passenger cars into the general (M1) passenger car fleet in the EU member states. The focal point of the study is the exploration of similarities and differences observed between the EU countries regarding the current structure of AF passenger car fleets, as well as development trends in this area. In this context, a clear scheme of "two speeds" emerges – parallel to the rapid diffusion of electric vehicles in the Nordic and Western European countries, the size and structure of the AF M1 vehicle stock remained largely unchanged in the Central-European countries, with the dominant role of widely established liquified petroleum

Received: 28.01.2024. Verified: 8.04.2024. Accepted: 24.09.2024

gas (LPG). The findings highlight the need to diversify the range of alternative fuels, which should be introduced gradually, in line with the classification proposed by the European Parliament and the Council.

Keywords: alternative fuels, sustainable innovation, sustainable development, passenger car fleet, EU–27, environment

JEL: O33, O57, Q01, Q42, Q55

Introduction

Over the past few decades, an increasing number of governments worldwide have declared a policy to transition towards a zero-emission environment. In Europe and the European Union of the 27 member states (EU–27), the goal of a carbon-neutral continent is to be achieved by 2050. A significant portion of Europe's greenhouse gas emissions originates from the transport industry, especially road transport: fuels in passenger and private cars, buses used in public transportation, and trucks used for business purposes. Therefore, the basic logic adopted by the global leaders so far is that to strengthen the efforts to achieve the goal of a zero-pollution environment, the fossil fuels still used in the motor fleet, such as oil and gasoline, should be replaced. The revolution that is already taking place in technology also includes the possibility of using alternative, more sustainable types of fuels in new engines that are already being designed and put into production for the manufacture of cars with modern technology. According to the European Commission's "2050 Long-term Climate Strategy" (European Environment Agency 2020), there is no single fuel solution for the future of low-emission mobility, but all main alternative fuel options are likely to be required, to different extents, in each of the transport modes (European Alternative Fuels Observatory n.d., *Alternative*…). The existence and availability of new types of fuels is the main challenge that needs to be addressed effectively and continuously to enable a sustainable transition to a society that will not pollute the environment in the same way as in the past, but instead, one that has taken a big step in the direction of sustainable development for the future of humanity.

Achieving climate neutrality by 2050 through the use of alternative fuels in transport requires the active participation of each member state, coordinated and supervised at an institutional level. Under the current legislative framework, by January 1, 2024, each Member State of the EU–27 was required to prepare and submit to the European Commission an interim national policy framework for the market development of alternative fuel infrastructure in the transport sector and the installation of the relevant infrastructure. On that basis, the European Commission will be able to issue recommendations to each member state within six months. These recommendations are expected to focus on the degree of ambition of the goals and objectives necessary to fulfill the obligations, as well as the policies and measures linked to the objectives and purposes of each

member state. Each Member State must take due account of the recommendations it receives from the European Commission for its national policy frameworks. Consequently, by January 1, 2025, each Member State is obliged to notify the European Commission of its definitive national policy framework.

Given their pivotal role in the European Union's (EU's) (and also global) climate policy, alternative fuels are at the center of research and science that explores the possibilities of production, storage, disposal, and consumption by end-users in a value chain that will contribute achieving zero-emission of exhaust gases into the atmosphere. The rate of adoption of alternatively fueled (AF) fleets is monitored and publicly reported through multiple institutions at both national and international levels. In this context, the European Alternative Fuels Observatory serves as the most comprehensive reference point. It consolidates data from both general sources (i.e., Eurostat, the European Commission's Mobility and Transport Department, the Urban Mobility Observatory, and the European Environment Agency) and country-specific ones (i.e., governmental sources, transport departments, local automotive associations). Periodic reports and occasional publications on the most recent developments in the auto industry on an international scale are also published by, inter alia, the European Automobile Manufacturers' Association and the International Energy Agency, with a strong emphasis on electric mobility.

The study aims to synthesize and evaluate, in a comparative manner, the current stage of adoption of AF passenger cars into the passenger car stock (M1) in the EU member states. It offers an alternative perspective on the issue. The emphasis is on the structure of the AF passenger car fleet, and the specific types of fuels are assessed based on their contribution to the overall growth or decrease of the AF M1 fleet as a whole. The relevant trends, market shares, and progression of the structure of AF car fleets are analyzed and internationally compared within a two-group framework, with countries divided according to the alternative fuel of primary use (electric/hybrid; transitional).

The article is structured as follows. After the introduction, which provides the general context of the study, the "Theoretical background" section defines and characterizes the alternative fuels utilized in the transport sector and briefly outlines their sustainable properties. The subsequent part ("Research method") presents the data sources and limitations, as well as a more detailed description of the analytical framework. Section four, the "Results", consists of three parts, where the development of the AF passenger car fleet is presented at different levels of aggregation – for the EU–27 as a whole and two previously identified groups: Group 1 (highest level of electrification) and Group 2 (lowest level of electrification). The main findings of the study are summarized in the "Conclusion" section.

Theoretical background

Based on the Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure and repealing Directive 2014/94/EU of the European Parliament and of the Council COME/2021/559 (European Commission 2021), alternative fuels are defined as fuels or power sources that serve as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to decarbonization and enhance the environmental performance of the transport sector. In that sense, alternative fuels can be described as sustainable innovation, defined as the newly developed products, processes, and technologies aimed to meet the market's needs with the capacity to generate positive social and environmental impacts (Cillo et al. 2019; Adomako and Nguyen 2023)[1]. Importantly, the positive effects of alternative fuels in relation to the environment and the associated economic consequences are indicated by the literature (Breitkreuz, Menne, and Kraft 2014; Martin, Larrazabal, and Perez-Ramirez 2015; Kumar 2020; Farghali et al. 2023; Liu 2023), although research is still being conducted on this topic.

A brief and basic description of the chosen type of alternative fuel is given below, along with the main characteristics and the important parameters that frame each one (Alternative Fuels Data Center n.d., *Alternative…*). There are eight types of alternative fuels (European Council for an Energy Efficient Economy 2023):

- electricity,
- hydrogen,
- ammonia,
- biofuels,
- synthetic and paraffinic fuels,
- natural gas, including biomethane, in gaseous form (compressed natural gas – CNG),
- liquefied natural gas (liquefied natural gas – LNG),
- liquefied petroleum gas (LPG).

They are classified into three categories: alternative fossil fuels for a transitional phase (CNG, LNG, LPG, synthetic and paraffinic fuels produced from non-renewable energy), alternative fuels for zero-emission vehicles (electricity, hydrogen, ammonia),

1 Therefore, sustainable innovation is associated with the broader concept of sustainability (Basiago 1995; DesJardins 2015) and examined within its three dimensions: economic, social, and environmental (Nasiri et al. 2022).

and renewable fuels (biofuels – biomass fuels and biofuels) (European Alternative Fuels Observatory n.d., *Alternative*…).

Electricity can be used to power electric vehicles, which are increasingly available. In general, the market contains three types of electric vehicles: a) battery electric vehicles (BEVs), b) plug-in hybrid electric vehicles (PHEVs), and c) hybrid electric vehicles (HEVs). All use electricity to improve vehicle efficiency, while some of them still use liquid fuels in conjunction with electricity (EVgo n.d.).

BEVs are fully electric vehicles with rechargeable batteries and no gasoline engine. The energy required for the car is produced from a battery pack, which is recharged from the grid. BEVs are zero-emission vehicles, and they do not generate any harmful emissions.

PHEVs have both an engine and an electric motor to drive the car. They can recharge their batteries through regenerative braking, which recoups energy that is otherwise lost in braking to assist the gasoline engine during acceleration. Their main difference from hybrids is that they have a much larger battery and can plug into the grid to recharge. PHEVs can travel approximately 10–50 kilometers before their gas engines come into operation, and then they run as regular hybrids and can travel several hundred kilometers on a tank of gasoline.

Like PHEVs, HEVs have both a gas-powered engine and an electric motor, and the energy that is required for the battery is produced by regenerative braking. However, unlike PHEVs, HEVs cannot plug into the grid to recharge.

Hydrogen is seen as one of the most promising fuels that can contribute to achieving a zero-carbon economy. It is abundant in the environment, and it is stored in water, hydrocarbons (such as methane), and other organic matter. One of the main challenges seems to be having available hydrogen as a fuel that can be efficiently extracted from these compounds. At the same time, hydrogen's energy content by volume is low, which creates problems with its storage and related conditions as it requires high pressures, low temperatures, or chemical processes to be stored properly. It is very important to overcome such obstacles since, for light-duty vehicles, there is a limited size and weight capacity for fuel storage. As per the existing market situation, light-duty fuel cell electric vehicles (FCEVs) can be fueled up at retail stations in less than five minutes and obtain a driving range of more than 400 kilometers distance (Alternative Fuels Data Center n.d., *Hydrogen*). Hydrogen production from fossil fuels emits a lot of carbon dioxide, but using renewable energy sources (hydropower, wind power, and photovoltaic) provides a nonpolluting alternative (Luo et al. 2020).

The use of ammonia as a fuel is not recent, but its importance has recently increased due to the possibility of decarbonizing various specific sectors. Ammonia is a molecule with the chemical formula NH3. In internal combustion engines (ICE), ammonia

efficiency improves when it is blended with other fuels. Doping ammonia with other fossil fuels (especially diesel) is the most technically efficient option, reducing CO_2 and NOx emissions (European Alternative Fuels Observatory n.d., *Alternative*…). Ammonia has several favorable attributes, the primary one being its high capacity for hydrogen storage (Thomas and Parks 2006).

Biofuels mean "biomass fuels" – gaseous and solid fuels produced from biomass. Biodiesel is considered a renewable fuel that is produced from animal fats, vegetable oils, and recycled cooking grease. It can be used in vehicles that consume diesel as a fuel. Biodiesel feedstocks can be categorized into several groups (Huang, Zhou, and Lin 2012):

- oil crops, including soybeans,
- oil trees, including pistachio and palm oil,
- other animal fat, waste oil food.

In particular, fatty acid methyl ester is of great importance as the raw materials used for its production are natural and renewable. All these types of biodiesels come either from vegetables or animal fat, and thus, they are biodegradable and non-toxic. The feedstock of biodiesel depends heavily on climate and local soil conditions, and because of that, different geographical regions align their intentions with different types of oil. For example, soybean oil is mainly used as a raw material in the US, while Germany uses mostly rapeseed oil.

Renewable diesel is a biomass-derived transportation fuel suitable for use in diesel engines. Its production is different from that of conventional biodiesel, allowing it to serve as a drop-in fuel where biodiesel blending is required. In addition, if waste feedstocks such as used cooking oil or animal fats are used, renewable diesel can offer significant CO_2 emissions reductions, qualifying it as a 2nd generation or advanced biofuel (IDTechEx n.d.). Recent fuel regulations support the production of renewable diesel from bio-feedstocks. However, one of the current issues with renewable diesel from vegetable oils and fats is the high level of n-paraffins, which leads to the careful selection of the right process technology to meet diesel cold flow specifications. The latest research shows that proper process technologies are being developed to produce renewable diesel from bio-feedstocks, offering refiners sustainable renewable diesel production options that align with seasonal product specifications (ExxonMobil n.d.).

Synthetic and paraffinic fuels are liquid fuels that typically have the same properties as fossil fuels and can be used in the same way as fossil fuels (No. 2019). The main difference between fossil and synthetic fuels is how they are produced: fossil fuels are formed over millions of years underground from organic matter that is turned into coal, natural gas, or oil. Synthetic fuels are produced by mimicking these natural processes using renewable resources. The production of synthetic fuels requires syngas, which is a mixture

of hydrogen (H) and carbon monoxide (CO). Turning syngas into fuel is an established industrial process where coal and natural gas are used as feedstocks. However, the main challenge is to produce syngas sustainably, which requires a large amount of energy from renewable resources, such as biomass, solar, wind, or hydro.

Compressed natural gas (CNG) technology has reached maturity for the general market. Natural gas is available and produced in specific geographical areas and can be supplied through an extensive natural gas distribution system. It is a ready-to-use fuel that is considered a clean-burning alternative fuel that must be compressed or liquefied for use in vehicles.

Natural gas vehicles (NGVs) are very similar to conventional vehicles in terms of performance. However, their share in the car market is much less than that of conventional vehicles such as gasoline and diesel vehicles because the main obstacle with natural gas is that less energy content can be stored in the same size tank. In heavy-duty vehicles, compression-ignited engines are slightly more fuel-efficient than spark-ignited natural gas engines. A dual-fuel engine increases the complexity of the fuel-storage system as it needs more storage of both types of fuel and the integration of diesel aftertreatment devices (Alternative Fuels Data Center n.d., *Natural*…).

Ethanol (CH_3CH_2OH) is a clear, colorless liquid, and it is considered a renewable fuel that is made from starch- or sugar-based feedstocks, such as corn grain (mainly in the United States), sugar cane (mainly in Brazil), or cellulosic feedstocks (i.e., wood chips or crop residues). It is also known as ethyl alcohol, grain alcohol, and EtOH. Ethanol has a higher octane number than gasoline, providing premium blending properties. Lower-octane gasoline can be blended with 10% ethanol to reach the standard 87 octane. It can be used in vehicles as a fuel in a blended form that contains both gasoline and diesel and ethanol's impact on fuel economy is dependent on the ethanol content in the fuel and engine specification (Alternative Fuels Data Center n.d., *Ethanol*…).

Propane is also well known as liquefied petroleum gas (LPG) or propane autogas, and has been used as vehicle fuel for several decades. There is quite a good variety of medium- and heavy-duty propane vehicle models that are already available on the market through original equipment manufacturers (OEMs). Propane is available for light- and medium-duty vehicles as they are designed to handle propane's higher temperatures and lower lubricity (Alternative Fuels Data Center n.d., *Propane*…).

It is important to understand that not all alternative fuels are fully sustainable since the term is mainly used to refer to all unconventional and untraditional energy sources. A typical example is gas – either in the form of natural gas or liquefied natural gas (LNG) – a fossil fuel that produces fewer greenhouse gas emissions and has a role to play in the energy transition in the short term. In the long run, however, alternative fuels

must be truly sustainable, and for that, they need to be produced from renewable sources that do not harm the environment (DHL n.d.).

The types of alternative fuels and their features affecting sustainable development are summarized in Table 1.

Table 1. Alternative fuels as sustainable innovation

Type of alternative fuels	Features of sustainable innovation
Electricity	– Supplied by electricity from the grid, coming increasingly from low-CO_2 energy sources – Emits no pollutants or noise
Hydrogen	– It is considered an alternative fuel for zero-emission vehicles – It is a zero-emissions alternative fuel produced from diverse energy sources – It is abundant in the environment
Ammonia	– No carbon emissions at the point of use – More energy-efficient to transport than hydrogen
Biofuels	– Renewable, biodegradable – Replacing fossil fuels with biofuels has several benefits in contrast to fossil fuels, which are exhaustible resources, while biofuels are produced from renewable feedstocks
Synthetic and paraffinic fuels	– They are considered alternative fossil fuels for a transitional phase – They are fully compatible with the existing global fuel infrastructure, and they can be used in conventional internal combustion engines – Renewable synthetic fuels are generally seen as a solution to decarbonize, in particular, those transportation sectors that cannot be electrified
Natural Gas	– It is considered an alternative fossil fuel for a transitional phase – Using natural gas will help reduce the amount of harmful emissions released into the atmosphere. – It is non-toxic, non-corrosive, and non-carcinogenic and can be used in spark-ignited internal combustion engines, like traditional fossil fuels, without being a threat to soil, surface water, or groundwater
Liquefied Petroleum gas (LPG)	– It is considered an alternative fossil fuel for a transitional phase – LPG is stored, shipped, and transported in tanks or cylinders – Primary uses for LPG include powering heating appliances and cooking equipment, as well as fueling vehicles
Liquefied natural gas (LNG)	– It is considered an alternative fossil fuel for a transitional phase – LNG is stored and shipped in purpose-built cryogenic tanks, and thus, LNG is sometimes not a viable option in many developing nations

Source: own elaboration.

Materials and methods

Scope of the study

The study aims to characterize and evaluate the current stage of adoption of AF passenger cars in the passenger car stock (M1) in EU member states. As the study emphasizes the heterogeneity of fuels considered a substitute for fossil oil sources, they were analyzed following the classification provided in the previously mentioned "Proposal for a regulation…", which includes three groups (European Commission 2021):

1. Alternative fuels for zero-emission vehicles: electricity, hydrogen, and ammonia.
2. Renewable fuels: biomass fuels and biofuels as defined in Article 2, points (27) and (33) of Directive (EU) 2018/2001; synthetic and paraffinic fuels, including ammonia, produced from renewable energy.
3. "Alternative fossil fuels" for a transitional phase: natural gas, in gaseous form (compressed natural gas (CNG)) and liquefied form (LNG); LPG; synthetic and paraffinic fuels produced from non-renewable energy.

In practice, the original classification could not be fully employed due to limited data availability, especially in relation to renewable fuels. The most consistent, internationally comparable data could be gathered from the database of the European Alternative Fuels Observatory, which constitutes *a key information support tool for the European Commission in the implementation process of Directive 2014/94/EU* (European Alternative Fuels Observatory n.d., *About…*). By default (apart from individual data shortages – see Table 2), the platform provides a detailed annual breakdown of the alternative vehicle fleet utilizing six types of alternative fuels (BEV, PHEV, H2, LPG, CNG, LNG) from 2009 to 2022. Consequently, the initial classification was transformed into binary form, with two categories:

1) alternative fuels for zero-emission vehicles: BEVs, PHEVs, and hydrogen (H);
2) 'alternative fossil fuels' for a transitional phase: LPG, LNG, and CNG.

In terms of vehicle fleet, the EAFO database presents data in line with the standards developed by the United Nations Economic Commission for Europe (UNECE), which includes passenger cars (M1), light commercial vehicles (N1), buses (M2 & M3), and trucks (N2 & N3)[2]. To preserve conciseness and clarity of information, the study focuses only on one, dominant vehicle class – M1. During the research period, it equaled 95.78% of the AF vehicle stock and had the biggest impact on the reduction

2 The full breakdown of the vehicle categories is presented in "Consolidated Resolution on the Construction of Vehicles (R.E.3)", (United Nations Economic Commission for Europe 2023).

of carbon emissions from road transport.[3] For the same reason, the study evaluates the changes within the total stock of M1 vehicles, leaving aside market share shifts pertaining to new registrations.

Table 2. Data availability concerning the passenger car fleet (M1)

	First obs.	Last obs.		First obs.	Last obs.
Austria	2011	2022	Italy	2009	2022
Belgium	2009	2022	Latvia	2010	2022
Bulgaria	2009	2022	Lithuania	2009	2022
Croatia	2009	2022	Luxembourg	2013	2022
Cyprus	2013	2022	Malta	2012	2022
Czechia	2009	2022	Netherlands	2009	2022
Denmark	2012	2022	Poland	2009	2022
Estonia	2012	2022	Portugal	2010	2022
Finland	2012	2022	Romania	2009	2022
France	2013	2022	Slovakia	2009	2022
Germany	2009	2022	Slovenia	2009	2022
Greece	2009	2022	Spain	2013	2022
Hungary	2009	2022	Sweden	2009	2022
Ireland	2012	2022			

Source: own elaboration, based on EAFO Database (European Alternative Fuels Observatory 2023).

Analytical framework

The current stage of development of the AF passenger car fleet (M1) in the EU–27 was diagnosed using a two-stage analytical framework. In the first step, the market shares of AF vehicles were analyzed to evaluate the collective progress of the European Community in its pursuit of a (more) sustainable road transport sector. The analysis starts with an overview of the current state of adoption of an alternative fleet, represented by the share of AF vehicles in the total passenger car stock (M1) at the end of the research period (2022). The descriptive, static approach is followed by an evaluation of changes concerning the abovementioned ratio observed over the research period (2009–2022). Both stages of the investigation consider the AF fleet at three levels

3 A detailed description of the M1 category reads as "Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat" (United Nations Economic Commission for Europe 2023). The percentage is derived from our calculations based on the EAFO database.

of aggregation: fully aggregated (total), semi-aggregated (zero-emission/transitional), and disaggregated (BEV, PHEV, H2, LPG, CNG, LNG).

The second stage analyzed individual differences between the countries in terms of the development of an alternative fleet of passenger cars. The main focus was on the degree of electrification of the AF M1 car fleet in a given country at the end of the research period, expressed through the ratio of cars utilizing the "alternative fuels for zero-emission vehicles" in relation to "alternative fossil fuels for a transitional phase". Two groups were then created:

1) countries with a dominant share (50% or more) of passenger cars that utilize "alternative fuels for zero-emission vehicles" in the total AF M1 vehicle stock;
2) the remaining countries, where the main alternative fuels constitute "alternative fuels for a transitional phase".

In the next step, the groups were examined in terms of the current relative size of the AF vehicle fleet, its structure, and growth over time, as well as the sources of the overall growth or decrease in the AF M1 fleet. The study is not intended to provide in-depth explanations for the identified trends, and only general, publicly accessible explanations are given to signal the potential directions for further research.

Results, discussion, and implications

The alternatively fueled passenger car fleet of the EU–27

In 2022, vehicles powered by alternative fuels accounted for 5.75% of the total EU–27 M1 passenger car fleet. Despite progress in electrifying road transport, at the end of the research period, the majority (60.75%) of AF M1 fleets still utilized fuels "for a transitional phase" – primarily LPG and CNG as an alternative. The use of LNG could be described as marginal, as it has been statistically demonstrated only in Lithuania and the Netherlands. Nearly all the clean-energy vehicle stock comprised one of the two variants of electric cars – BEVs or PHEVs, with a balanced ratio and similar growth rates (Table 3). As of 2022, hydrogen (H2) could not be considered a significant alternative energy source, as it was used in only 0.002% of passenger cars.

Table 3. Development of AF passenger car fleet within the M1 vehicle stock in the EU–27 (%)

	BEV	PHEV	H2	LPG	CNG	LNG	AF fleet (Total)	Share (1)	Share (2)
2013	0.021	0.015	0.000	3.068	0.417	–	3.520	98.998	1.002
2014	0.034	0.025	0.000	3.087	0.445	–	3.592	98.358	1.642
2015	0.052	0.055	0.000	3.103	0.464	–	3.674	97.073	2.927

	BEV	PHEV	H2	LPG	CNG	LNG	AF fleet (Total)	Share (1)	Share (2)
2016	0.071	0.081	0.000	3.099	0.467	–	3.718	95.909	4.091
2017	0.103	0.107	0.000	3.048	0.468	–	3.726	94.361	5.639
2018	0.155	0.144	0.000	3.142	0.478	–	3.920	92.363	7.637
2019	0.249	0.194	0.000	3.131	0.486	–	4.060	89.070	10.930
2020	0.450	0.385	0.001	3.069	0.492	0.000	4.397	80.989	19.011
2021	0.800	0.731	0.001	3.034	0.483	0.000	5.050	69.659	30.341
2022	1.189	1.066	0.002	3.011	0.482	0.000	5.750	60.748	39.252

Explanatory notes:

Share (1) of the AF passenger car stock (M1) that utilizes "alternative fuels for a transitional phase".

Share (2) of the AF passenger car stock (M1) that utilizes "alternative fuels for zero-emission vehicles".

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

Between 2013 and 2022, the EU–27 stock of AF passenger cars grew by 63.34%, from 3.52% to 5.75% of the total M1 fleet. Although the growth was generally consistent, it was hardly noticeable from 2013 to 2017, when the relative size of the AF fleet was almost entirely determined by the prevalence of its major components – LPG and CNG-fueled vehicles, which remained steady over the research period. This trend was ended by the rapid growth of BEV and PHEV fleets in recent years (mainly after 2019), which resulted in a 2.26% share of the clean-energy fleet in total M1 stock in 2022 (Figure 1).

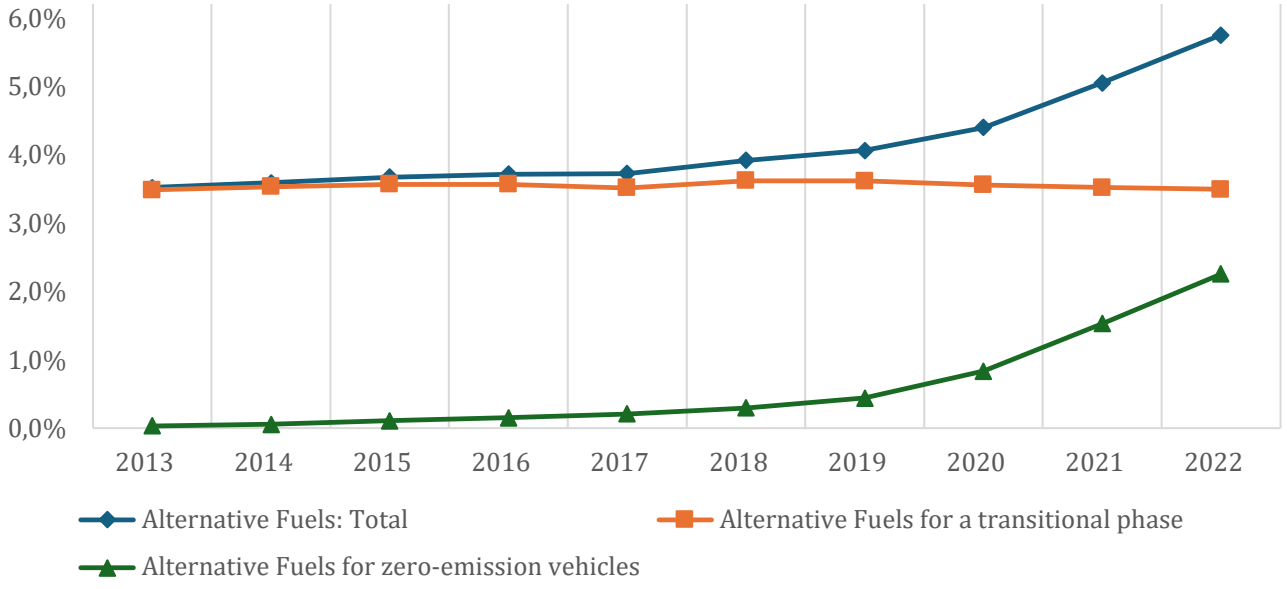

Figure 1. Visual presentation of growth in alternatively fueled passenger car fleet within the M1 vehicle stock in the EU–27

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

Group 1 – countries where zero-emission alternative fuels (BEV, PHEV, H2) play a predominant role

Given the steady share of passenger cars that use transitional fuels, the growth of AF M1 stock was determined by the speed of its electrification. At the end of the research period, the electric (BEV) and hybrid (PHEV) passenger cars were the leading AF fleets in 15 of the 27 EU member states, comprised mainly of Nordic and Western European countries (Table 4). The ratio of 84.16% to 15.84% indicates an advanced stage of the process, which was characterized by extraordinary dynamism. For the vast majority of the countries in Group 1, the proportion of transitional to clean-energy fuels fully reversed over less than a decade, which is illustrated in Figure 2. The turning point came in 2019 when, following Regulation (EU) 2019/631, the EV fleet finally outnumbered gas-powered vehicles. This began a rapid (exponential) growth phase, which led to a share of 3.33% EVs in total M1 vehicle stock at the end of the research period – significantly higher than the EU average (2.26%) (Figure 3).

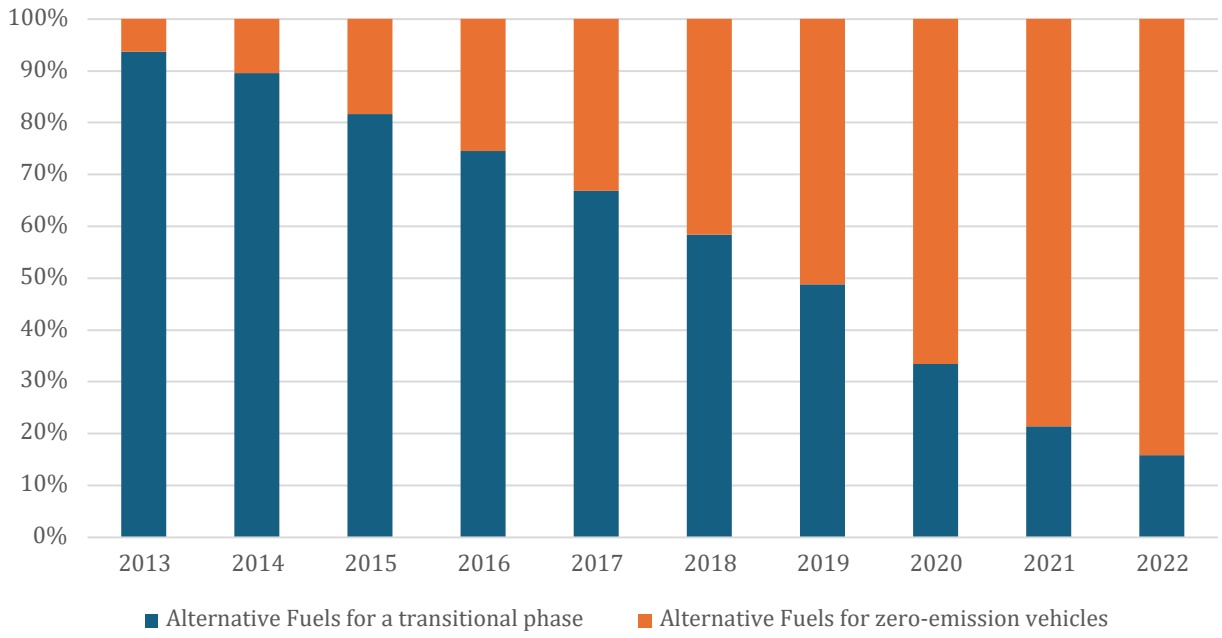

Figure 2. The progression of the structure of the passenger car fleet powered by alternative fuels in Group 1

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

At the current stage of development, the Group 1's share of the AF fleet in total M1 stock remains lower (3.96%) than the analogous fraction calculated for the EU-27 as a whole (5.75%).[4] On an individual level, the ratio was highest in Sweden, which also

4 Since the highest shares of AF fleet were observed in countries with lower population levels (Sweden, Netherlands, Denmark, Luxembourg), which jointly accounted only for 10.85% of group's total AF vehicle fleet, the difference is reduced when the medians (group 1: 3.22%; EU–27: 3.38%) or averages (group 1: 4.17%; EU–27: 4.62%) are compared.

achieved the highest growth rate of the AF fleet in the EU–27. The rapid adoption of BEV and PHEV vehicles in the Nordic countries is attributed primarily to the purchase incentives aimed at reducing the price gap between EVs and internal combustion engine vehicles. Among them, fiscal incentives played the biggest role, primarily exemptions from or reductions in vehicle registration taxes (which are exceptionally high compared to the rest of the EU), with the rates differentiated based on CO_2 emissions or fuel economy ratings (International Energy Agency 2018). In Sweden, with the lower standard registration tax rates, the main government-based incentive constituted a one-off "super green car rebate" subsidy (*supermiljöbilspremie*) of a varying amount, granted after the purchase of a new car with less than 60 g/km CO_2 emission rate. Introduced in 2012, the scheme was abruptly abolished on November 8th, 2022.

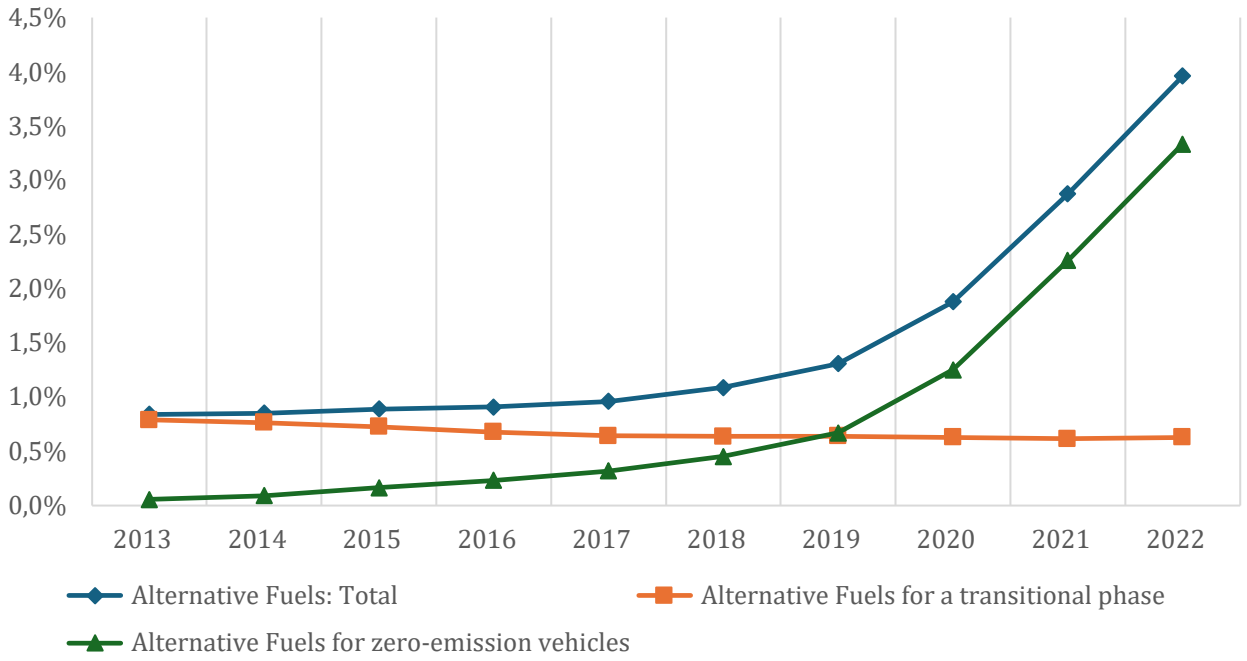

Figure 3. Visual presentation of growth in the alternatively fueled passenger car fleet within Group 1's M1 vehicle stock, 2013–2022

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

Lastly, a small fraction of the Nordics' impressive AF fleet growth rate can be attributed to a parallel increase in gas-powered car fleets (CNG), which shows that "transitional" and clean-energy solutions do not have to be mutually substitutable. Among the three countries in question, it was most evident in Finland, where the share of CNG passenger cars in the total M1 stock increased by 1305.75% (from 0.03% in 2012 to 0.42% in 2022), which contributed 8.69% to the total AF fleet growth.

In Sweden, the percentage of CNG cars has almost doubled since 2009 (from 0.46% to 0.90%), but the growth stalled permanently in 2012 with the introduction of the previously discussed price subsidies for clean-energy passenger cars. Outside of the region, even more evident parallel growth was observed in Spain and Malta, where the expansion

of transitional (predominantly LPG) vehicle stock constituted 28.29% and 25.97% of the total AF growth rate within the respective periods (Table 2). The opposite scenario took place in the Netherlands and Hungary, where the shrinking fleet of LPG passenger cars reduced the EV-driven growth of the AF fleet by as much as 43.08% and 33.37%, respectively.

A detailed, individual structure of the alternatively fueled passenger car fleet in 2022 is presented in Table 4.

Table 4. Detailed structure of Group 1's alternatively fueled passenger car fleet, 2022

2022	BEV (%)	PHEV (%)	H2 (%)	LPG (%)	CNG (%)	LNG (%)	AF fleet (Total, % of M1)	AF fleet growth (pp.) †	Share (%)‡
DK	3.460	3.481	0.008	0.000	0.004	–	6.954	6.901	99.934
IE	1.510	1.070	–	0.023	0.008	–	2.611	2.601	98.824
LU	3.260	2.859	0.001	0.059	0.033	–	6.212	6.082	98.525
AT	2.140	0.821	0.001	0.006	0.101	–	3.069	2.987	96.513
SE	4.179	5.500	0.001	0.000	0.901	–	10.582	10.109	91.482
FI	1.285	2.840	0.000	0.000	0.422	–	4.547	4.508	90.718
BE	1.560	3.080	0.002	0.286	0.317	–	5.245	4.424	88.498
FR	1.730	1.046	0.001	0.439	0.007	–	3.224	2.668	86.156
CY	0.093	0.110	–	0.036	–	–	0.238	0.237	85.077
NL	3.690	2.101	0.007	1.180	0.085	0.000	7.062	4.052	82.098
DE	2.000	1.911	0.004	0.695	0.173	–	4.783	3.724	81.857
MT	0.820	0.856	–	0.581	–	–	2.257	2.237	74.260
ES	0.420	0.543	0.000	0.312	0.068	–	1.343	1.329	71.703
PT	1.160	1.014	0.000	0.944	0.003	–	3.121	2.309	69.673
HU	0.387	0.353	–	0.560	0.055	–	1.354	0.554	54.588
TOTAL Group 1	1.759	1.571	0.002	0.501	0.126	0.000	3.959	3.119	84.160

Explanation of abbreviations: DK – Denmark; IE – Ireland; LU – Luxembourg; AT – Austria; SE – Sweden; FI – Finland; BE – Belgium; FR – France; CY – Cyprus; NL – Netherlands; DE – Germany; MT – Malta; ES – Spain; PT – Portugal; HU – Hungary.

Explanatory notes:

† The percentage-point change in the AF fleet share within M1 stock during the research period (see Table 2).

‡ The share of passenger cars utilizing the "alternative fuels for zero-emission vehicles" in the AF vehicle stock (BEV, PHEV, H2).

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

Group 2 – the EU countries with the predominant role of transitional alternative fuels (LPG, CNG, LNG)

Changes pertaining to passenger cars utilizing gaseous fuels had incomparably more significance in the case of countries experiencing earlier stages of the electrification process, which relied on LPG as the main alternative to gasoline and diesel vehicles (Group 2). Like Group 1, Group 2 is largely geographically homogenous, as it almost exclusively comprises Central and Eastern European (CEE) countries, apart from Italy and Greece. Due to the prominent cases of established use of LPG in said countries, the group achieved in 2022 a higher share of AF passenger cars (with Poland being the EU's leader) but also a considerably lower growth rate. From 2018, the increase in the size of the EV fleet – although exponential – was sufficient only to offset the parallel decline in gas car usage, which has resulted in maintaining the general level and structure of the AF M1 vehicle stock (see Figures 4 and 5).

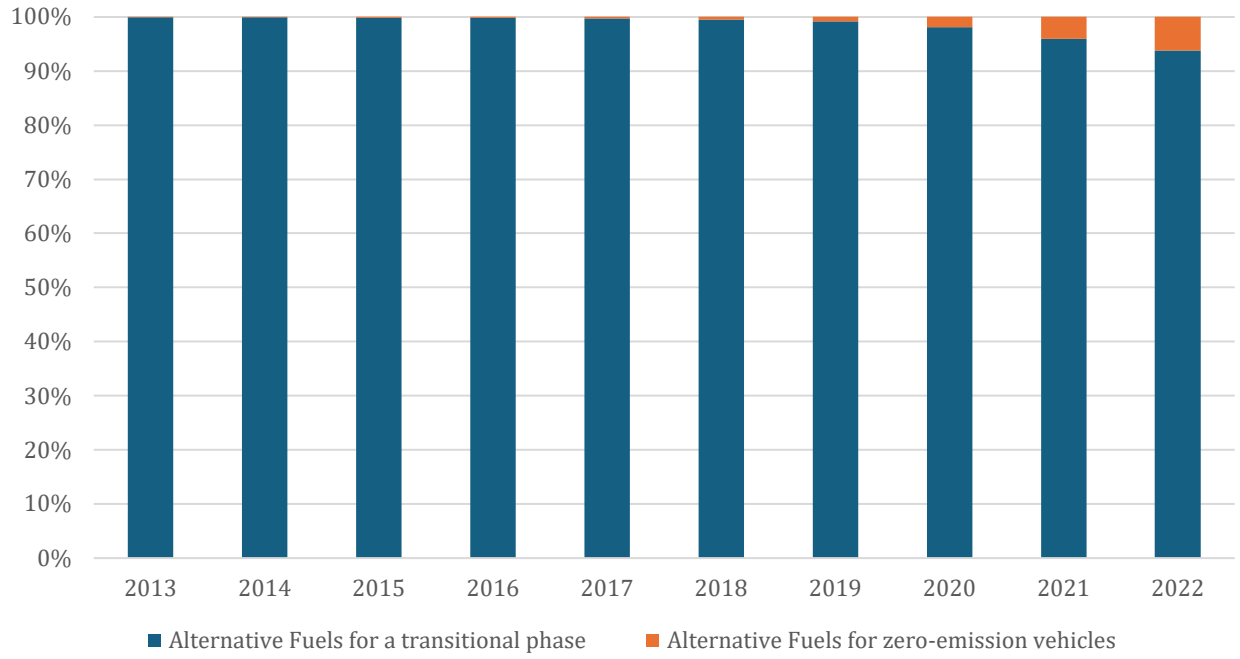

Figure 4. The progression of the structure of Group 2's passenger car fleet powered by alternative fuels

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

The individual level and trajectory of the AF fleet's growth is much more diverse than reported in the previous group. The most important feature is the presence of four countries experiencing an overall decline in the relative share of AF fleet: Lithuania (–4.86 p.p.), Czechia (–1.51 p.p.), Poland (–1.31 p.p.), and Romania (–1.16 p.p.). In all the cases, the decline was led by a substantial decrease in the market share of LPG-powered vehicles, which has not been compensated for by a parallel growth of CNG, LNG, or EV fleets (including hybrids). Instead, almost all of the group's passenger car markets (except for Italy) experienced an increasing demand for diesel vehicles. They have

been gradually replacing petrol vehicles, and in 2021, constituted almost half (45.71%) of the group's ICE passenger cars fleet. The trend was most noticeable in Lithuania, where the diesel market share growth of 62.79% increased the relative size of the ICE fleet by 9.80% (Eurostat 2023)[5].

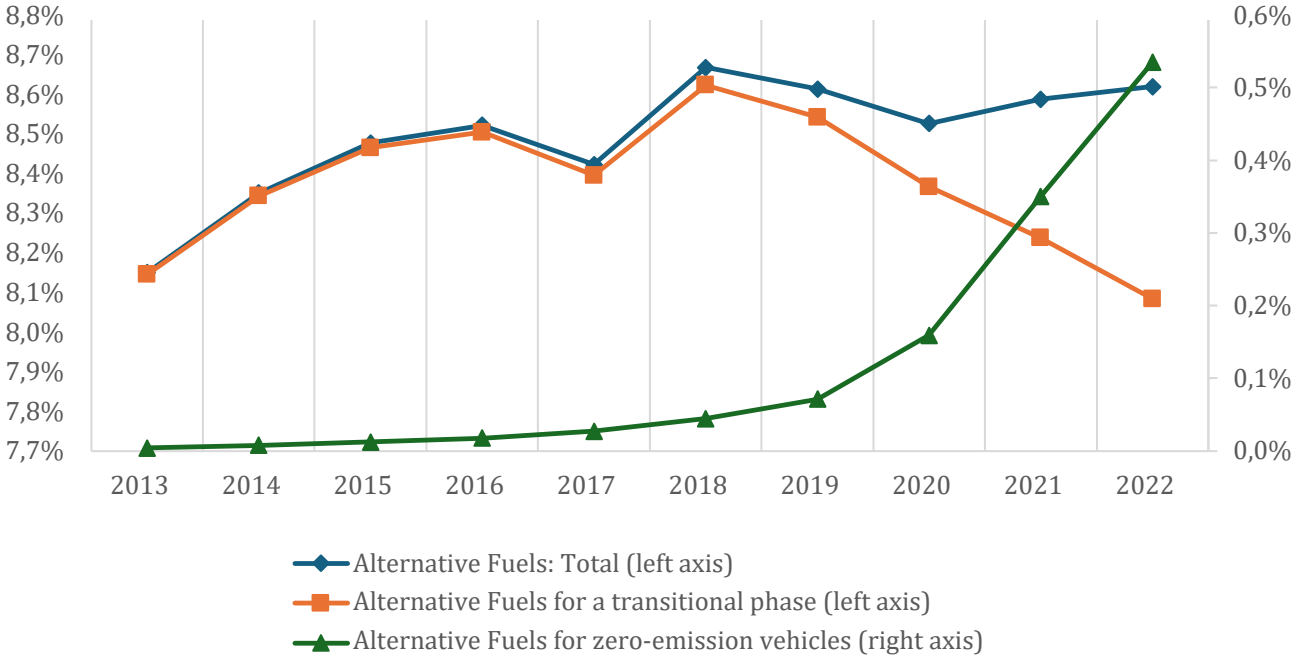

Figure 5. Visual presentation of growth in the alternatively fueled passenger car fleet within Group 2's M1 vehicle stock, 2013–2022

Source: own calculations based on EAFO Database (European Alternative Fuels Observatory 2023).

As indicated by a positive aggregated AF fleet growth rate (0.47 p.p.), the predominant scenario within Group 2 was the increase in the share of the AF fleet, which resulted almost entirely from an expansion of the LPG-fueled passenger car fleet. The biggest and most consistent growth of this kind was observed in Italy (3.99 p.p.), and it is largely attributable to favorable taxation, vehicle acquisition and conversion incentives, as well as local measures to encourage the purchase of clean vehicles (World LPG Association (WLPGA) and Liquid Gas Europe 2022). The LPG stock also grew considerably in Latvia and Greece, but the upward trend was more unstable, with the AF share peaking in the middle of the research period (in 2014 and 2016, respectively) and decreasing afterward.

The demand for "autogas" vehicles was generally driven by cost factors. Over the years, LPG has enjoyed a substantial excise-tax advantage, which translated into a significant, favorable price gap compared to diesel and gasoline. For example, in 2021, the pump price of LPG in Italy was equal to 43.48% of that of petrol and 47.55% of that

5 Own calculations based on Eurostat's Passenger cars, by type of motor energy [ROAD_EQS_CARPDA] dataset (Eurostat 2023). Scope of the data: years 2013–2021; countries: Poland, Latvia, Croatia, Italy, Lithuania, Czechia, Romania, Estonia, Slovenia.

of diesel. Since 2014, the demand has additionally been boosted in Italy by a government scheme that partially covers the conversion purchase costs of an LPG vehicle, with a refund amount conditional on CO_2 emissions. In 2019, the scheme was abolished in favor of a new eco-bonus program that promotes the purchase of a new electric, hybrid, or methane gas-powered car (World LPG Association (WLPGA) and Liquid Gas Europe 2022).

Table 5. Detailed structure of Group 2's alternatively fueled passenger car fleet, 2022

2022	BEV (%)	PHEV (%)	H2 (%)	LPG (%)	CNG (%)	LNG (%)	AF fleet (Total, % of M1)	AF fleet growth (pp.)†	Share (%)‡
PL	0.096	0.099	0.000	12.580	0.019	–	12.794	– 1.306	98.471
BG	0.107	0.067	–	5.980	0.739	–	6.893	1.053	97.478
LV	0.366	0.073	–	6.200	0.031	–	6.670	3.362	93.421
EL	0.101	0.197	–	3.624	0.078	–	4.000	3.610	92.560
HR	0.209	0.089	–	3.070	0.007	–	3.375	0.385	91.165
IT	0.431	0.459	0.000	6.380	2.452	–	9.722	3.991	90.845
LT	0.439	0.295	0.000	6.150	0.051	0.003	6.939	– 4.861	89.424
CZ	0.221	0.139	0.000	2.500	0.363	–	3.225	– 1.505	88.824
RO	0.295	0.105	–	2.790	0.003	–	3.193	– 1.161	87.493
SK	0.178	0.165	0.000	1.840	0.109	–	2.292	2.202	85.023
EE	0.350	0.075	0.000	0.728	0.252	–	1.405	1.035	69.703
SI	0.635	0.129	–	0.940	0.019	–	1.723	1.443	55.659
TOTAL group 2	0.277	0.257	0.000	7.032	1.051	0.000	8.619	0.469	93.797

Explanation of abbreviations: PL – Poland; BG – Bulgaria; LV – Latvia; EL – Greece; HR – Croatia; IT – Italy; LT – Lithuania; CZ – Czechia; RO – Romania; SK – Slovakia; EE – Estonia; SI – Slovenia.

Explanatory notes:

† The percentage-point change in the AF fleet share within M1 stock during the research period (see Table 2).

‡ The share of passenger cars utilizing the "alternative fuels for a transitional phase" in the AF vehicle stock (LPG, CNG, LNG).

Source: own calculations, based on the EAFO Database (European Alternative Fuels Observatory 2023).

Conclusion

The deployment of alternative fuel vehicles, defined as vehicles powered by sources that serve as a substitute for fossil oil sources, is an important measure in achieving the EU's objective of reducing greenhouse gas emissions from transport by 90% by 2050 compared

to 1990 levels. The study characterized this process on a sample of EU–27 countries based on the developments observed between 2009 and 2022.

The results indicate that the speed of diffusion of electric and hybrid vehicles is largely heterogeneous across the EU–27, with an evident two-speed pattern. At the end of the research period (2022), the largest group, which comprised 15 out of the 27 EU member states, represented the countries with a predominant share (84.16%) of electric (BEV) and hybrid (PHEV) vehicles in their AF passenger car fleet (Group 1). The group, comprised mainly of Nordic and highly developed Western European countries, was characterized by a share of AF vehicles within the total M1 vehicle stock that was lower than the EU average (3.96% in 2022) yet exceptionally dynamic and rapidly growing. Although almost all the growth can be attributed to the exponential expansion of BEV/PHEV vehicles, some of the countries experienced a parallel increase in the gas-powered fleet (LNG/LPG). This was most evident in Spain and Malta, where the expansion of the LPG vehicle stock constituted 28.29% and 25.97% of the total AF growth rate within the respective periods (Table 2). The opposite scenario took place in the Netherlands and Hungary, where the shrinking fleet of LPG passenger cars reduced the EV-driven growth of the AF fleet by as much as 43.08% and 33.37%, respectively.

"Transitional" gaseous fuels (mainly LPG) were the leading alternative fuel in Group 2, which consists of CEE countries, Italy, and Greece, with an even more one-sided ratio of 93.80% to 6.20%. Over the last decade, the relative size of the group's AF M1 stock grew significantly slower than in Group 1 – from 8.15% in 2013 to 8.62% in 2022, with a peak of 8.67% in 2018. The lack of growth from 2018 onwards stems from the fact that the dynamic expansion of electric and hybrid vehicle M1 stock has been fully offset by the parallel decline in LPG usage. In four CEE countries (Lithuania, Czechia, Poland, and Romania), the recent contraction of LPG-fueled vehicle stock exceeded the EV growth, which led to an overall decline in the relative share of the AF fleet.

The results emphasize the need to diversify alternative fuels, which should be introduced gradually, as outlined by their classification proposed by Directive 2014/94/EU of the European Parliament and the Council, depending on the socio-economic development and infrastructural readiness of the country. In this context, the main focus is LPG, which remained the EU's most widespread alternative fuel in 2022, utilized in 52.37% of its AF passenger car fleet. Given the current circumstances, such as a shrinking LPG fleet and rising demand for diesel vehicles, exclusively focusing on battery-electric vehicles in LPG-dominated countries is likely to lead to a temporary increase in the market share of ICE cars (assuming the current pace of electrification remains unchanged). Consequently, this may result in higher greenhouse gas emissions from transport. Statistical verification of this scenario could be the subject of further research.

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Paliwa alternatywne jako zrównoważona innowacja we flocie pojazdów UE–27: diagnoza i perspektywy rozwoju

Rozszerzenie floty pojazdów napędzanych paliwami alternatywnymi stanowi ważny instrument realizacji celów klimatycznych Unii Europejskiej. Celem badania jest scharakteryzowanie i ocena, w sposób porównawczy, obecnego etapu popularyzacji samochodów osobowych napędzanych paliwami alternatywnymi w państwach członkowskich UE. Punktem centralnym badania jest eksploracja podobieństw i różnic obserwowanych pomiędzy krajami unijnymi w odniesieniu do aktualnej struktury floty pojazdów napędzanych paliwami alternatywnymi oraz tendencji rozwojowych w tym zakresie. W tym kontekście zaobserwować można wyraźny schemat „dwóch prędkości" – równolegle do szybkiego rozpowszechniania pojazdów elektrycznych w krajach skandynawskich i zachodnioeuropejskich wielkość i struktura floty pojazdów napędzanych alternatywnie pozostała w dużej mierze niezmieniona w krajach Europy Środkowej, z wciąż dominującą rolą utrwalonego na tych rynkach skroplonego gazu płynnego (LPG). Wyniki badania podkreślają potrzebę dywersyfikacji paliw alternatywnych, które należy wprowadzać stopniowo, zgodnie z klasyfikacją zaproponowaną w dyrektywie 2014/94/UE Parlamentu Europejskiego i Rady.

Słowa kluczowe: paliwa alternatywne, zrównoważone innowacje, zrównoważony rozwój, flota samochodów osobowych, UE–27, środowisko