a scientific open access quarterly

International Entrepreneurship Review

ISSN 2658-1841

2026, vol. 12, no. 2

KRAKOW UNIVERSITY OF ECONOMICS
Department of International Trade
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ISSN 2658-1841 2026, Vol. 12, No. 2

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Publisher

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Cover and DTP: Marek Sieja

Reviewers

All articles are double-blinded peer-reviewed at least by two independent reviewers.
The detailed list of reviewers is published at our website once a year.

Original Version

The online journal version has been the only one since 2019.
The online journal is the primary and reference version.

ISSN 2658-1841 (since 2019)
ISSN 2543-537X, eISSN 2543-4934 (in the years 2015-2018)

Abstracting/Indexing

The journal, and all its articles, is abstracting and/or indexing
in international databases, including:

ESCI Web of Science TM Core Collection (USA)
Clarivate Analytics (Beijing, China)
DOAJ (England, UK)
Sherpa Romeo (England, UK)
ERIH Plus (Norway)
Publons (Beijing, China)
ProQuest (USA)
EBSCO (USA)
Google Scholar (USA)
EconPapers – RePEc (Sweden)
Crossref (USA)
BazEkon (Poland)
BazHum (Poland)
Index Copernicus (Poland)
ROAD (USA)
WorldCat (Netherlands)

Identification and Originality

All articles published in IER are tagged with an identification number
employing the Digital Object Identifier (DOI) System.
IER uses the Crossref Similarity Check service powered by iThenticate to verify the originality of articles
submitted to the journal.

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10.15678/IER.2026.1202.01

Organic farming and market development in the European Union in times of global economic turbulences

Agnieszka Hajdukiewicz, Bożena Pera

ABSTRACT

Objective: This article aims to examine the latest trends in the development of the organic farming and market for organic agricultural products in the European Union in the context of global economic uncertainty and turbulences caused by the COVID-19 pandemic and current geopolitical tensions.

Research Design & Methods: We used quantitative research methods (*e.g.*, descriptive statistics, hierarchical cluster analysis, Pearson's correlation coefficient calculations) to analyse trends in organic farming and market development in the EU between 2015 and 2023. We based the study on statistical data provided by the Research Institute of Organic Agriculture (FiBL) and Eurostat.

Findings: The economic turmoil of recent years caused by the COVID-19 pandemic and Russian invasion of Ukraine has affected the organic products market, and in particular the demand for organic products, but in different ways in each of these crises.

Implications & Recommendations: Knowledge of development trends in the organic market is important for entrepreneurs in the agri-food sector, as it reveals market opportunities associated with participation in more sustainable agri-food systems. It highlights the need for EU policymakers to continue to support and promote the development of sustainable agriculture.

Contribution & Value Added: The study contributes to a broader understanding of the latest development trends in organic farming and the organic products market. It also reveals the opportunities and limitations associated with this form of agriculture, which represents a more environmentally-friendly alternative to conventional farming.

Article type:	research article
Keywords:	organic farming; European Union; global turbulences; organic production; organic market development
JEL codes:	Q13, Q15, Q18, F14, O13

Received: 11 February 2026 Revised: 13 May 2026 Accepted: 25 May 2026

Suggested citation:
Hajdukiewcz, A., & Pera, B. (2026). Organic farming and market development in the European Union in times of global economic turbulences. *International Entrepreneurship Review,* 12(2), 7-25. https://doi.org/10.15678/IER.2026.1202.01

INTRODUCTION

Climate change, biodiversity loss, and environmental degradation have led the European Union to make green transition its main objective (Arora, 2018; Dziekański, Popławski, & Straka, 2025; Sztorc & Savenkovs, 2025). By implementing a new economic growth strategy known as the Green Deal, the EU is seeking to play a leading role in the global ecological transition. Simultaneously, it recognises that this strategy will increase the EU's competitiveness and lead to a gradual but significant transformation of European economies (European Commission, 2018).

Scholars often see agroecology as the heart of the European Green Deal (De Schutter, 2023). It is a way to promote low consumption of inputs, little or no use of pesticides, and little or no use of nitrogen fertilisers. This means a transformation of agricultural production models and, through the

'Farm to Fork' strategy contained in the Green Deal, it affects the conditions for agriculture and agricultural markets in the EU (Boix-Fayos & de Vente, 2023). One of the key ways to achieve the objectives of the 'Farm to Fork' strategy is to support organic farming and develop the market for organic products. According to research, organic farming constitutes an environmentally friendly practice and an alternative to conventional farming, which should be further developed so that by 2030, 25% of the total agricultural area is under organic farming (European Commission, 2020). However, the pandemic and the war in Ukraine, as well as the recent geopolitical tensions, pose a challenge to the organic sector and undermine the possibility of achieving the strategic objectives of the 'Farm to Fork' strategy. We have noticed a lack of detailed research demonstrating the recent development of the organic market, which we believe constitutes a research gap. Especially since most research in recent years has focused on integrated agroecological systems, and these go beyond organic farming practices and organic certification (Mouratiadou *et al*., 2024; Bezner Kerr, 2023).

The following research questions guided our analysis:

RQ1: What are the main trends in the development of organic farming and the market for organic agricultural products in the European Union?

RQ2: What is the awareness of EU citizens regarding ecological, environmental and health issues and their attitude towards organic products?

RQ3: How resilient has the organic market been to the shocks caused by the pandemic and the war in Ukraine?

Based on the above research questions, we aimed to examine the latest trends and prospects for the development of organic farming and the market for organic agricultural products in the European Union in the context of global economic uncertainty and turmoil caused by the COVID-19 pandemic and current geopolitical tensions. The article begins by presenting the essence and main principles of organic farming, examining its links with environmental policy and agroecology, and identifying its main benefits and development constraints. We then analyse the main trends in the development of this form of agricultural activity in European Union countries in recent years. We also investigate the situation on the organic product market, including consumption trends and consumer attitudes towards these products. Finally, we conclude on the state and prospects of organic production and the market for these products, considering changes in the global environment and EU policy priorities for the agri-food sector.

Knowledge of development trends in the organic market is important for entrepreneurs in the agri-food sector, because it reveals possible market opportunities associated with participation in more sustainable agri-food systems. It also highlights the need for EU policymakers to continue to support and promote the development of sustainable agriculture.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The agri-food sector constitutes a strategic sector for the European Union and plays a key role in ensuring food security at the regional and global levels. Both EU policymakers and consumers perceive food as one of the sectors of greatest importance for the provision of basic services to citizens (European Commission, 2025). In addition, the EU had a competitive advantage in the global market for many agri-food products, which corresponded to their high share in global exports and generated a high positive trade balance (Pawlak, 2017). The EU's trade surplus in agri-food products with third countries (outside the EU-27) reached 63.6 billion EUR in 2024 (DG-AGRI EC, 2025). However, the EU remains dependent on imports of many agri-food product groups (European Union, 2025).

Simultaneously, unsustainable and industrial agriculture is the largest driver of biodiversity and habitat loss, and it contributes to climate change, contaminating soils and water bodies (Common, 1995; IFOAM, 2025). The proximity and intensity of the interaction between agriculture and the environment makes the sector's activities particularly vital for the transition towards sustainability. Redefining world agricultural systems is of interest to environmental policy, not only in its sectoral dimension, but also as an element of a broader, horizon dimension, shaping the conditions and scope of use of environmental resources on a large scale in the entire economy and society.

The implementation of environmental policy requires, among other things, specifying goals and effectively selecting tools. The choice of its goals and adequate tools, which include both legal regulations and economic measures, is determined by many factors, including the current state of knowledge about the environment, environmental protection priorities in the context of other economic and social policy goals, and the availability of financial resources for environmental protection. This leads to heterogeneity of states' ecological policies and the measures they implement (Lamy & Pons, 2023).

By implementing Green Deal initiative, the European Union has become a pioneer in attempting to find a better balance between economic growth and the environment (Kwilinski *et al*., 2024). In December 2019, Ursula von der Leyen affirmed that the Green Deal aimed to 'reconcile the economy with our planet, to reconcile the way we produce and the way we consume with our planet and to make it work for our people' (Charveriat, 2023). In May 2020, the European Union introduced the 'Farm to Fork' strategy, which is an element of the Green Deal. The strategy approaches agriculture from a sustainable food systems perspective (Fayos & de Vente, 2023). It launches a much more integrated, coordinated, and cross-sectoral policy for a more sustainable food system. The 'Farm to Fork' strategy is expected to be a key driver for structural changes that, among others, will reduce Europe's dependence on imported animal feed and nitrogen fertilisers produced from fossil fuels, it also promotes quality systems, including organic products and products with geographical indications.

Organic production constitutes one of the key notions of this strategy. Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 defines it as: 'an overall system of farm management and food production that combines best environmental and climate action practices, a high level of biodiversity, the preservation of natural resources and the application of high animal welfare standards and high production standards in line with the demand of a growing number of consumers for products produced using natural substances and processes' (Regulation (EU), 2018/848).

As stated by the International Federation of Organic Agriculture Movements (IFOAM), organic farming is an agricultural production approach designed to maintain and support the well-being of soils, ecosystems, and human populations. Rather than relying on inputs that may cause harmful side effects, it draws on ecological principles, biological diversity, and natural cycles tailored to local environmental conditions. By its very nature, organic agriculture integrates traditional practices, modern innovation, and scientific knowledge to protect the environment we all share, foster equitable relationships, and enhance the overall quality of life for everyone involved. It is based on 4 core principles (IFOAM, 2016), which represent the basic aims which organic farming and food systems must strive to achieve:

1. Principle of Health — Organic farming must preserve and improve the well-being of soil, plants, animals, people, and the entire planet, treating them as interconnected and inseparable elements of a single system.
2. Principle of Ecology — Organic farming must be grounded in living ecological systems and natural cycles, cooperating with them, drawing inspiration from them, and actively contributing to their preservation.
3. Principle of Fairness — Organic farming must foster relationships built on equity, ensuring just access to shared environmental resources and equal life opportunities for all.
4. Principle of Care — Organic farming must be conducted with caution and a sense of responsibility, with the goal of safeguarding the health, welfare, and environment of both present and future generations.

The first two principles relate to the use of agroecological methods, such as recycling nutrients and organic matter to improve soil health and increase functional diversity to minimise the occurrence of pests and diseases in crop production, as well as the proper management of livestock health and welfare. The latter two refer to the ethical and ecologically just use of natural resources and the prudent use of new technologies (Halberg & Muller, 2013).

We consider organic farming to be a particularly relevant research topic when considering the harmful impacts of conventional agriculture on the local and global environment, as we can see it as part of the solution to environmental challenges, contributing through sustainable practices and rewards to the achievement of several Sustainable Development Goals, especially SDG 13 'Climate Action,' which

concerns taking urgent action to combat climate change and its impacts; SDG 14 'Life below Water,' which refers to the need to conserve and sustainably use the oceans, seas, and marine resources for sustainable development; SDG 15 'Life on Land,' which emphasises the role of protecting, restoring, and promoting sustainable use of terrestrial ecosystems as well as SDG 3 'Good Health and Well-being,' which focuses on ensuring healthy lives and promoting well-being for all at all ages. Benefits of organic farming include among others improved soil structure and fertility due to the use of organic fertilizers and crop rotations (Jiang *et al.*, 2022), enhanced biodiversity through reduced chemical inputs and habitat preservation (Gomiero *et al.*, 2011), lower greenhouse gas emissions and increased carbon sequestration in organic systems (Scialabba & Müller-Lindenlauf, 2010), and reduced exposure to pesticides and antibiotics, leading to potentially healthier food products (Mie *et al.*, 2017).

The growing organic sector also creates jobs and attracts younger farmers, preventing them from leaving the countryside, offering a combination of business opportunities with environmental progress and social responsibility. This is of particular importance in the context of structural changes in the agri-food sector in the European Union, resulting from significant discrepancies in the scale of agricultural activity and the ageing of the farming population.

The term 'organic farming' has a similar but not identical meaning to 'agroecology.' The common goals make organic farming and agroecological farming similar, although agroecological practices are not necessarily applied in organic farming. De Shutter (2023) emphasises that agroecology extends beyond a series of designated practices such as organic farming, as it is a general approach aimed at reducing the use of inputs, reducing the costs of production and the farmer's dependence on the use of these costly inputs. Agroecology encompasses not just farming but also food systems, policies, and social movements. It emphasises farmer empowerment and local economies. If we consider ecological and social transformation, agroecology offers a more comprehensive and grassroots-based approach.

Despite its narrower scope, organic farming, as a certified production system that adheres to strict guidelines for avoiding synthetic fertilisers, pesticides, GMOs, and artificial additives in food production (Miśniakiewicz *et al.,* 2021), also serves to reduce the use of external inputs. It encourages crop rotation, composting, and natural pest control. When considering both consumer-driven sustainability and regulated standards, organic farming — with its focus on farm-level practices and market certification — offers a more structured and market-oriented system than agroecology.

Organic products have a high and growing market value (Pawlewicz *et al.,* 2020), as there is an increasing number of environmentally conscious consumers who value high-quality healthy food and are willing to pay a higher price for certified organic products. Organic production is the cornerstone of EU quality policy and one of the EU's agricultural product quality schemes, alongside geographical indications and traditional specialities guaranteed. It plays a dual social role. On the one hand, it provides a concrete market response to consumer demand for healthy products, thereby supporting competitiveness, and on the other hand, it supplies publicly available goods that contribute to environmental protection. The EC declares its continued support for organic farming, while noting that other, more integrated approaches could be further promoted (EC, 2025).

However, organic farming currently faces many challenges and constraints to further development as an alternative to conventional farming systems. These limitations stem from both sectoral factors related to the specific nature of these farming practices and structural trends in agriculture, as well as global conditions. Sectoral barriers include lower yields on organic farms compared to conventional farms (Schrama *et al.,* 2018), which extreme weather events may further reduce. Another limitation is the lengthy and costly process of converting conventional farms to organic farms (Verburg *et al.*, 2022), which can translate into bureaucratic burdens. Organic products are also typically higher-priced, which may limit their availability to some consumers (Bryła, 2016). The ban on GMOs in organic production reduces the availability of food on the market, which raises public concerns (Meemken & Qaim, 2018). One of the main factors in the development of organic farms in the European Union was the high level of subsidies for this production system, which, however, in some situations (changes in the requirements for receiving subsidies, reduction of support rates) may cause a regression in the development of organic farms (Pawlewicz *et al.,* 2022).

From a global perspective, the organic farming sector, like the economy as a whole, has been struggling with the effects of the pandemic and has been under pressure from serious geopolitical tensions (Song & Zhou, 2020; Ibn-Mohammed *et al.,* 2021; Sahota, 2022; Naseer *et al.,* 2023). Our research will focus mainly on the impact of these global factors on the development of organic production and the market for these products.

Motivated by the results of the literature review, and seeking to examine the latest trends and prospects for the development of organic farming and the market for organic agricultural products in the European Union in the context of global economic uncertainty and turmoil caused by the COVID-19 pandemic, the war in Ukraine and current geopolitical tensions, we put forward the following hypotheses:

H1: The development of organic farming slowed down during the period of global turbulence caused by the COVID-19 pandemic and the war in Ukraine.

H2: The growth rate of the organic product market declined during the years of global turbulence caused by the COVID-19 pandemic and Russia's invasion of Ukraine.

RESEARCH METHODOLOGY

We used data provided by the Research Institute of Organic Agriculture (FiBL) and Eurostat to analyse trends in organic farming and market development in the EU between 2015 and 2022. The statistical analysis of the data covered the size of organic farmland, the structure of organic production in terms of volume, per capita consumption and retail sales of organic products, as well as the number of entities engaged in organic farming. We used quantitative research methods such as descriptive statistics, hierarchical cluster analysis, and Pearson's correlation coefficient calculations.

We applied cluster analysis and descriptive statistics to determine in detail the current level of organic farming development in EU countries. The variables used were the total organic farmland in the EU MCs; the share of organic crop area in the total agricultural area in the EU member country (OCAMC) and the share of the organic farmland of the member country in the total organic agricultural land of the EU (OCAEU). We ran Ward's linkage, a hierarchical clustering method, to identify the clusters.

Attempting to assess EU organic farming development, we applied the indicator of the annual average growth rate of organic farming area during the COVID-19 pandemic (2020-2021), the war in Ukraine (2022-2023), and global turbulence (2020-2023). Analysing the changes of organic product market during the global turbulence period, we used the growth rate of organic retail sales and compared it to the retail sale of food, beverages and tobacco in the same years as above.

We divided organic products into classes according to the classification applied in the Annual crop statistics (ACS). The seven groups of various crop products included in our analysis were: cereals for the production of grain; dry pulses and protein crops for the production of grain; root crops; industrial crops; plants harvested green from arable land; fresh vegetables; permanent crops for human consumption (European Commission & Eurostat, 2017).

Research on consumer attitudes towards organic products used the results of a Eurobarometer survey published in the 2023 EU Ecolabel Report. We conducted a correlation analysis using Pearson's correlation coefficient to examine the relationships between variables representing different attitudes and perceptions of organic products by consumers.

RESULTS AND DISCUSSION

Examining the potential of organic farming as an alternative to conventional farming systems, we began our analysis by identifying development trends in organic farming in the EU as a whole and changes taking place in EU Member States.

The area under organic farming and the share of organic farming area in the utilised agricultural area give some indication as to the importance of this type of farming in the European Union. The agricultural area of organic crops in the EU increased by almost 6 million hectares between 2015 and 2022 to almost 17 million hectares, but still had a modest share of the total acreage of cultivated crops.

Although the share of organic crops in total agricultural acreage increased by approximately 4 percentage points, it reached 10.5% in 2022, which is far from the goal to achieve 25% of total farmland under organic farming by 2030. In 2023, 17.7 million hectares of farmland in the EU were organic, with 10.9% of the EU's farmland certified organic. Data shows a particularly significant increase in the share of organic crops in the agricultural crop area between 2019 and 2020. However, this was the consequence of maintaining the area of organic agricultural crops at a similar level while reducing the acreage of total cultivated crops in the European Union (Figure 1). Although still far from achieving the Green Deal goal, it is worth noting that organic farmland in the EU is gradually developing, recording growth year on year, despite the turbulence caused by crisis phenomena and geopolitical tensions.

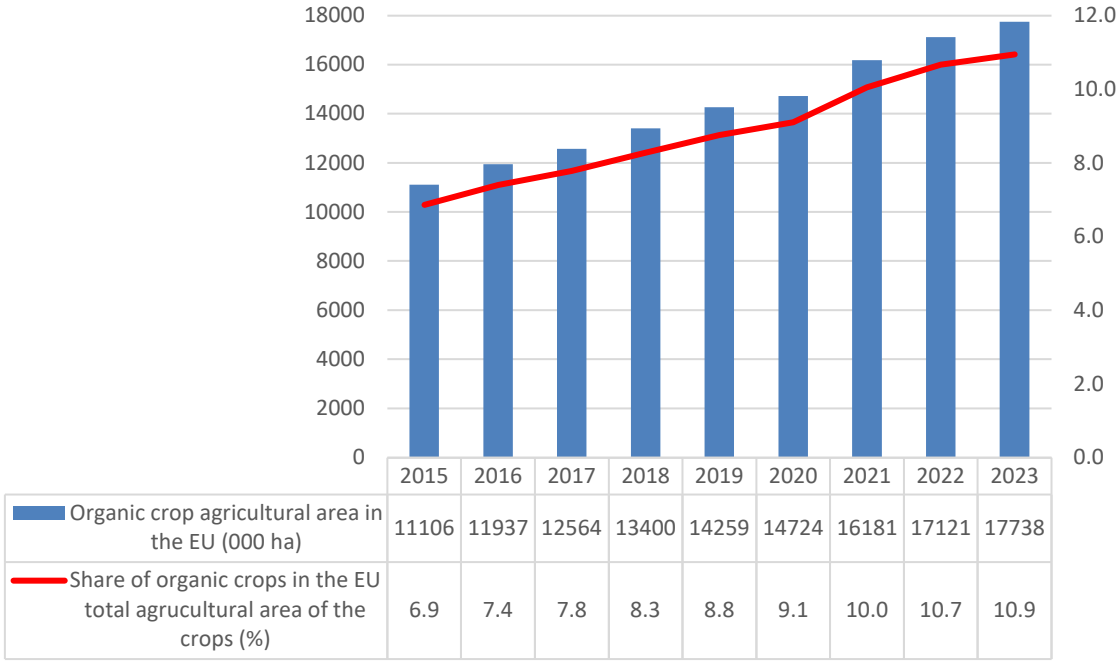

Figure 1. Organic crop agricultural area in the EU (thousand ha) and share of organic crops in the EU total agricultural area of the crops (%) in 2015-2023
Source: own elaboration based on Eurostat & FiBL.

Table 1. Annual average growth rate the EU area under organic farming vs. the crops utilised agricultural area in the analysed periods in 2015-2023 (%)

Description	2015-2019	2019-2023	2019-2020	2020-2021	2021-2022	2022-2023
Agricultural area of the crops	0.17	-0.31	-0.72	-0.41	-0.33	0.20
Area under organic farming	6.45	5.61	3.27	9.89	5.81	3.61

Source: own study based on Eurostat & FiBL.

Throughout the study period, the rate of change in the area used for organic farming was significantly higher than for conventional farming. During the period of global turbulence, the growth rate of organic areas decreased slightly compared to the previous years (about 1 p.p.), but still remained high (5.61%). The annual average growth rate of agricultural land used for organic farming was higher during the COVID-19 pandemic than in the period following Russia's invasion of Ukraine (Table 1).

In the analysis, we used descriptive statistics to examine the changes that occur in the size of the lands allocated to organic crops by the EU member states.

The results of the descriptive statistics confirmed significant progress in expanding the organic agricultural area between 2015 and 2023, while at the same time the gap between the country with the smallest cultivated area and the country with the largest area increased during the period under review. In 2015, the smallest cultivated area in the EU member states was 30 ha and the largest was 1968.6 thousand ha. In 2023, it was 66 ha and 2986.4 thousand ha, respectively. The average cultivated area increased from 393.0 thousand ha to 657.0 thousand ha. In 2015, the area under organic

cultivation in half of the EU Member States was higher than 213.6 thousand ha, whereas in 2022 it was already 312.8 thousand ha. But it decreased by 9 thousand ha in 2023 (Table 2). Using the median and the lower and upper quartiles, we divided all EU Member States into four groups, taking the size of the acreage of cultivated organic crops as the only variable. To indicate changes over time of analysis, we compared the respective groups of countries in 2015, 2022, and 2023.

Table 2. Descriptive statistics for organic agricultural crop area in EU member states in 2015-2023 (thousand ha)

Measures/Year	Mean	Lower Quartile (Q1)	Median (Q2)	Upper Quartile (Q3)	Minimum	Maximum
2015	393.0	73.0	213.6	519.0	0.030	1968.6
2016	424.0	78.5	221.7	536.6	0.024	2018.8
2017	446.9	83.5	234.1	496.3	0.041	2082.2
2018	479.3	89.0	239.7	519.9	0.047	2246.5
2019	511.1	93.1	291.2	535.2	0.055	2354.9
2020	545.3	99.1	300.0	540.4	0.067	2517.5
2021	600.2	86.9	302.2	718.4	0.066	2775.7
2022	627.3	103.4	312.8	745.7	0.066	2875.5
2023	657.0	119.9	303.4	701.2	0.066	2986.4

Source: own study based on Eurostat.

Table 3. The EU member states' groups according to the organic crop area (OA) in 2015, 2022 and 2023: Distribution of countries based on median and lower and upper quartiles*

Description	Group members in 2015	Group members in 2022	Group members in 2023
Countries with the lowest OA up to the size of Q1	Belgium, Cyprus, Ireland, Luxembourg, Malta, the Netherlands, Slovenia,	Belgium, Cyprus, Ireland, Luxembourg, Malta Netherlands, Slovenia,	Belgium, **Croatia**, Cyprus, Luxembourg, Malta, Netherlands, Slovenia
Countries with the medium-low size OA between Q1 and Q2 sizes	Bulgaria, Croatia, Denmark, Estonia, Hungary, Lithuania, Slovakia,	Bulgaria, Croatia, Denmark, Estonia, **Latvia,** Lithuania, Slovakia,	Bulgaria, Denmark, Estonia, **Ireland,** Latvia, Lithuania, Slovakia
Countries with the medium-high size OA between Q2 and Q3 sizes	Czechia, Finland, Greece, Latvia, Portugal, Romania, Sweden	**Austria,** Czechia, Finland, **Hungary, Poland**, Romania, Sweden	Austria, Czechia, Finland, Hungary, Poland, Romania, Sweden
Countries with the high size OA above Q3 size	Austria, France, Germany, Italy, Poland, Spain	France, Germany, **Greece,** Italy, **Portugal**, Spain	France, Germany, Greece, Spain, Italy, Portugal

* Countries that have changed their group affiliation (up or down) between 2015 and 2022, and 2022 and 2023 are marked in bold.

Source: own study.

The development of organic agricultural land during the study period did not result in major changes in the membership composition of the distinct groups. France, Spain, Italy, and Germany formed the core of the group with the highest organic acreage in both 2015 and 2022, with Greece and Portugal joining them in the latter year. In contrast, the segment of countries with the smallest organic acreage included Belgium, Ireland, the Netherlands, Slovenia, Luxembourg, Cyprus, and Malta. Overall, the twenty-one EU member states did not change group. Three countries (Latvia, Austria, and Poland) saw a relative deterioration in the position of organic farming in 2022 compared to 2015, resulting in a move to a lower segment. For the other three countries (Greece, Portugal, and Hungary), there was an improvement, and they moved up a segment in 2022. We recorded two significant changes in the country breakdown between 2022 and 2023: Croatia's position deteriorated relatively in terms of organic acreage, while Ireland moved up to the EU member states with the medium-low sized OA. (Table 3) The changes that occurred in OA indicate uneven growth and significant diversity among EU countries (Table 2 and 3).

We also applied a cluster analysis to detect a detailed and up to date level of development of organic farming in the EU countries. The used variables were the share of organic crop area in the total agricultural area in the EU member country (OCAMC) and the share of the organic farmland

of the member country in the total organic agricultural land of the EU (OCAEU). We run Ward's linkage, a hierarchical clustering method, to identify the clusters. Running Ward's linkage clustering method, we get 4 clusters.

Table 4. Summary of clusters according to the organic share in the total agricultural land in the EU member country (OCAMC) and the share of the organic farmland of the member country in the total agricultural land of the EU (OCAEU)

MS	OCAMC		OCAEU		MS	OCAMC		OCAEU	
	2015					2023			
	Mean	Range	Mean	Range		Mean	Range	Mean	Range
Cluster 1: {DE, ES, FR, IT}	7.73	7.24	13.77	8.56	Cluster 1: {DE, ES, FR, IT}	12.96	9.09	14.23	6.19
Cluster 2: {CZ, EE, LA, AT, SW}	15.82	8.01	3.65	3.74	Cluster 2: {EE, AT, PT}	24.08	4.51	3.36	3.58
Cluster 3: {DK, GR, LT, PL, PT, SI, SK, FI}	7.49	5.87	2.43	5.08	Cluster 3: {CZ, DK, GR, LA, SI, SK, FI, SW}	14.56	7.08	2.32	4.91
Cluster 4: {BE, BG, IE, HR, CY, LU, HU, MT, NL, RO}	2.82	4.91	0.73	2.32	Cluster 4: {BE, BG, IE, HR, CY, LT, LU, HU, MT, NL, PL, RO}	5.66	8.03	1.20	3.91

Note: AT – Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY Cyprus, CZ – Czechia, DK – Denmark, EE – Estonia, FI – Finland, FR – France, DE – Germany, GR – Greece, HU – Hungary, IE Ireland, IT – Italy, LT – Lithuania, LU – Luxembourg, LV – Latvia, MT – Malta, NL – the Netherlands, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, ES – Spain, SE – Sweden.
Source: own study.

The analysis results provided a breakdown of EU countries into four groups in terms of the share of lands used for organic farming in the total agricultural area at the national and EU levels. Germany, France, Spain, and Italy formed the group of countries that play the most significant role in organic agriculture in the EU. Germany's share of organic farmland in the total agricultural area of the country increased from 6.3% in 2015 to 9.8% in 2022, but despite this, Germany recorded the lowest results among the countries in this group. The share of organic farmland in the total organic farmland area in the EU was around 10%. The share of land assigned to organic agriculture for each of the four countries was the largest compared to the whole European Union. However, in the case of Spain and Italy, there was a slight decrease in it in 2015 compared to 2022. All objects classified in this group recorded an increase in the share of organic agricultural acreage in the total national acreage, most significantly in the case of Italy (from 11.8% to 18.1%) and France (from 4.5% to 10.1%). Czechia, Estonia, Latvia, Austria, and Sweden were recognised as a separate cluster in 2015. This group represented a relatively high share of the agricultural area under organic farming in the total national acreage and a relatively low share of this area in the total EU organic acreage. We classified small EU countries with the highest share of organic farming in a country's agricultural acreage into this cluster. Austria was the country with the highest percentage of land converted to organic farming and used 20.3% of total arable land for organic crops, while the other countries in this group reached between 12.3% and 17.4% in 2015. The share of croplands under organic agriculture exceeded 25% of total arable land in Austria in 2019. The agricultural organic crop area increased significantly in Finland, Slovakia, Portugal, Greece, and all mentioned countries joined this cluster in 2022. Eight EU countries belonged to a segment that brought together countries with relatively low shares of agricultural organic crop area in the country and in the EU in 2015. The organic crop areas were significantly developed by Slovakia, Finland and Portugal. Moreover, in 2022 this group of countries joined a cluster that included Sweden, Austria, Latvia, Estonia, and Czechia. The largest cluster encompassed ten worst-performing EU countries in organic agriculture.

Only Croatia managed to move into another group of EU countries characterised by better performance in 2022. Meanwhile, Poland joined this group mainly due to the deterioration of the share of the country's organic farmland in the total agricultural land of the EU (Table 4).

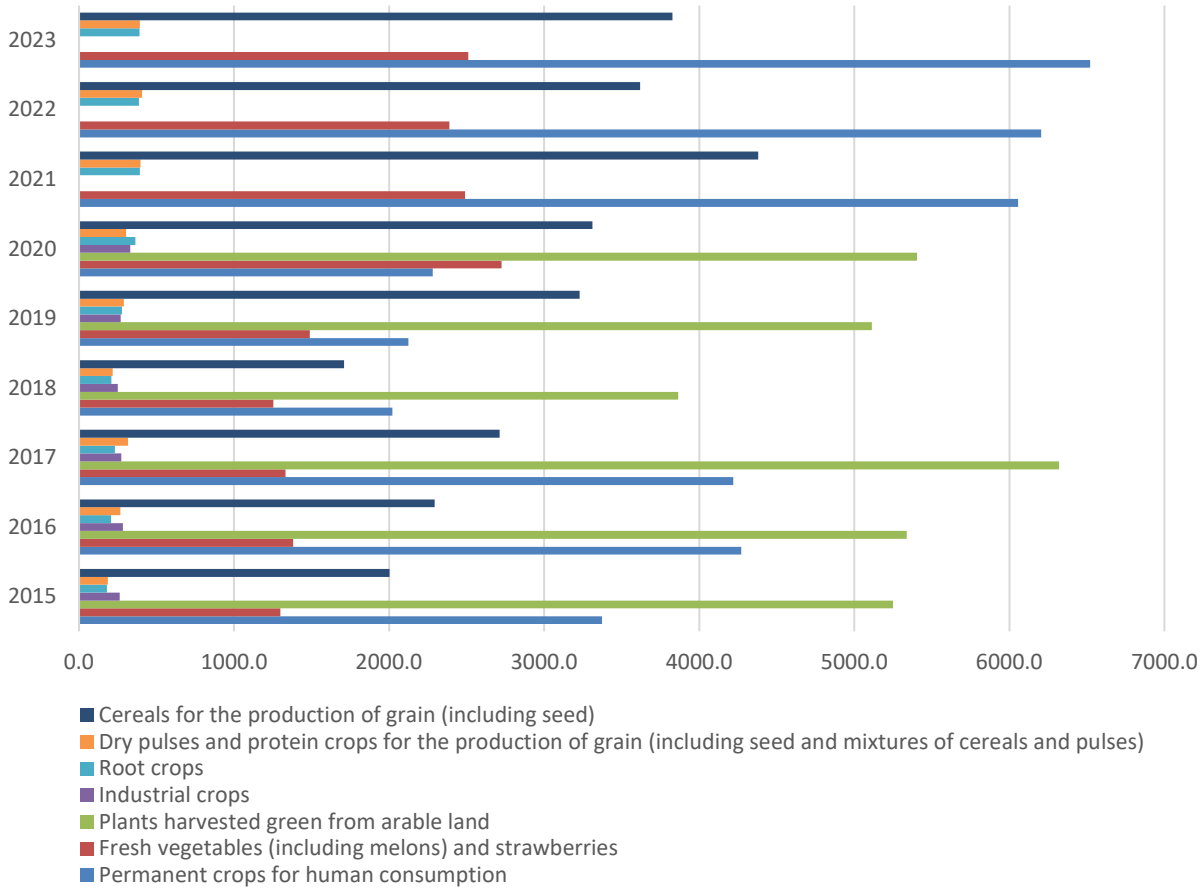

Figure 2. Organic production of the European Union by seven main product categories in 2015-2023 (thousand tonnes)
Source: Eurostat.

Between 2015 and 2023, there were significant changes in the volume of organic production. For industrial crops and green crops harvested from arable land, we conducted the analysis only up to 2020 due to the lack of more recent data. We observed the largest changes in the case of permanent crops for human consumption. This class includes fruits, berries and nuts, citrus fruits, grapes, olives and other permanent crops intended for human consumption. The volume of this product group increased from around 3 372 in 2015 to 4 219 thousand tonnes in 2017, and then fell to 2 021 thousand tonnes in 2018. During the COVID-19 pandemic, this group recorded an increase from 2 124 in 2019 to 2 280 thousand tonnes in 2020. In 2021, there was a significant increase to 6 056, and the volume of permanent crops intended for human consumption increased by another 200 000 tonnes when the Russian invasion of Ukraine began in 2022. The following year saw an increase of 300 000 tonnes. During the period under review, we observed a similar upward trend for dry legumes and protein crops intended for grain production. The production of fresh vegetables increased from 1 299 000 tonnes in 2015 to 1 381 000 tonnes in 2016. The increase in production continued in 2019-2020. During this period, the production of the group under review increased from 1 488 000 to 2 726 000 tonnes. In 2021, a decrease of approximately 230 thousand tonnes was recorded, and in 2022, a decrease of 102 thousand tonnes. However, in 2022-2023, the upward trend returned. The production volume of root crops changed in the same direction as that of fresh vegetables. The volume of cereal production increased from 2 003 000 tonnes in 2015 to 2 713 000 tonnes in 2017, while in 2018 there was a decrease

of approximately 1 000 000 tonnes. Starting in 2019, the trend changed, and the volume of the examined group of organic products increased from 3 230 thousand tonnes in 2019, through 3 310 thousand tonnes in 2020, to 4380 thousand tonnes. In 2022, there was a decrease in the volume of cereals by 761 thousand tonnes, while in 2023, there was an increase of 208 thousand tonnes (Figure 2).

The period of global turbulence (the COVID-19 pandemic and Russia's invasion of Ukraine) did not disrupt the high production rate of certain types of organic crops, *e.g.*, in the case of permanent crops and fresh vegetables. However, the production of three other studied crop groups (*e.g.*, root crops, dry pulses and protein crops for production of grain, cereals for production of grain) were more sensitive to global turmoil (Table 5).

Table 5. Annual average growth rate in production of selected categories of organic products in 2016-2023 (%)

Organic product category	2015-2019	2019-2023	2019-2020	2020-2021	2021-2022	2022-2023
Permanent crops for human consumption	-10.91	32.36	7.34	165.57	2.46	5.08
Fresh vegetables (including melons) and strawberries	3.47	13.95	83.16	-8.64	-4.11	5.07
Root crops	11.32	8.87	30.77	8.35	-2.00	-1.15
Dry pulses and protein crops for the production of grain (including seed and mixtures of cereals and pulses)	11.71	7.90	4.88	30.99	2.49	-3.72
Cereals for the production of grain (including seed)	12.68	4.33	2.51	32.31	-17.38	5.73

Source: own study based on Eurostat.

Moving on to the analysis of the demand for organic products, we examined per capita consumption of organic products. The analysis covered selected countries classified into different clusters distinguished according to the share of organic crops area in total farmland.

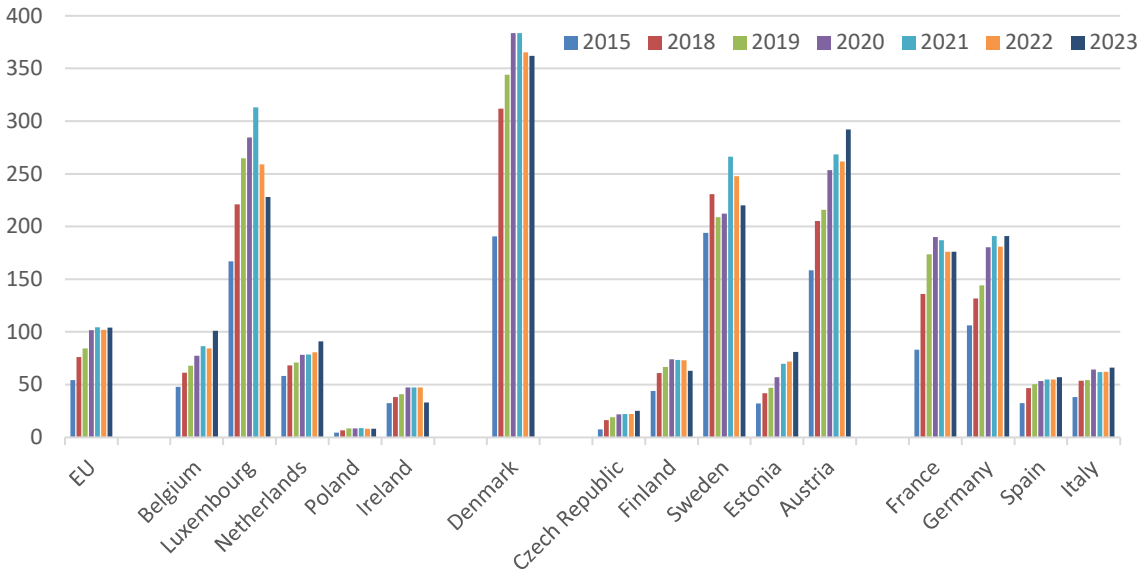

Figure 3. Organic consumption per capita in EU selected countries in 2015-2023 (EUR)
Source: own elaboration.

The per capita consumption of organic products increased during the study period in the countries analysed, except for 2022, when it decreased in several countries (France, Germany, Denmark, Finland, Sweden, Austria, Belgium, Luxembourg, Poland). The highest consumption of organic products throughout the years was recorded in Denmark and the lowest – in Poland. The following year, the downward trend in per capita consumption continued in Denmark, Sweden, Finland, Luxembourg, and Ireland. France and Poland maintained their per capita consumption levels in 2022 and 2023. Average per capita consumption in the EU fell in 2022 compared to 2021, but returned to 2021 levels in 2023. Germany ranked only 5th in terms of per capita consumption (behind Denmark,

Austria, Luxembourg, and Sweden), despite the largest organic market in the EU (Figure 3, 4), and the second largest in the world, after the US.

The data in Figure 4 shows that the largest organic markets in Europe saw growth in 2023, with Austria showing the highest growth and France showing the lowest. Among EU countries outside the main organic markets, the largest growth was recorded in Estonia (+13.0%), the Netherlands (+12.5%), and Belgium (+9.0%). Overall, retail sales of organic products increased by 2.9% in 2023, but have been highly volatile in previous years (Figure 5).

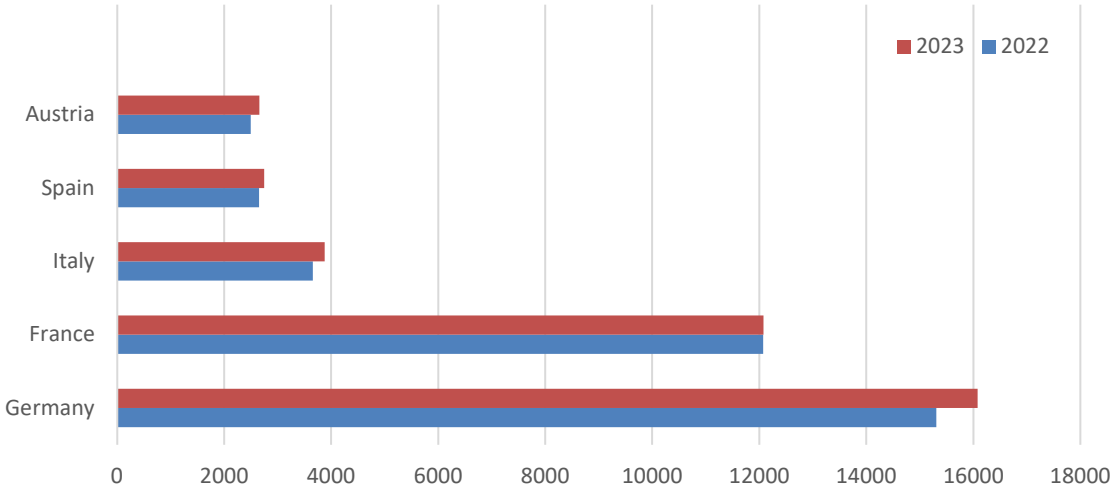

Figure 4. Top organic markets in the European Union in 2022-2023 (million EUR)
Source: own elaboration based on (Trávníček *et al*., Schlatter & Willer, 2025).

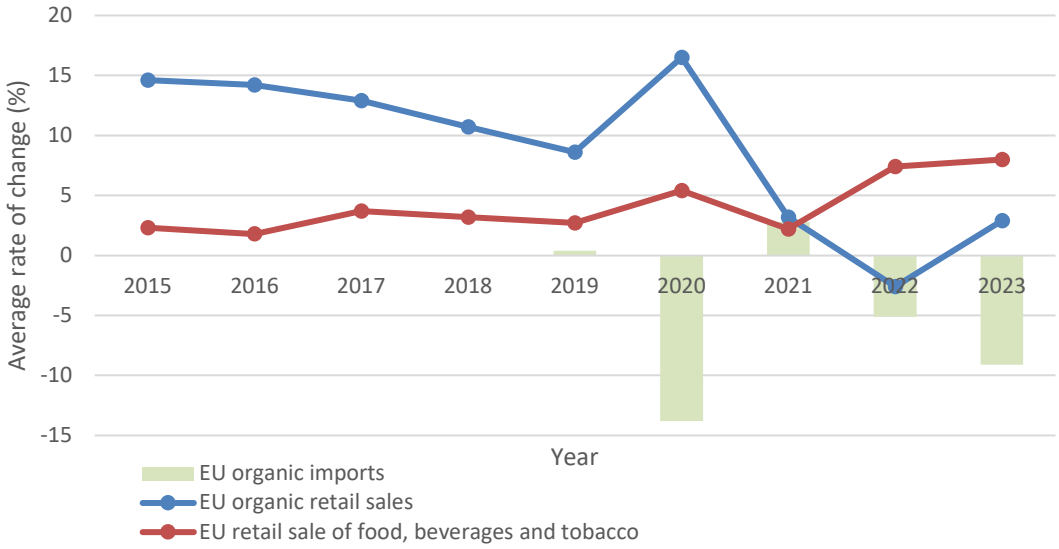

Figure 5. EU average rate of change of organic retail sales compared with total retail food, beverages and tobacco sales in 2015-2023 (y-to-y change, %)
Source: own elaboration based based on FiBL and Eurostat.

Retail sales of organic products in the EU accelerated rapidly in 2020, growing even faster than total retail sales of food, beverages and tobacco products. Despite a noticeable slowdown in organic sales growth in 2021, which fell to the levels recorded for overall food retail sales, organic sales did not decline during and after the pandemic. These results were a bit surprising, but we can explain them by the fact that consumers were staying home to eat, had more time to cook meals, and this resulted in them purchasing organic products more often and in larger quantities. At the same time, in 2020, we

observed a significant decline in organic product imports, probably related to disruptions in international supply chains during the pandemic (Figure 5).

The results of the analysis conducted for the years of the war in Ukraine showed the opposite market reaction. In 2022, there was a negative growth rate for organic products, while the total retail sales of food, beverages, and tobacco products increased. During the first two years after Russia invades Ukraine, there was a negative growth rate in imports of organic products, which amounted to approximately 5% in 2022 and deepened by another 4 percentage points in 2023. We may attribute this to rising living costs and high inflation, which have increased consumers' price sensitivity, causing them to pay closer attention to product prices when shopping. It is difficult to assess unequivocally whether the resilience of the organic market to external shocks was lower than that of other agri-food markets, especially since demand for organic products rebounded in 2023, with retail sales in the sector analysed growing by 2.9%. Moreover, the largest organic product markets in Europe have again recorded growth. However, the fact is that disruptions in supply chains caused a collapse in imports of organic products to the European Union during the pandemic. The decline in import volumes continued after Russia's invasion of Ukraine (Figure 5).

Table 6. Annual average growth rate of the EU organic retail sales in 2015-2023 (%)

Category	2015-2019	2019-2023	2019-2020	2020-2021	2021-2022	2022-2023
Organic retail sales	11.58	4.77	16.5	3.2	-2.6	2.9
Retail sale of food, beverages and tobacco	3.10	5.75	5.4	2.2	7.4	8.0
Organic import	n/a	-6.5	-13.8	2.8	-5.1	-9.1

Source: own study based on FiBL & Eurostat.

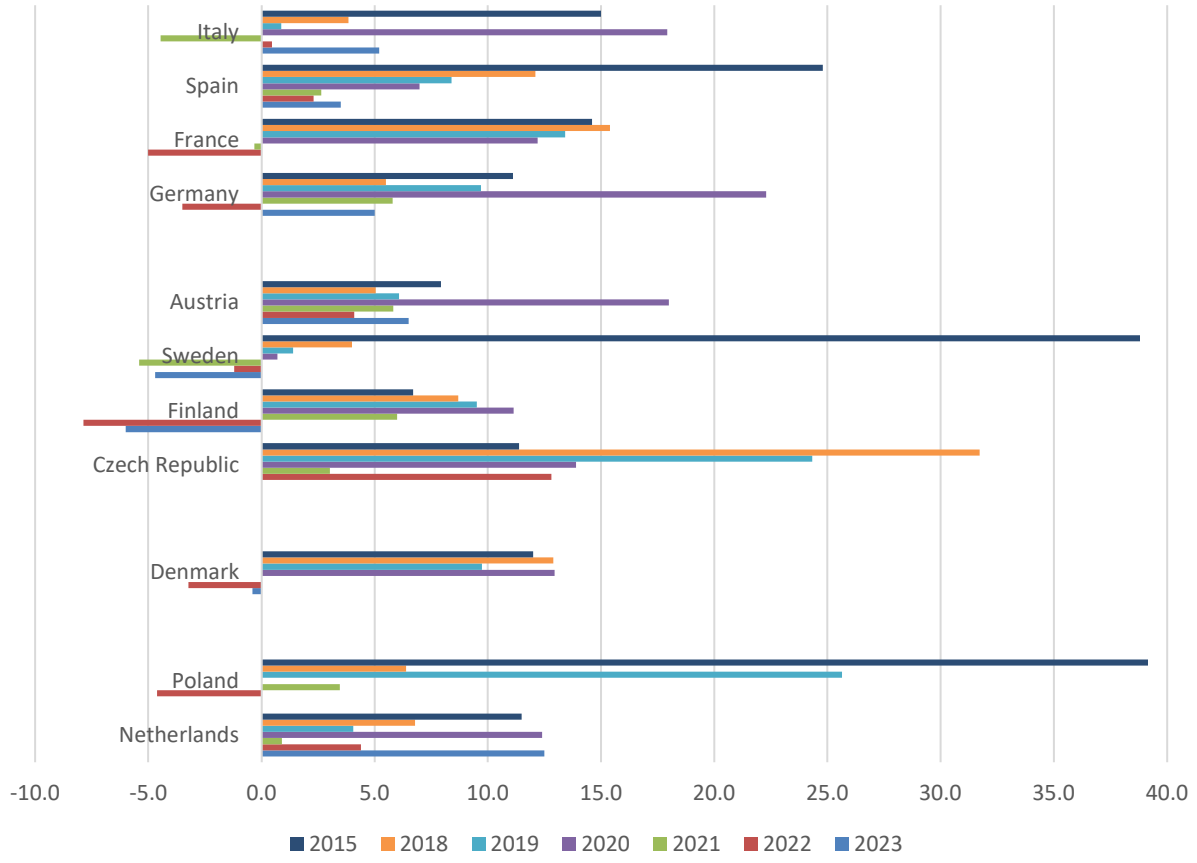

Figure 6. The organic retail sales rate of change for the selected member states in 2015-2023 (y-to-y change, %)
Source: own elaboration based on FiBL survey and on national data sources from certifiers and Eurostat.

The annual average growth rate of the EU organic retail sales fell significantly in 2019-2023 compared to 2015-2019. However, we observed the opposite trend for total retail sales of food, beverages, and tobacco, where the annual average rate of change increased during the years of global turmoil. Imports of organic goods were the most sensitive to global turbulences. The average rate of change in imports was negative throughout the studied period (Table 6).

The reactions of studied EU member states to the COVID-19 pandemic shock and the war in Ukraine were similar to the shifts observed across the EU. In none of the 11 EU analysed countries did the COVID-19 pandemic trigger a decline in organic food sales in 2020. In contrast, the Russia's invasion of Ukraine contributed to decline in organic sales in 6 out of the 11 EU countries studied (France, Germany, Sweden, Finland, Denmark, and Poland). For 2022, the data shows the largest increase in organic food sales in the Czech Republic. In some other countries (the Netherlands, Austria, Spain and Italy), there was a slight increase in organic food sales. In 2021, organic food sales declined in France and Sweden and continued to decline in 2022. The decline in retail sales of organic products continued in 3 of the 11 countries analysed (Denmark, Finland, and Sweden) in 2023. Sales of organic products remained at the same level as in the previous year in France, the Czech Republic, and Poland (Figure 6).

As with retail sales, EU member countries responded differently to organic imports during the COVID-19 pandemic and after Russia's invasion of Ukraine. We selected the same countries in Table 4 as those considered in Figure 6.

Table 7. The share of the country in organic import and rate of change for selected EU countries in 2018-2024 (y-to-y change, %)

Countries	The share of the country in organic imports							Rate of change (y-to-y change)					
	2018	2019	2020	2021	2022	2023	2024	2019	2020	2021	2022	2023	2024
Austria	1.3	1.0	1.1	1.2	1.9	2.3	1.6	-21.0	8.4	14.9	44.6	9.3	-26.5
Czechia	1.1	0.7	0.9	1.0	1.2	0.7	0.9	-32.3	25.4	20.2	12.6	-51.0	40.5
Denmark	4.7	4.2	2.9	2.1	2.4	2.8	3.2	-5.3	-32.0	-24.8	3.8	9.2	20.2
Finland	0.6	0.7	0.7	0.6	0.5	0.5	0.4	26.2	-2.6	-12.9	-8.1	-20.6	-2.0
France	7.9	8.4	9.8	9.5	10.2	9.2	7.4	12.6	14.1	-1.1	2.1	-17.6	-14.3
Germany	15.8	15.2	17.6	18.0	16.5	16.8	16.2	1.2	13.6	5.2	-13.1	-7.2	2.2
Italy	6.9	6.3	8.5	7.8	6.5	10.0	10.0	-2.9	30.9	-4.7	-21.0	39.7	6.1
Netherlands	35.2	36.4	30.7	32.9	36.3	32.1	35.4	8.9	-17.4	10.2	4.6	-19.6	17.3
Poland	0.7	1.0	1.3	1.3	1.2	1.1	1.2	51.5	23.2	3.6	-12.0	-16.6	11.0
Spain	2.9	3.5	4.0	3.2	3.2	3.6	3.0	27.1	12.0	-16.8	-5.9	1.4	-11.8
Sweden	6.2	6.7	6.4	6.4	5.6	5.6	4.6	13.6	-5.8	2.5	-16.4	-9.3	-13.3

Source: own study base on EC Agricultural and rural development, 2025.

All selected 11 EU Member States, including representatives of different groups in terms of market importance, accounted for over 80% of the EU's organic imports. The COVID-19 pandemic and Russia's invasion of Ukraine impacted imports of organic products. The analysis showed that Russia's invasion of Ukraine contributed more to the decline in imports than the COVID-19 pandemic (Table 7).

The EU remains dependent on imports in many agri-food commodity groups, mainly fruit and nuts, oilseeds and protein crops, and cereals. Categories of imported organic commodities showed varying levels of resilience to the COVID-19 pandemic and Russia's invasion of Ukraine. During the COVID-19 pandemic, negative growth was recorded in five out of nine categories. The most vulnerable group turned out to be arable crops and plant-based products, including cereals, oilseeds and protein, and sugar and isoglucose group. Russia's invasion of Ukraine contributed to changes in all categories of imported organic commodities (Table 8).

As already mentioned, organic farming can be an attractive alternative to conventional farming, especially among agricultural entrepreneurs looking for new market opportunities. The results of the analysis of the number of operators seem to confirm the growing interest in this form of farming. The number of producers in organic farming has increased over the analysed period from approximately 265.7 thousand in 2015 to 434.6 thousand in 2023. As the organic market grew, the number of pro-

cessors, exporters, and importers also increased. The number of the companies exporting organic commodities grew two and a half times (from 1957 in 2015 to 4898 in 2023). More importers supplied the EU market with the organic commodities. The number of entrepreneurs dealing with imports was higher than the number of exporters, but it increased at a slower rate (from 3512 in 2015 to 6727 in 2023). The organic processors constituted a large group of enterprises operating on the EU market. Their number rose from 52178 in 2015 to 89379 in 2023 (Table 9).

Table 8. Share of organic agri-food import volumes and rate of growth (y-to-y change) by class and key-product categories in 2018-2024 (%)

Class and category	Share of organic agri-food imports							Rate of growth (y-to-y change)					
	2018	2019	2020	2021	2022	2023	2024	2019	2020	2021	2022	2023	2024
Fruit, vegetables and olive oil	39.0	41.1	44.5	46.6	46.3	47,8	47.9	10.8	6.3	6.8	-5.7	-5.8	6.4
Fruit and nuts	29.7	31.7	35.4	37.0	37.1	38.9	39.2	12.1	9.5	6.6	-4.8	-4.6	7.3
Preparations of fruit, nuts and vegetables	5.2	4.9	4.8	5.2	5.2	5.0	5.0	-0.7	-5.5	11.2	-3.9	-13.7	7.6
Arable crops and plant based poducts	50.1	47.7	42.5	38.0	39.3	38.2	39.0	0.0	-12.5	-8.8	-1.8	-11.4	8.3
Oilseeds and protein crops	19.7	20.0	17.9	16.1	18.0	17.0	16.8	6.5	-12.2	-8.4	6.6	-14.2	4.9
Cereals	17.9	13.8	10.5	8.9	9.2	10.2	10.5	-19.1	-25.4	-13.6	-1.5	0.6	9.5
Sugar and isoglucose	7.4	8.8	8.2	7.4	7.1	6.2	6.3	25.4	-8.3	-8.5	-8.8	-20.8	7.8
Coffee, tea, cocoa and spices	8.4	8.6	9.7	10.1	10.2	10.1	8.8	6.7	11.5	5.8	-3.6	-10.3	-7.3
Coffee, tea, cocoa and spices	8.4	8.6	9.7	10.1	10.2	10.1	8.8	6.7	11.5	5.8	-3.6	-10.3	-7.3
Wine, beverages and food preparations	1.9	2.0	2.5	3.1	2.9	2.5	2.6	10.1	22.8	24.7	-10.8	-22.6	12.9
Mixed food preparations and ingredients	1.2	1.4	1.8	2.3	2.2	1.9	2.1	16,8	32,9	28.2	-9.1	-22.0	17.7
Wine and wine based products	0.6	0.6	0.6	0.6	0.6	0.4	0.4	-4.5	4.8	1.4	-13.2	-29.0	4.2
Non-edible	0.6	0.7	0.7	2.1	1.3	1.4	1.7	15.2	1.9	216.1	-44.0	1.2	28.4
Non-edible for technical use	0.5	0.5	0.6	0.7	0.7	0.6	0.7	11.7	19.8	17.3	-3.1	-21.4	12.9

Source: own study based on EC Agricultural and rural development, 2025.

Table 9. The number of organic operators and the average rate of change (y-to-y change) in 2015-2023

Years	The number of organic operators				The average rate of change (y-to-y change)			
	Organic exporters	Organic importers	Organic processors	Organic producers	Organic exporters	Organic importers	Organic processors	Organic producers
2015	1957	3510	52178	265677				
2016	2059	3941	57202	291721	5.2	12.3	9.6	9.8
2017	2676	4504	63384	302131	30.0	14.3	10.8	3.6
2018	3152	5016	69368	321772	17.8	11.4	9.4	6.5
2019	3130	5559	74866	338212	-0.7	10.8	7.9	5.1
2020	3614	5878	77893	349509	15.5	5.7	4.0	3.3
2021	4126	6642	84452	384968	14.2	13.0	8.4	10.1
2022	4296	6505	87436	426688	4.1	-2.1	3.5	10.8
2023	4898	6727	89379	434577	14.0	3.4	2.2	1.8

Source: own study based on FiBL.

Interestingly, the number of producers, exporters, and processors did not decrease either during the pandemic or after Russia attacked Ukraine. However, in 2022, there was a noticeable decrease in the number of importers, probably due to the general decline in import activity related to disruptions in global supply chains. This might have been a temporary decline, as an increase in their number was already recorded in 2023. Global turbulence could have caused a slowdown in business activity in two groups of organic operators: organic importers and organic processors. On the other hand, there was a slight increase in organic producers. Organic operators proved to be more resilient to market turmoil caused by the COVID-19 pandemic than Russia's invasion of Ukraine (Table 9).

The growing interest in organic farming is a response to new trends in consumer behaviour in today's marketplace that are creating new business opportunities. Notably, there is a growing demand for organic products from eco-conscious consumers who are concerned about the environment and from the consumers desiring healthy and natural food. And many consumers in the European Union seem to make purchasing decisions based on environmental impact. According to Eurobarometer

study (2023), the majority of respondents across surveyed EU countries state that a product's environmental impact plays a 'very' or 'rather important' role in their buying choices, although the size of these majorities differs considerably from country to country with the largest shares recorded in Portugal, Italy, and Romania. Approximately 80% of respondents believe that choosing products with a reduced environmental footprint has a measurable positive effect on the environment; of these, 33% 'strongly agree' and 48% 'somewhat agree' with this view. A somewhat lower proportion, yet still representing a majority, indicated that they had actually purchased products specifically due to their reduced environmental impact, with 18% 'strongly agreeing' and 42% 'somewhat agreeing'. In 23 EU Member States, at least half of all respondents confirmed that they 'strongly' or 'somewhat agree' that they have made such environmentally motivated purchases. The countries with the highest levels of agreement on this point were Romania, at 78%, and Italy, at 74%.

Table 10. The value of the Pearson's correlation coefficient between the responsible choices of the purchased products in EI countries

Variables	Importance of environmental impact of the product on buying it	Buying products with a lower environmental impact makes a difference for the environment	Lower environmental impact makes consumers' decision on buying the products	Awareness of the EU Ecolabel	EU Ecolabel provides lower environmental impact	Frequency of buying products with ecolabels
Importance of environmental impact of the product on buying it	1.000	0.621*	0.821*	-0.069	0.672*	0.486*
Buying products with a lower environmental impact makes a difference for the environment	0.621*	1.000	0.794*	-0.308	0.611*	0.423*
Lower environmental impact makes consumers' decision on buying the products	0.821*	0.794*	1.000	-0.228	0.617*	0.613*
Awareness of the EU Ecolabel	-0.069	-0.308	-0.228	1.000	-0.197	0.036
EU Ecolabel provides lower environmental impact	0.672*	0.611*	0.617*	-0.197	1.000	0.303
Frequency of buying products with ecolabels	0.486*	0.423*	0.613*	0.036	0.303	1.000

Source: own study based on Eurobarometer.

The question arises whether this relatively high environmental awareness of EU consumers translates into a high awareness of the EU Ecolabel and their trust that products with the EU Ecolabel truly have a lower environmental impact than similar products on the market.

We conducted the correlation analysis using of the Pearson's correlation coefficient to examine the relationships between variables representing various consumers' attitudes and perceptions about organic products. We discovered that the importance of the environmental impact of the product in purchasing decisions is strongly positively correlated, among others, with a strong belief that buying products with a lower environmental impact makes a difference for the environment and with the declaration of purchasing products specifically because of their lower environmental impact, while it is not correlated with awareness of the EU Ecolabel (Table 10). This results from low general awareness of the EU Ecolabel. The findings indicate that, across the European Union, 48% of survey participants (had not previously encountered the EU Ecolabel logo, and 38% reported recognising it. Furthermore, 14% of respondents were uncertain as to whether they had come across the logo before. Among all surveyed countries, France stood out as the only one where a majority of participants (61%) confirmed having seen the EU Ecolabel logo.

At the same time, awareness of the Eco Label was not correlated with trust in the Eco Label and declared frequent purchases of EU Eco labelled products (Table 10). This may indicate some problems in ensuring the credibility of the eco-label as a reliable quality signal. In addition to promotional activities related to the eco-label, building greater credibility requires improving the control process conducted by independent certification bodies. Certifiers must be vigilant and succeed in revealing departures from standards and opportunistic behaviour to build up the reputation of quality assurance labels. Consumers will then be more willing to pay a premium price for products with organic quality labels, which will encourage the growth of the organic market.

CONCLUSIONS

Organic farming contributes to sustainable development, reducing the detrimental effects of agriculture on local and global environments and boosting ecological transformation towards more sustainable food systems. It combines the best sustainable practices with the market response to the demand of a growing number of consumers for natural and healthy products. The development of organic farming is high on the list of priorities of the European Union's environmental policy, as expressed, among others, in the 'Farm to Fork' strategy included in the Green Deal.

In the years 2015-2023, the organic farming sector in the EU has expanded steadily, in terms not only of the area used for organic farming but also of the overall number of organic operators registered in the European Union, which shows that it can be an attractive alternative to conventional farming. However, despite the noticeable development of organic farming in recent years, the EU's target to achieve 25% of total farmland under organic farming by 2030 seems far from being achieved. Further expansion of organic production will require appropriate EU policy, including promotional activities and appropriate financial support.

The analysis results show that the to the economic turbulence of recent years, caused by the COVID-19 pandemic and the Russian invasion of Ukraine affected the organic farming and demand for organic products, but in a different way in each of these crises, which was a rather unexpected result of the analysis. During the pandemic, organic food sales in the EU have accelerated rapidly, even faster than the total food sales, indicating the growing interest of consumers in purchasing healthy food of assured quality. The reaction to the war in Ukraine was opposite. The retail sales of organic products declined, especially in Germany, which is the largest market for organic products in the European Union. The decline in the growth rate of the organic products market was significantly greater than that of the overall agri-food market. The research provided certain evidence supporting both hypotheses, as the overall average growth rate of organic farmland and the organic market during the period of turmoil after 2019 was lower than in the previous period. However, they indicate a varied response of the organic market depending on the type of crisis (dynamic growth during the pandemic and a subsequent slowdown during the war in Ukraine) and the category of organic crops.

An opportunity for its further development is the growing ecological awareness of consumers in the European Union, most of which declare that the environmental impact of a product plays a significant role in their purchasing decisions. However, it is necessary to intensify promotional activities in this area that will increase awareness and recognition of the EU Ecolabel and those that will build trust in it by improving the control process carried out by independent certification bodies.

There are some limitations to our study that require consideration. We based the quantitative research on the FIBL and Eurostat data, which were not complete, as some countries did not report all information or do so with a delay. In addition, the effects of geopolitical tensions, especially Russian invasion of Ukraine, have not yet fully manifested themselves, and more time and continued research are needed to fully assess their impact on the development of organic farming and the organic products market.

Despite the limitations, this study contributes to expanding knowledge about changes in organic farming and the organic product market, which is especially important for producers, as it reveals possible market opportunities related to participation in more sustainable agri-food systems. It also highlights the need for further support and promotion of the development of sustainable agriculture by EU policymakers.

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The contribution share of authors was equal and amounted to 50% for each of them.
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Acknowledgements and Financial Disclosure

The authors would like to thank the anonymous reviewers for all their suggestions and valuable comments, which were very useful in improving the paper. Agnieszka Hajdukiewicz's part of publication was financed from the subsidy granted to Krakow University of Economics – Project no. 028/EEZ/2025/POT. Bożena Pera's part of publication was financed from the subsidy granted to Krakow University of Economics – Project no. 039/EEZ/2026/POT.

Use of Artificial Intelligence

The authors used deepl.com for proofreading.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Published by Krakow University of Economics – Krakow, Poland

International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.02

Private equity investments in early-stage financing during COVID-19

Josephine Gemson, Matthew Orcutt

ABSTRACT

Objective: This paper explores the trends of Private Equity (PE) investments and their financing strategies in early-stage financing during COVID-19. The questions asked are: How does a shock such as a global pandemic which led to a subsequent closure of every sector in every country affect the allocation of PE resources among portfolio start-ups? What are financing strategies of PE investors in such an environment?

Research Design & Methods: This study uses data sourced from S&P Global with all direct and completed investments by PE investors / sponsors between 2020 and 2022. Research methods to test the hypotheses include data visualisation, and regression and mediation analysis.

Findings: Data analysis indicates an initial muted performance in the first two quarters of 2020 in both number and volume of investments. The average investment was USD 3.48 million in 2020, to increased to USD 4.58 million in 2021, and increased again to USD 5.03 million in 2022, indicating increasing comfort among PE firms in investing within a changing environment. PE firms continued to invest in familiar regions including North America, Asia, and Europe, and showed selective participation through larger average investments in newer regions, such as the Caribbean. Seed financing was by far the largest financing stage both in terms of number (69% of sample) and volume (65% of sample) with pre-series B having largest average deal investments. Regression analysis revealed that foreign investments significantly influenced the relationship between offering type and deal size. While international offerings had a positive association with foreign investments, mediation analysis indicated that foreign capital ultimately decreased investment size.

Implications & Recommendations: This study highlights the resilience of global PE investments and their adaptive investment strategies during the COVID-19 pandemic. The rapid rebound in deal activity suggests that PE firms preferred investing in mature ecosystems and established sectors to position themselves to preserve value. Selective larger investments in emerging regions, such as the Caribbean, suggest opportunities for value creation. The mediating role of foreign PE investment on offering types and deal sizes indicates PE preference for simpler and lower-risk transactions during periods of heighted uncertainty.

Contribution & Value Added: First, this study enriches the literature PE financing and entrepreneurial activity. Second, it contributes to the growing literature on crises by examining the impact of COVID-19 on start-up financing. Third, this paper provides insights into strategic investing by PE firms during periods of heightened uncertainty. Finally, the examination of PE-investments in entrepreneurial activity adds to the study and practice of entrepreneurial finance by highlighting the role of foreign investments in deal making when faced with systemic risks and their strategies towards resilience and capital preservation.

Article type:	research article
Keywords:	Private Equity Investments; Start-up Financing; COVID-19 crisis; mediation analysis; foreign investment
JEL codes:	G24, G01, D08

Received: 21 September 2025 Revised: 25 April 2026 Accepted: 29 April 2026

Suggested citation:
Gemson, J., & Orcutt, M. (2026). Private equity investments in early-stage financing during COVID-19. *International Entrepreneurship Review,* 12(2), 27-45. https://doi.org/10.15678/IER.2026.1202.02

INTRODUCTION

The COVID-19 pandemic triggered a massive shock in economic markets the world over. At the onset of the pandemic in Q1 2020, governments and policy makers centred on the immediate measures to curtail the spread of the virus and protect the lives of citizens by restricting travel, closing public spaces, business centres and offices, and schools. Physical movement of people and goods were hindered, negatively affecting all industries including the financial systems of the world and how entrepreneurial deals were facilitated.

In 2019, however, PE firms worldwide had dry powder worth USD 2.5 trillion, money which was at an all-time high, and up 4.17% from the previous year, ready to be allocated. PE firms can be considered the most consummate deal makers operating today (Nolop, 2007), with their enormous capital in hand, and various strategies which could be employed in environments rife with uncertainty and information asymmetry.

In this study, we explore the trends of PE investments in early-stage financing between 2020 and 2022, and their response to the COVID-19 pandemic and its aftermath. It addresses the following questions: How does a shock such as a global pandemic which led to a subsequent closure of every sector in every country affect the allocation of PE resources among portfolio start-ups? What are financing strategies of PE investors in such an environment? Results indicate initial muted performance in deal volume and number followed by gradually recovery. PE investments flowed into tried and tested regions and sectors to preserve capital and select regions to grow revenue. Seed financing was the prevalent start-up type. Foreign investments were also notable, and international PE firms acting as "gatekeepers" that shaped deal structures and investment decisions. The rest of the paper is organized as follows. The next section provides a review of financing entrepreneurial start-ups and entrepreneurial activity during times of crises, with a focus on the COVID-19 pandemic. Next, the data used for the study is highlighted along with the methods used in this paper. It is followed by the analysis of data. The results of the analysis are subsequently presented and discussed. Finally, the study is summarized with concluding remarks and directions for future research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

COVID-19 and Other Financial Crises

The COVID-19 pandemic and the resulting crisis has had a plethora of negative connotations attached to it including being considered the worst economic downturn since the Great Depression in the 1930s (Gopinath, 2020), and the biggest crisis of modern times (Wojcik & Ioannou, 2020). It caused unprecedented disruptions to economic activity in every sector and in every country the world over (Goodell, 2020; Hassan *et al.*, 2020; Ludvigson *et al.*, 2020), and had even been labelled a 'Black Swan' event (Sequoia Capital, 2020; Taleb, 2007).

Bernake (1983) argued that crises events introduce shocks that ripple through the economy, causing financing systems to fail, and disrupting both local and international markets. Examples of crises over the last few decades include the Great Depression of the 1930s, the Technology Bubble of 2000, and the Global Financial Crisis of 2008. Bernake (2008) concluded that the Great Depression and the subsequent financial collapse affected monetary channels, disrupted worldwide mechanisms of credit, and even affected countries that did not have domestic banking crises.

The collapse of the Technology Bubble in 2000 had a large body of academic research limited to the United States, mostly due to the location of the crisis. Townsend (2015) concluded that venture capitalists (VCs) most exposed to the information technology sector were more likely to invest in non-information technology sector companies following the collapse. The study also noted that information technology-focused VCs with sufficient capital exhibited a similar shift, due to expected liquidity constraints in the future. Although the average funding per round increased during this period (De Vries & Block, 2010), the firms that received financing were in general, more mature than those funded before the bubble collapsed (Green, 2004; De Vries & Block, 2010).

The 2008 Financial Crisis caused a liquidity supply shock, leading to a collapse in available financing. Limited studies (Conti *et al.*, 2019) on the impact of the financial crisis suggest an overall negative impact on entrepreneurial activity.

Block *et al.* (2010) noted that capital commitments to US venture funds unexpectedly fell from USD 28.6 billion in 2008 to USD 15.2 billion USD in 2009, a 47% decrease from the previous year. Results also indicated a decrease in both the amount of capital raised per funding round (Block & Sandner, 2009; Block *et al.*, 2010; and De Vries & Block, 2011) and the number of financing rounds (Block & Sandner, 2009; Block *et al.*, 2010; and De Vries & Block, 2010; Conti *et al.*, 2019). Gemson (2024) concluded that PE firms showed heightened risk aversion during this period and, rather than exiting the market, altered deal selection parameters while choosing targets.

While the pandemic and its aftermath are rightfully characterised a crisis, academic literature emphasises important contrasts with earlier crises such as the Technology Bubble of 2000 and the Global Financial Crisis of 2008. Lagarde (2020) stressed that the crisis that arose from the pandemic is exogeneous, with sources detached from economic fundamentals.

Conditions just prior to the pandemic showed little indication of a slowdown in entrepreneurial financing. From the fundraising perspective, dry powder had steadily increased world-wide over the past decade. In 2019, the volume of global dry powder reached an all-time high of USD 2.5 trillion, up from USD 2.4 trillion in 2018.

On March 11th, 2020, the World Health Organization declared COVID-19 a global pandemic, triggering widespread economic shutdowns and severely disrupting entrepreneurial and financial systems. Howell *et al.* (2020) noted an immediate decrease in the number of funding rounds in the United States, between March and April 2020. However, they argue that possible funding decisions were more likely to be influenced by determinants rather than liquidity concerns. While past crises (2000 Tech Bubble and 2008 Financial Crisis) had liquidity constraints, the liquidity crisis during COVID-19 was relatively short-lived due to the aggressive intervention of central banks. Instead, economic shutdowns, unemployment, and solvency concerns became larger issues for businesses.

Global data indicates that as many as half of all small firms temporarily ceased trading since the lockdown and as many as 60% of small and medium-term enterprises SMEs were at risk of running out of cash reserves (Bartik *et al.*, 2020; Cowling *et al.*, 2020; Giupponi & Landais, 2020). Brown *et al.* (2020) found the volume of new equity transactions in the UK declined markedly following the outbreak of the COVID-19, with seed financing – capital to the most nascent entrepreneurial start-ups facing the greatest obstacles obtaining financing – being most acutely affected.

Early-stage Financings in Times of Crisis

Financing is an essential element of the start-up ecosystem. It provides the much-needed capital to firms that are often deemed unsuitable for traditional means of financing such as bank loans and other forms of debt. Such companies usually lack stable cash flows (Berger & Udell, 1998), have few tangible assets to warrant as collateral and could face the threat of operating losses for many years (Gompers, 1999) making them very risky. However, they are known to offer high potential returns and are vital to the economy by fostering radical innovation, technical advancement, employment growth, and higher aggregate incomes to society.

Capital in such environments comes from business angels and private equity (PE), including venture capitalists (VCs) (Hall & Lerner, 2010; Kerr *et al.*, 2014) who help create this impact (Mason, 1999; Samila & Sorenson, 2011; Nanda & Rhodes-Kropf, 2013) and are a key ingredient for the development and growth of innovative start-ups (Breschi *et al.*, 2021).

Beyond capital provision, early-stage financing is predicated on the need for a close engagement between entrepreneurs and investors (De Clercq & Sapienza, 2006) translating into relational interactions including oral pitches entrepreneurs undertake to secure investments (Clark, 2008), social impromptu meetings for coffee to emphasise crucial parts of the decision making process (Huang & Knight, 2017), and other activities that could generate soft information and reduce information opacity associated with start-ups (Shane & Cable, 2002) helping investors structure deals appropriately to ensure success.

Brown *et al.* (2020) opined that the unique nature of entrepreneurial finance may make it highly susceptible to shocks, such as one arising from the crisis after the Covid-19 pandemic. Gompers *et al.* (2022) demonstrated how the pandemic affected the overall strategy and operations of PE firms, requiring them to seek innovative ways to respond to heightened uncertainty. Based on a survey of more than 200 PE managers, the authors concluded that the industry adapted over time and from more "normal" times, for both preservation and creation of value.

The internationalization of PE is an ongoing trend (Aizenman & Kendall, 2008) with foreign PE firms contributing capital (Humphery-Jenner & Suchard, 2013) and stimulating international syndication and expansion across borders to build geographically diversified portfolios (Tykvova & Schertler, 2011), including investments in emerging markets. While PE investments have been shown to increase deal or project sizes (Gemson & Rajan, 2011) and provide certification effects (Megginson & Weiss, 1991), extant literature on foreign PE on domestic firms and performance provides mixed results (Rojec & Knell, 2018) with positive, negative, and neutral spillover effects that vary from region to region.

Studies highlight mechanisms influencing these outcomes, including the competition effect (Aldatmaz & Brown, 2020), the absorptive capacity of local firms to incorporate technology transfers (Scott-Kennel, 2004), and the level of foreign presence. Institutional environments and investment climates were key determinants of positive effects of foreign PE investment on the domestic PE sector. Accordingly, the positive effect of foreign investment on offering structure is based on the premise that favourable ecosystems provided participants with adequate environments for support, growth, and success. With PE investors placing a much greater weight on revenue growth during COVID-19 (Gompers *et al.*, 2022), it is expected that investors structure transactions strategically to manage fund performance. We hypothesise that foreign PE structure their investments through specific offering structures to protect scale and, consequently, investment size.

It is therefore hypothesised that foreign investment is expected to affect offering types positively (negatively), which in turn, increases (decreases) the size of the investment. PE investments into target companies can be through a domestic offering, an international offering, or a global and domestic offering. These offering represent transaction-level features agreed upon by the PE investor or sponsor and the target firm and may include foreign investor participation.

H1: The relationship between domestic offerings and investment size is mediated by foreign investment.

H2: The relationship between international offerings and investment size is mediated by foreign investment.

H3: The relationship between global and domestic offerings and investment size is mediated by foreign investment.

The mediating effect of foreign investment on deal offering and size of investment is described in Figure 1.

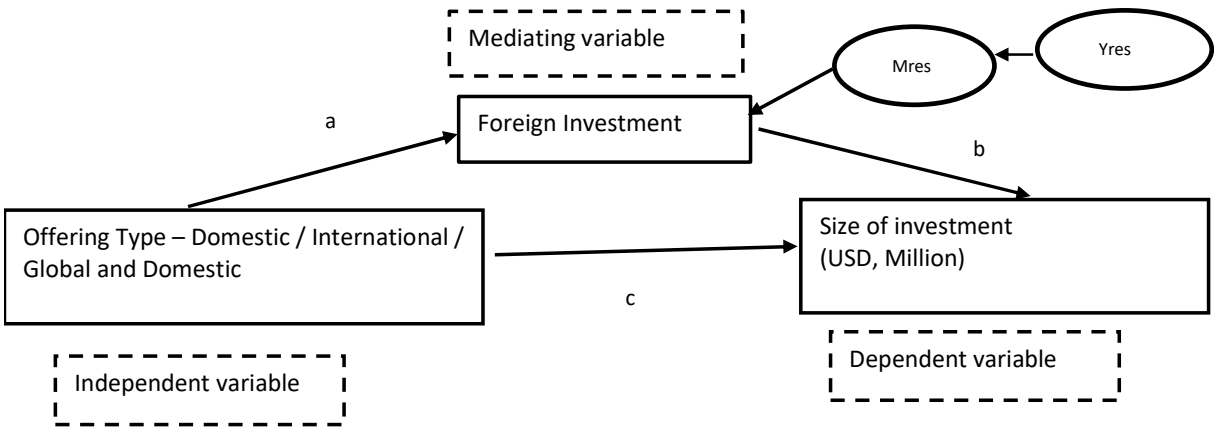

Figure 1. The mediating effect of foreign investment on offering type and size of investment
Source: own elaboration.

RESEARCH METHODOLOGY

The Sample

To examine PE investment strategies in entrepreneurial financing during the COVID-19 pandemic, data was sourced from S&P, covering all direct and completed investments by PE investors / sponsors between January 1, 2020, and December 31, 2022. This database contains details of completed PE investments globally, including investment date, portfolio company name, industry type, transaction type, transaction features, PE investor or sponsor, investment amount, and type of investment activity.

A capital investment by the PE investor or sponsor into a portfolio company (target) was taken as the unit of the analysis. This capital investment represents the transaction between the investee company (portfolio company / target) and the investor (PE investor(s) or sponsor(s)) and contains information about the parties in the transaction, financial arrangements, and deal characteristics. Details include name(s) of the PE investor or sponsor (investor), portfolio status, and activity, the portfolio company name (investee), the primary industry, and geographical region, deal amount (in USD, Million), and the portfolio status.

The final sample consisted of 12 123 PE investments, with a total investment value of USD 55 806.03 million. These investments span across 14 different industries across 8 different world regions and 100 different countries.

Summary Statistics

Table 1 presents summary statistics for the sample.

Table 1. Summary snapshot of PE investments in early-stage financing, 2020-2022

Time Period	Total Deals			With foreign PE investment		
	Number of deals	Volume of deals (USD, Million)	Average Size of Deal (USD, Million)	Number of deals	Volume of deals (USD, Million)	Average Size of Deal (USD, Million)
Qtr1, 2020	439	USD 1 463.17	USD 3.30	150	USD 534.52	USD 3.56
Qtr2, 2020	484	USD 1 640.25	USD 3.39	201	USD 737.67	USD 3.67
Qtr3, 2020	618	USD 2 164.02	USD 3.50	245	USD 1 055.03	USD 4.31
Qtr4, 2020	769	USD 2 842.73	USD 3.70	350	USD 1 452.86	USD 4.15
Qtr1, 2021	780	USD 3 086.37	USD 3.96	357	USD 1 575.90	USD 4.41
Qtr2, 2021	1 007	USD 4 530.56	USD 4.50	496	USD 2 497.88	USD 5.04
Qtr3, 2021	1 210	USD 5 492.2	USD 4.54	573	USD 2 822.31	USD 4.93
Qtr4, 2021	1 341	USD 7 140.34	USD 5.32	718	USD 4 349.50	USD 6.06
Qtr1, 2022	1 633	USD 8 199.13	USD 5.02	847	USD 4 377.74	USD 5.17
Qtr2, 2022	1 452	USD 7 132.09	USD 4.91	797	USD 4 620.42	USD 5.80
Qtr3, 2022	1 260	USD 5 812.23	USD 4.61	653	USD 3 114.45	USD 4.77
Qtr4, 2022	1 130	USD 6 302.94	USD 5.58	582	USD 4 113.73	USD 7.07
Total	12 123	USD 55 806.03		5 969	USD 31 252.00	

Source: own study of data, sourced from S&P Global.

An examination of Table 1 indicates a muted performance in investments in the first two quarters of 2020 in both number and volume of investments. Liquidity constraints were relatively short-lived, and number and volume of investments began to increase in pace from the third quarter of 2020 onwards, indicating that PE investors quickly adapted from more "normal" times (Gompers *et al.*, 2022). Q3 2020 clocked a 28% increase in number of deals and a 32% increase in volume of deals compared to Q2 2020, with similar increases in Q4 2020. While Q1 2021 had an increase in number and volume of deals, Q2 2022 showed sharp increases of 29% and 47% in number and volume as compared to the previous quarter. Declines in deal count were observed in the second, third, and fourth quarter of 2022; however, total volume rebounded in Q4 2022. Overall, PE investment activity in the start-up space followed an upward trajectory over the sample period.

Average investment size increased from approximately USD 3.48 million in 2020 to USD 4.58 million in 2021, and USD 5.03 million in 2022, representing a 67.7% increase from USD 3.33 million in Q1 2020 to USD 5.58 million in Q4 2022. Deals with foreign PE investment accounted for 49.24% by way of number and 56% by way of volume and followed similar pattern. Average deal size for transactions with foreign PE investment was USD 4.92 million, significantly larger as compared to USD 4.36 million for the full sample. Deals with foreign PE investment were significantly larger in volume and average deal size indicating their noticeable presence in deal activity.

Methods

This study examines the allocation of PE investments in start-up financing and analyses the determinants of PE investments during the COVID-19 pandemic. Specifically, it tests whether investment size depends on offering type and whether this relationship is mediated by foreign PE participation.

First, trends of PE activity were examined using data visualization techniques including, bar graphs and pie charts to illustrate changes in deal count, deal volume, and average deal size across world regions, industries, and financing stages. These visual tools facilitate intuitive interpretation of PE investment patterns in entrepreneurial financing.

Second, mediation analysis using linear regression was conducted to examine the determinants of deal size and explore how investment origins (foreign PE investments) mediate the relationship between deal offerings and size of the investment. The mediation framework proposed by Baron and Kenny (1986) was employed. In the first stage, the mediator was regressed on the independent variables; in the second stage, the dependent variable was regressed on the independent variable; and in the final stage, the dependent variable was regressed on both the independent variable and the mediator. While the independent variable was expected to show a statistical significance in the first two steps, in the third step, the independent variable turned non-significant, while the mediator emerged significant. Finally, the Sobel test was run to indicate the significance of the coefficients and standard errors.

The dependent variable is investment size, measured in 2015 US dollars. The mediating variable is foreign investment. Independent variables include domestic-only offering, foreign-only offering, and global and domestic offering, involving three sets of mediation analysis.

Variables examined in the mediation analysis included deal level characteristics such as foreign investment, domestic offering, international offering, and global and domestic offering which characterize the origin of the PE investment into the target.

Table 2 presents a list of variables used in the analysis.

The Hausman specification test (Hausman, 1978) was applied to assess potential endogeneity in foreign investments, domestic offerings, foreign offerings, and global and domestic offerings A Hausman 2-stage model was applied to these four variables, and the predicted values of these variables were estimated and used in the mediation analysis.

Table 2. Variables used in the analysis

Variable	Represents	Meaning
Variables representing investments		
INV	Investment size / capital infusion into a deal (USD, Million)	The amount of capital infusion by the PE investor(s) / sponsor(s) into a target company on a specified date, i.e., the deal amount. The deal size or the investment size is used to represent the level of risk surrounding the transaction
VOL	Volume of Investment (USD, Million)	The sum of capital infusions by PE investor(s) / sponsor(s)
AVGINV	Average investment size (USD, Million)	The average size of capital infusion by PE investor(s) / sponsor(s) in a particular period into a particular silo (industry / region)
MAXINV	Maximum investment size (USD, Million)	The maximum amount of capital into a deal by PE investor(s) / sponsors in a particular time period / industry / region
Variables representing deal level characteristics		
PEENTRY	First PE investment into a target	This is a binary variable: 1 represents if the investment represented the first time the PE investor invested into the target, 0 otherwise
INCSTAKE	An investment of a PE firm into a target that represents an increase or decrease in original stake	This is a binary variable: 1 represents if the investment represented an increase or decrease in the original stake, 0 otherwise
NOINVEST	The number of PE investor(s) / sponsor(s) in that investment	1 if the PE investor invested alone, >1 to represent the number of investors in the syndicate
REGULD	Regulation D	This is a binary variable: 1 represents if the investment had a Regulation D feature, 0 otherwise
DOMOFF	Domestic Offering	This is a binary variable: 1 represents if the investment was using a domestic offering, 0 otherwise
INTOFF	International Offering	This is a binary variable: 1 represents if the investment was made using an international offering, 0 otherwise
GLODOMOFF	Global and domestic offering	This is a binary variable: 1 represents if the investment was made using a global and domestic offering, 0 otherwise
Variables representing world regions		
AFRICA / AISA / CARIBBEAN / EUROPE / MIDEAS / NORTHAMER / SOUTHAMER / OCEANIA	Investment in countries located in Africa / Asia / Caribbean / Europe / Middle East / North America / South America / Oceania	
LOWINCOME	Investments in low-income countries	
Variables representing industry		
AGRI / BIOTECH / FINAN / FOOD / HEALTH / INDUS / INFRA / MANU / MEDIA / RETAIL / SERVICES / TECH / OTHERS	Investments in the agriculture / biotechnology and pharmaceuticals / financial / food industry / health industry / industrials / infrastructure and real estate / manufacturing / media / retail sector / services sector / technology sector / others	
Variables representing stage of investment		
ACCEL / ANGEL / CROWD / PRESEED / PREA / PREB / SEED	Investments in accelerator financing / angel financing / Crowd funding / Pre seed financing / Pre-Series A / Pre-Series B / Seed Financing	

Source: own study.

RESULTS AND DISCUSSION

PE Investments Across World Regions

Figure 2 presents the geographical distributions of PE investments in entrepreneurial ventures across eight different world regions: Africa, North America, South America, Asia, Caribbean, Europe, the Middle East, and Oceania. These regions are classified based on the location of the country in which the target company is headquartered. Panel A presents the number of deals over the period, while Panels B and C present the total deal value (USD, Million), and average deal size (USD, Million), respectively.

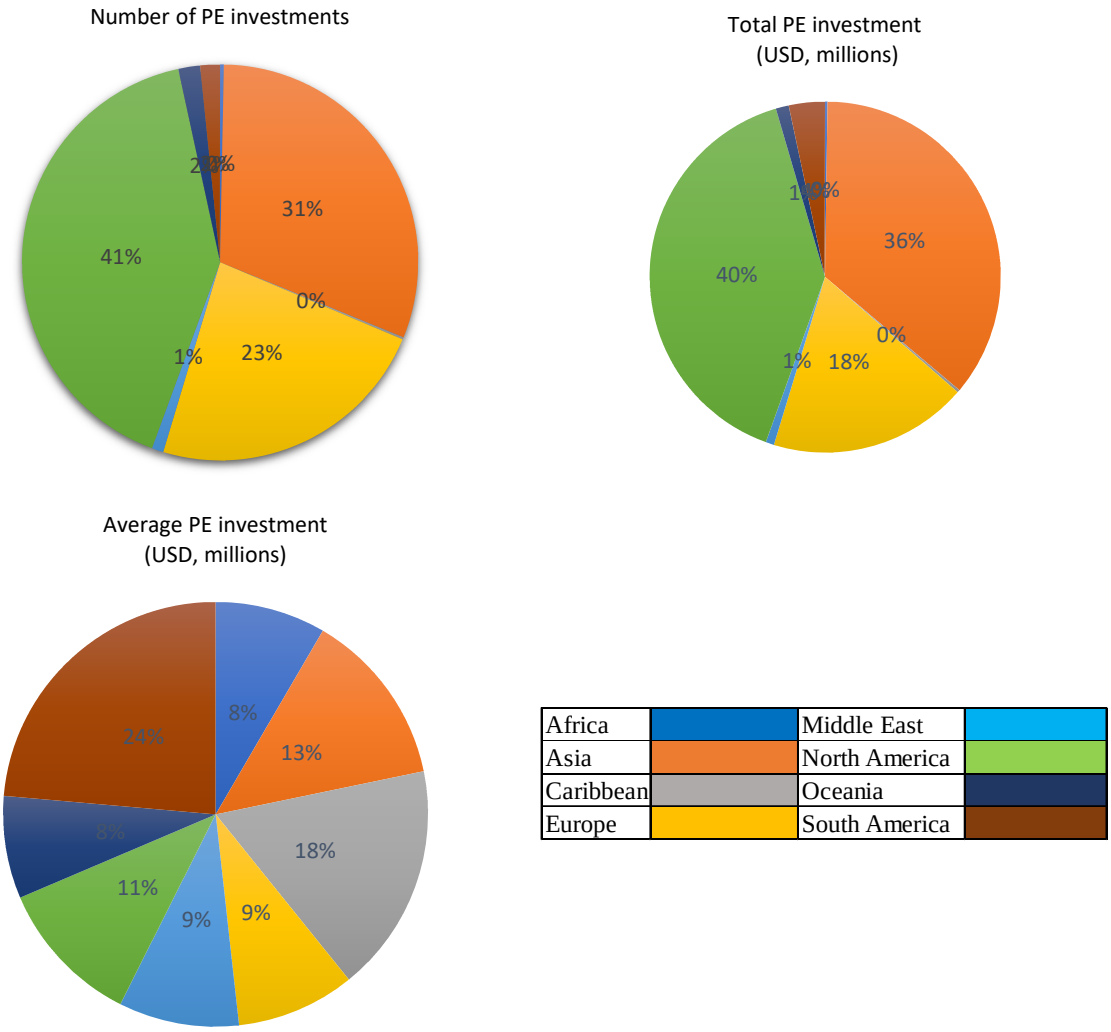

Figure 2. Summary of PE investments across world-regions, 2020-2022
Panel A: Total number of investments. Panel B: Total volume of PE investments (USD, Million), Panel C: Average investment size (USD, Million).
Source: own elaboration of data sourced from S&P Global.

Figure 2 provides insights into the geographical distribution of PE investments across regions. North America accounted for the largest percentage of deals, both in number (40.5% of the sample) and volume (39.5% of the sample) and comprises of USA, Canada, Mexico, and Bermuda. This result is unsurprising, as the United States has long been considered a leading start-up ecosystem. The findings confirm this characterisation, with 37.3% of PE-backed entrepreneurial firms in the sample being located in the United States. With its history of population, technology, entrepreneurial culture, and government regulation, the United States continues to lead globally in the start-up

space, with the technology sector the having number of PE investments (2361 deals). North America was followed by Asia (30.4% of number of investments and 35.5% of volume of investments) and then by Europe (23% of number of investments and 18.2% of volume of investments). While Europe has traditionally been viewed as a close rival to the United States in terms of the start-up ecosystem development, countries in Asia – particularly China and India – received sizable PE investments during the pandemic years. Collectively, North America, Asia, and Europe dominated the sample, accounting for 94% of deal count and 93.2% of total deal volume.

When average investment size is considered, the two largest investments during this period in South America and Asia were excluded from the analysis, as they skewed the sample being 275% and 248% larger than the average deal size, respectively. Average investments were highest in the Caribbean (notabily the British Virgin Islands, BVI), followed by Asia and North America. While nations in the Caribbean have made starting a business much easier in recent years, the BVI are also known to be a tax haven, attracting offshore corporations and investors. The BVI and Cayman Islands was also added to the Organization for Economic Corporation and Development (OECD) white list in 2009, enhancing their global reputation.

Average PE investments into targets in Asia were USD 5.36 million, approximately 19.6% larger than average PE investments in North America. This was followed by investments in Asia, indicating that PE firms were comfortable operating as foreign investors. Average PE investments in Europe were USD 3.63 million, 4.39% lower than in Africa and 3.52% lower than in the Middle East, placing Europe sixth among world regions in terms of average PE investment size.

PE Investments Across Industry Types

Figure 3 indicates that PE investments in start-up financing spanned a wide range of industries. While PE (as VC) was historically concentrated in investments in the technology sector, its extreme success has caused it to expand its breath of investments into other industries. Nevertheless, the technology sector continues to dominate PE entrepreneurial financing between 2020 and 2022, accounting for the largest number of deals by number (42.98%) and volume (39.31%). This was followed by the media sector (12.04% of deals and 9.67% of volume) and the healthcare sector (8.74% of deals and 7.66% of volume).

The technology space has, in the past few decades, been the prime industry space for startups with this trend persistent in the sample too. The pandemic years also saw a notable increase in investments in interactive media and services and home entertainment companies, increasing the presence of media sector in both number of deals and volume of PE investment. This could be attributed to the shifts in work patterns and lifestly priorities during lockdowns. Healthcare, another traditional hub for start-up activity, ranked third in terms on PE investment activity.

When average deal size is considered, the industrial sector, biotech and phamaceuticals sector, financial sector, infrastructure and real estate sector, and manufacturing sector commanded larger than average deal sizes. Several large investments in the semi-conductor subsector (average investment size of USD 17.3 million) contributed to higher average deal size in the industrial sector. While infrastructure and real estate require large capital infusions (Gemson & Rajan, 2015), PE typically invest in later stage financing in these sectors.

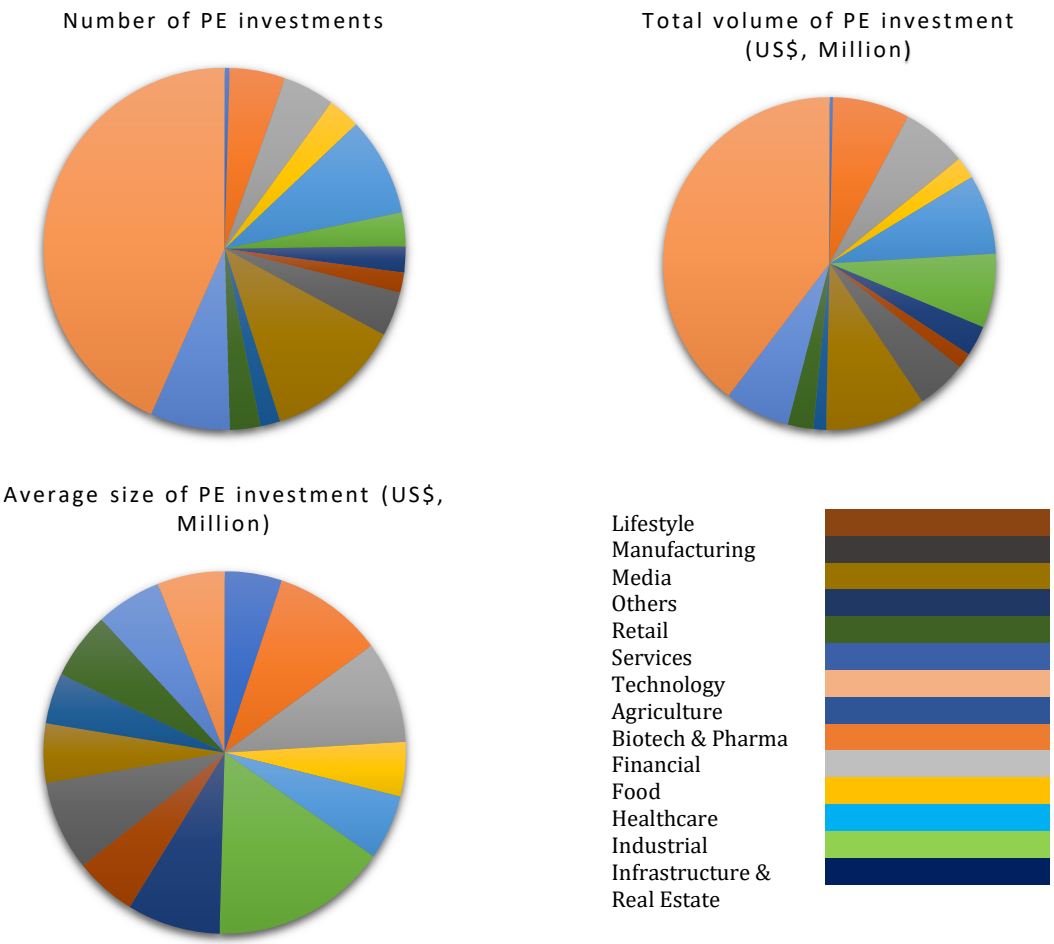

Figure 3. Summary of PE investments across industry types, 2020-2022
Panel A: Total number of investments. Panel B: Total volume of PE investments (USD, Million), Panel C: Average investment size (USD, Million). Panel C: Maximum investment size (USD, Million)
Source: own elaboration of data sourced from S&P Global.

PE Investments Across Start-up stages

Figure 4 presents the type or stage of entrepreneurial financing that received PE investments between 2020 and 2022. The financing stages include accelerator, bridge, angel financing, crowd-funding, pre-seed, pre-series A, pre-series B, and seed financing. Panel A presents the number of deals in each financing stage over the period in question 2020-2022, while Panel B and Panel C present the total deal amount (USD, Million) and the average deal amount (USD, Million) respectively of the sample.

Seed financing dominated PE investment activity, both in terms of number and volume. The sample included 8 354 rounds of seed financing, with a total value of approximately USD 36 billion, representing 69% of the deals by number and 65% of the deals by volume. The results from this study are different from Brown *et al.* (2020) who found that seed financing in the UK was most acutely affected by the crisis. Pre-series A ranked second with 1 655 deals contributing USD 9 966.67 million and angel funding with 1 037 deals totalling USD 5 721.92 million. The dominance of seed and pre-series A financing suggests PE investors favoured ventures that moved beyond ideation and validation phases, suggesting their preference for moderate-risk opportunities.

Accelerator and crowdfunding investments were rare (36 deals each),indicating that these models were not preferred by PE investors, perhaps due to information asymmetries and failure risks in these stages. While pre-series B accounted for only 1.1% of the number of deals in the sample and 3.7% of volume of deals in the sample, they recorded the highest average deal sizes with an average pre-series

B investment of USD 15.1 million, Despite abundant liquidity during this period, PE firms adopted to more selective screening and moderate-risk opportunities; however, they also indicated their willingness to make sizable investments once firms demonstrated scalability and resilience. In terms of average deal sizes, pre-series A investments were around USD 6 million while angel investments and crowdfunding investments were between USD 5 – USD 5.5 million. Pre-seed financing had the smallest average investment with USD 1.98 million.

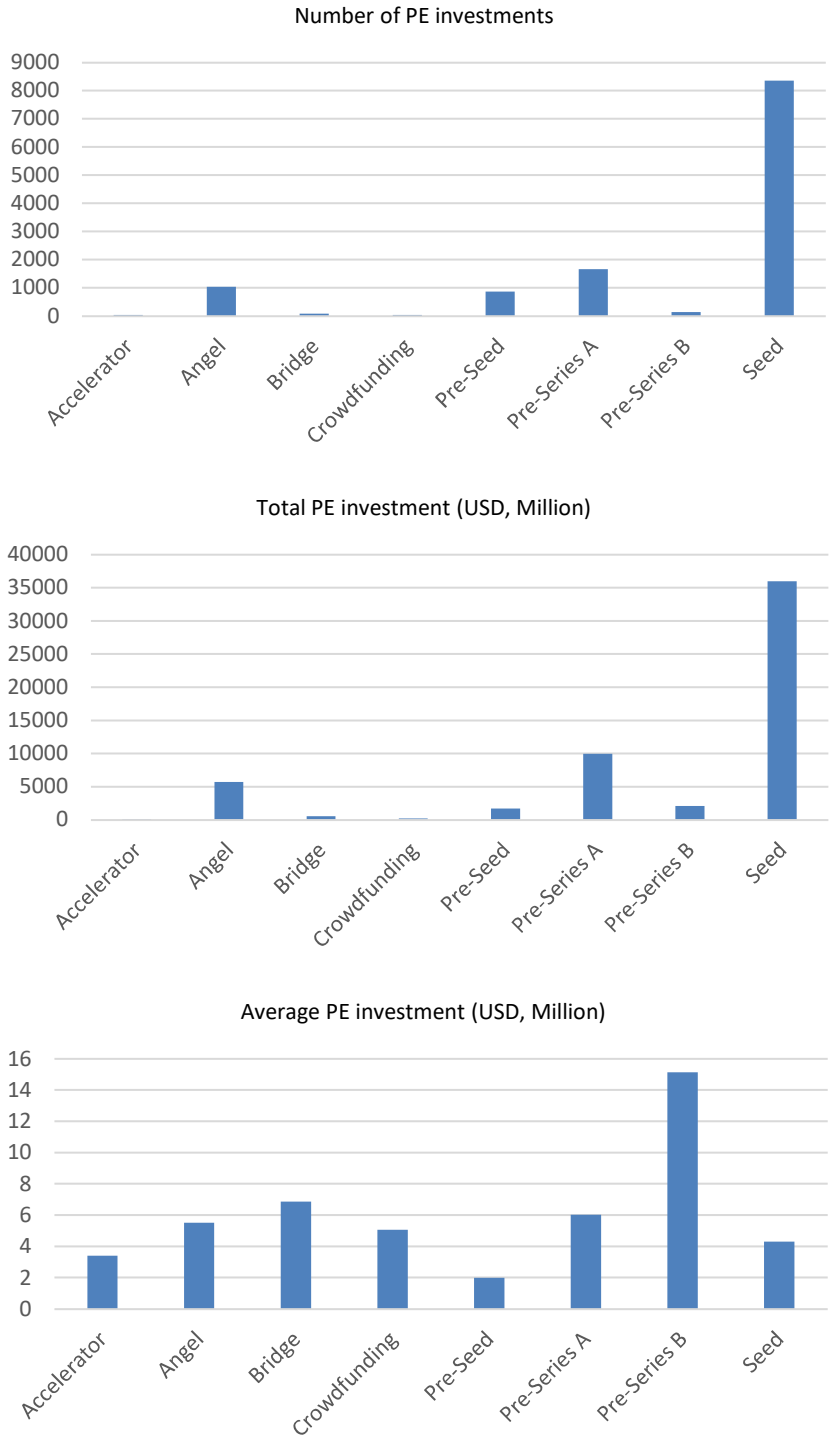

Figure 4. Summary of the data used for the analysis.
PE investments across various entrepreneurial financing stages between 2020-2022
Source: own elaboration of data sourced from S&P Global.

The Mediating Effect of PE Foreign Investment on Offering Type

Table 3 presents the results of the mediation analysis run on R.

The results indicate that domestic offerings (DOMOFF), negatively and significantly affect the mediator variable FOREIGN under Step 2, Model 1 (-4.06, $p<0.001$). When DOMOFF and FOREIGN are included jointly in the regression, DOMOFF has no direct effect on investment size (-7.692, $p>0.10$), while FOREIGN exerts a negative and significant coefficient (-7.505, $p<0.01$) on size of the investment. These results are unchanged, even when control variables are included, indicating full mediation. The Sobel Test confirms the significance of the indirect effect (Test statistic 2.744, Std Error 11.098, $p<0.05$).

Model 2 shows that international offerings (INTOFF) significantly and positively affect FOREIGN (3.832, $p<0.001$). When INTOFF and FOREIGN are jointly included in the regression, INTOFF loses significance (-10.441, $p>0.10$), while FOREIGN retains a negative and significant coefficient (-5.024, $p<0.05$) on size of the investment, indicating a full mediation. When control variables are included, INTOFF has no direct effect (-7.149, $p>0.10$), indicating a full mediation, while FOREIGN exerts a negative but non-significant coefficient (-3.248, $p>0.10$) on size of the investment. The Sobel Test confirms the significance of the indirect effect (Test statistic -2.512, Std Error 7.644, $p<0.05$).

Model 3 indicates that global and domestic offerings (GLODOMOFF) positively and significantly affects FOREIGN (2.488, $p<0.001$). When GLODOMOFF and FOREIGN are jointly included in the regression, it is found that GLODOMOFF continues to retain its significance, although it emerges with a negative coefficient (-34.254, $p<0.001$). The magnitude of the coefficient increased (-20.954 to -34.254), indicating no partial mediating effects. When control variables are considered, GLODOMOFF was still negatively significant (-31.615, $p<0.01$). The increasing magnitude of the coefficient suggests no mediating effect, indicating that FOREIGN does not mediate the relationship between global and domestic offerings and investment size.

The regression analysis to examine determinants of size of PE investment indicated a mediating relationship between offering type and foreign investment. Foreign investments acted as a mediator with respect to types of offerings. Both purely domestic offerings and purely international offerings are positively mediated to the size of investment. However, an offering which has both global and domestic features is not affected by the present of foreign investment.

Foreign investments significantly influenced the relationships between offering type and deal size. In both domestic offerings and international offerings, the presence of foreign investment reduced deal sizes, suggesting cross-border capital was more cautious. Domestic capital lost their significance when foreign investments were introduced indicating that these markets relied on foreign backing to sustain large transactions for credibility and liquidity. Such markets had lower deal valuations and lacked depth and appetite to sustain large PE transactions without foreign investments. While international offerings had a positive significance with foreign investments, mediation analysis indicated that foreign capital ultimately decreased investment size. Investors seemed more cautious and muted when creating value to scale market opportunities. Foreign investment did not mediate the relationship between global and domestic investment indicating that PE investors viewed these deals as too complex and perhaps exposed to systemic risks.

The non-significance of Regulation D indicated that structural and / or regulatory deal features were not bottlenecks in determining deal sizes. Rather foreign investment acted as a gatekeeper of deal size. PE firms seemed to target resilient industries and middle-income markets while de-prioritising structures that were high-risk and required purely domestic funding.

Table 3. Results of the mediation effect of foreign investment on type of offering towards size of investment

Model 1 - Domestic Offering			Model 2 - International Offering			Model 3 - Global and Domestic Offering		
Step 1: Testing the effect of domestic offering on size of investment			Step 1: Testing the effect of international offering on size of investment			Step 1: Testing the effect of global and domestic offering on size of investment		
Number of observations	12123		Number of observations	12123		Number of observations	12087	
Prob >F	0.002		Prob >F	0.0008		Prob >F	0.0000	
R square	0.0008		R square	0.0009		R square	0.0021	
Adjusted R square	0.0007		Adjusted R square	0.0008		Adjusted R square	0.0020	
Variable	Coefficient (Standard Error)		Variable	Coefficient (Standard Error)		Variable	Coefficient (Standard Error)	
DOMOFF	22.762 *** (7.370)		INTOFF	-29.691 *** (8.865)		GLODOMOFF	-20.954 *** (4.130)	
CONST	1.113 (1.141)		CONST	5.624 *** (0.344)		CONST	7.138 *** (0.524)	
Step 2: Testing the effect of domestic offering on foreign investment			Step 2: Testing the effect of international offering on foreign investment			Step 2: Testing the effect of global and domestic offering on foreign investment		
Number of observations	12123		Number of observations	12123		Number of observations	12087	
Prob >F	0.0000		Prob >F	0.0000		Prob >F	0.0000	
R square	0.6940		R square	0.4277		R square	0.8370	
Adjusted R square	0.6940		Adjusted R square	0.4277		Adjusted R square	0.8369	
Variable	Coefficient (Standard Error)		Variable	Coefficient (Standard Error)		Variable	Coefficient (Standard Error)	
DOMOFF	-4.06 *** (0.024)		INTOFF	3.832 *** (0.040)		GLODOMOFF	2.488 *** (0.010)	
CONST	1.115 *** (0.004)		CONST	0.361 *** (0.002)		CONST	0.191 *** (0.001)	
Step 3: Testing the effect of domestic offering and foreign investment on size of investment			Step 3: Testing the effect of international offering and foreign investment on size of investment			Step 3: Testing the effect of global and domestic offering and foreign investment on size of investment		
Number of observations	12123	12123	Number of observations	12123	12123	Number of Observations	12087	12087
Prob >F	0.0002	0.0000	Prob >F	0.0002	0.0000	Prob >F	0.0000	0.0000
R square	0.0014	0.0145	R square	0.0014	0.0145	R square	0.0023	0.0153
Adjusted R square	0.0012	0.0124	Adjusted R square	0.0013	0.0124	Adjusted R square	0.0021	0.0132

Model 1 - Domestic Offering			Model 2 - International Offering			Model 3 - Global and Domestic Offering		
FOREIGN	-7.505 *** (2.735)	-5.249 * (3.068)	FOREIGN	-5.024 ** (2.000)	-3.248 (2.623)	FOREIGN	5.345 (3.761)	7.265 * (4.349)
DOMOFF	-7.692 (13.320)	-6.642 (13.362)	DOMOFF			DOMOFF		
INTOFF			INTOFF	-10.441 (11.715)	-7.149 (11.803)	INTOFF		
GLODOMOFF			GLODOMOFF			GLODOMOFF	-34.254*** (10.227)	-31.615*** (10.460)
AFRICA		2.108 (1.870)	AFRICA		2.084 (1.868)	AFRICA		2.447 (1.876)
ASIA		2.310* (1.278)	ASIA		2.311* (1.278)	ASIA		2.473* (1.283)
CARIBBEAN		2.736 (4.009)	CARIBBEAN		2.726 (4.009)	CARIBBEAN		2.596 (4.014)
EUROPE		0.558 (1.242)	EUROPE		0.555 (1.242)	EUROPE		0.619 (1.247)
MIDEAS		1.891 (2.072)	MIDEAS		1.872 (2.071)	MIDEAS		2.180 (2.077)
NORTHAMER		0.970 (1.232)	NORTHAMER		0.959 (1.233)	NORTHAMER		0.986 (1.237)
SOUTHAMER		8.088*** (1.827)	SOUTHAMER		8.069*** (1.826)	SOUTHAMER		8.219*** (1.834)
LOWINCOME		-2.268*** (0.646)	LOWINCOME		-2.253*** (0.645)	LOWINCOME		-2.338*** (0.648)
AGRI		-0.122 (2.501)	AGRI		-0.125 (2.500)	AGRI		-0.195 (2.503)
BIOTECH		2.944** (1.045)	BIOTECH		2.951** (1.045)	BIOTECH		2.850** (1.048)
FINAN		2.724** (1.074)	FINAN		2.722** (1.073)	FINAN		2.709** (1.076)
FOOD		-0.351 (1.206)	FOOD		-0.352 (1.206)	FOOD		-0.342 (1.207)
HEALTH		0.375 (0.932)	HEALTH		0.380 (0.932)	HEALTH		0.305 (0.934)

Model 1 - Domestic Offering			Model 2 - International Offering			Model 3 - Global and Domestic Offering		
INDUS		6.750*** (1.198)	INDUS		6.760*** (1.198)	INDUS		6.749*** (1.201)
INFRA		2.143* (1.295)	INFRA		2.149* (1.295)	INFRA		2.071 (1.300)
MANU		1.944* (1.104)	MANU		1.955* (1.104)	MANU		1.911* (1.107)
MEDIA		0.175 (0.893)	MEDIA		0.175 (0.893)	MEDIA		0.168 (0.895)
RETAI		0.898 (1.236)	RETAI		0.899 (1.236)	RETAI		0.884 (1.238)
SERVI		0.502 (0.973)	SERVI		0.503 (0.973)	SERVI		0.498 (0.975)
TECH		0.629 (0.803)	TECH		0.629 (0.803)	TECH		0.583 (0.804)
PEENTRY		0.504 (0.466)	PEENTRY		0.496 (0.466)	PEENTRY		0.564 (0.467)
INCSTAKE		0.312 (0.605)	INCSTAKE		0.317 (0.605)	INCSTAKE		0.506 (0.610)
NOINVEST		0.712*** (0.100)	NOINVEST		0.710*** (0.100)	NOINVEST		0.705*** (0.100)
REGULD		0.480 (0.562)	REGULD		0.479 (0.562)	REGULD		0.360 (0.565)
CONST	9.478 ** (3.255)	3.766 (3.601)	CONST	7.436 *** (0.799)	2.018 (1.868)	CONST	6.115 *** (0.890)	0.324 (1.948)
Sobel Test			Sobel Test			Sobel Test		
Test statistic	2.744		Test statistic	-2.512		Test statistic	34.161	
Std Error	11.098		Std Error	7.664		Std Error	0.389	
p-value	0.006		p-value	0.012		p-value	0.000	

*** significant at 99% CI, ** significant at 95% CI, * significant at 90% CI – A test of the statistical significance of the mediation effect was done using bootstrapping in R. Please contact the authors for more details on this analysis.

Source: own study.

CONCLUSIONS

This study examined PE investments in early-stage financing by analysing allocation of PE funds and PE investing strategies during the COVID-19 pandemic. We observed and analysed trends in global PE investments and the mediating effect of the foreign PE investor, influencing deal size in an effort to preserve and create value.

This study examined the allocation of PE resources among portfolio start-ups and the financial strategies used by PE firms during the COVID-19 pandemic when they held record volumes of dry powder. The pandemic constituted an exogeneous shock that caused expected levels of divergence, including limiting physical movement of goods and services and disrupting startup financing. While early-stage financing is often constrained by capital and depends on close relationships between the entrepreneur and the investor, it was interesting to examine the allocation of investments and investing strategies, in terms of both value preservation and value creation.

After a temporary slowdown during the first two quarters of 2020, deal activity rebounded steadily in number, volume, and average size indicating that PE investors adapted quickly. PE investment activity was robust in mature ecosystems including North America, Asia, and Europe, and in tried and tested industries such as the technology sector. Such investments reflected strategies focused on preserving value. In terms of value creation, regions in the Caribbean (notable BVI) and Pre-series B financing witnessed larger average deal sizes suggesting selective PE participation and the ability to scale investments. Foreign PE investments played a mediating role influencing offering type and deal size. While structural and / or regulatory deal features did not emerge as bottlenecks in determining deal sizes, foreign investments significantly influenced domestic offerings and international offerings separately. Deals which were perceived too complex or exposed to systemic risk were avoided.

Thus, early-stage firms seeking PE investments during periods of crisis may benefit from demonstrating scalability and operational robustness. Policy makers aiming to attract PE capital should focus on reducing deal complexity and facilitating cross-border investment structures without regulatory frictions.

While this study examined trends of global PE investments early-stage financing, it was not free from challenges. While data was sourced from the S&P global database care was taken to verify the correctness of deals, this database may not capture all transactions. Further, this sample is limited to the extent of variables publicly available. Many deals had missing key variables and therefore, had to be dropped from the analysis. The availability of complete information and additional variables could certainly increase the insights that could be derived.

This study used data visualisation and the regression approach used by Baron and Kenny (1986) with mediation. The changing nature of R-square and Adjusted R-square values through Steps 1,2, and 3 is acknowledged. The high R-square and adjusted R-square value in Step 2 indicates that offering type strongly predicts foreign investment, while mediation analysis prioritises causal pathways and may not prioritising on maximising R-square. Having additional variables could provide data for more complex regression techniques to increase insights.

While this study provided insights into the investing trends, techniques, and strategies of PE firms during the COVID-19 crisis, this paper does not discuss subsequent global inflation, and interest rate increases that arose immediately after the pandemic. Future research could investigate these studies and whether the results of investing strategies are indeed favourable. Gompers *et al.* (2022) noted that PE firms expected the performance of their existing funds to decline, future studies could examine the performance funds in the course of such strategic decision making.

While adding to the literature on the impact of crises in financial markets, notably PE and start-ups, this study opens avenues to contrast and compare the impact of COVID-19 crisis on PE investment activity.

While financing start-ups and entrepreneurship provides rich rewards and growth to various economies, a deeper examination of the nature of PE financing strategies will shed insights into successful, private, entrepreneurial targets.

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The contribution share of authors amounted to 80% for first and corresponding author and 20% for second author. JG – conceptualisation, literature writing, methodology, calculations, discussion MO – methodology, calculations.

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Acknowledgements and Financial Disclosure

The authors would like to acknowledge financial assistance provided by the King's University College Research Grant for sections of this research.

Use of Artificial Intelligence

ChatGPT was used to proofread selected sections of this paper.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Published by Krakow University of Economics – Krakow, Poland

International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.03

Global supply chain disruptions and United States industries: Winners and losers

Marcin Pietrzak

ABSTRACT

Objective: The article aims to examine how pressure in the global supply chains affects United States industry-level equity returns and volatility, showing which sectors are winners and losers under high- versus low-pressure regimes.

Research Design & Methods: I adopted a quantitative design, modelling 49 U.S. industry-portfolio returns from January 1998 to June 2024 using a two-regime Markov-Switching autoregressive model with transition probabilities that are a function of the global supply chain pressure index (GSCPI).

Findings: Heightened pressure cleaves the cross-section: commodity and capital goods industries enjoy higher long-run returns, while defensives outperform only in tranquil periods, so the regime shift turns winners into losers and vice-versa. Moving into the high-pressure state also amplifies volatility across most sectors and pushes roughly half of them into negative territory, revealing a stark volatility-growth trade-off.

Implications & Recommendations: Regularly tracking supply-chain pressure allows investors and policymakers to anticipate shifts in sector-level risk-return profiles and to adopt broad, resilience-enhancing strategies to smooth market volatility and sustain economic stability.

Contribution & Value Added: The article introduces a regime-switching model linking global supply-chain disruptions to the U.S. sectoral equity dynamics, uncovering asymmetric effects on returns and volatility that linear models overlook.

Article type: research article

Keywords: global supply chains; equity market; volatility; autoregressive model; Markov-switching model

JEL codes: E32, F23, F47

Received: 28 May 2025 | Revised: 14 March 2026 | Accepted: 27 March 2026

Suggested citation:

Pietrzak, M. (2026). Global supply chain disruptions and United States industries: Winners and losers. *International Entrepreneurship Review,* 12(2), 47-63. https://doi.org/10.15678/IER.2026.1202.03

INTRODUCTION

Supply chains constitute a fundamental component of the global economy. Recent years have demonstrated the vulnerability of these networks to macroeconomic and financial stress, as evidenced by pandemic shutdowns, transportation bottlenecks, and geopolitical fragmentation, resulting in delays, shortages, and abrupt changes in input prices. Policy responses, including reshoring, 'friendshoring,' and resilience programs, reflect a growing consensus that supply-chain disruptions are recurring rather than exceptional events (Baldwin & Freeman, 2020; Ivanov, 2020). The central question is not whether supply chains are important, but rather which sectors are most exposed and whether certain industries systematically benefit when global supply chains experience stress.

Production network research shows that shocks affecting one firm or sector can spread to other parts of the economy through supplier-customer relationships and input-output linkages. These effects depend on a sector's role in the supply chain (Acemoglu *et al*., 2012; Barrot & Sauvagnat, 2016; Carvalho *et al*., 2021). The operations and finance literature shows that firm-level supply chain interruptions reduce shareholder value, hurt performance, and increase equity risk (Hendricks & Singhal, 2003; 2005a; 2005b).

Macrofinancial studies use aggregate supply chain pressure to study inflation and financial conditions (Benigno *et al*., 2022; Ascari *et al*., 2024; Ginn, 2024). However, we know little about how overall supply-chain pressure affects industry equity returns and volatility or if this link is nonlinear.

I addressed this gap by analysing how the GSCPI affects industry equity returns and volatility. I also identified which industries gain or lose as supply-chain pressure rises. In the analysis, I used monthly value-weighted returns for 49 U.S. industry portfolios (January 1998 to June 2024) in a two-regime Markov-switching AR(1) model. I modelled transition probabilities as a logistic function of the GSCPI (Filardo, 1994; Hamilton, 1989), varying over time. This allows expected returns, persistence, and volatility to differ between low- and high-pressure regimes, rather than assuming a constant linear relationship.

The findings show that high supply chain pressure leads to distinct shifts in sector performance rather than a general market decline. Commodity-linked and capital goods industries consistently outperform their own low-pressure-regime returns during periods of high pressure. In contrast, defensive and interest-rate-sensitive industries experience higher returns when supply chain pressures are low. Volatility rises under high-pressure conditions, but the extent of the increase varies across industries. These results highlight a clear shift in risk-return trade-offs as supply constraints intensify. Subsequent sections detail the data, methodology, results, and broader implications.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Supply chain issues became critical during COVID-19 and the recovery. Bottlenecks, input shortages, and delays tracked closely with big swings in inflation, output, and risk. Supply chain stress spreads through networks and affects industries differently. This section reviews evidence and develops hypotheses on how supply pressure impacts sector equity returns.

Macroeconomic research shows input-output links spread firm- or sector-level shocks upstream and downstream, amplifying fluctuations. In network models, local disruptions can have large macro effects if they hit central suppliers or vital input sectors. Acemoglu *et al*. (2012) show that network structure shapes volatility. Empirical studies find that disruptions move through production networks via supplier and customer ties. For example, Barrot and Sauvagnat (2016) use disasters to isolate supplier shocks that then affect customers, with larger effects on specific inputs. Carvalho *et al*. (2021) examined the Great East Japan Earthquake and documented the propagation of supply chain shocks and their macroeconomic impacts.

This suggests that supply chain disruptions affect industries unequally. Upstream, commodity-linked, and input sectors may face demand, price, or capacity shifts, unlike downstream or consumer-facing sectors. Network impacts can be nonlinear; bottlenecks and delays may cause persistent backlogs, not just short-term. Recent empirical work addresses these complexities by using composite global bottleneck measures rather than single indicators. For example, Benigno *et al*. (2022) developed the GSCPI, which combines transportation costs and delivery times into a single worldwide barometer of supply chain pressures.

A complementary macro literature links global supply chain pressures to inflation dynamics and persistence. For example, Ascari *et al*. (2024) found that global supply chain shocks have lasting effects on Euro Area inflation. Tillmann (2024) found that inflation's reaction to supply chain pressures can be asymmetric in Europe, suggesting that adverse shocks may have stronger, longer-lasting impacts than easing events. While these articles focus on inflation, they matter for asset pricing. Supply-driven inflation and activity affect discount rates and risk premia.

Finance and operations research on supply chains began with firm-level event studies. Hendricks and Singhal (2003) showed that supply chain 'glitches' reduce shareholder value. Later, they linked disruptions to weaker performance (2005a) and found longer-term underperformance in stock and higher equity risk (2005b). Hendricks *et al*. (2020) study stock reactions to supply chain shocks from the Great East Japan Earthquake.

The literature shows disruptions affect equity through cash-flow (lost sales, higher costs, or shortfalls) and risk (more uncertainty, higher returns demanded by investors) channels. But identifying firm events does not directly show how broad bottlenecks map onto industry-wide returns or nonlinear effects.

A growing body of asset-pricing research shows that economic linkages and network position shape risk and returns. Cohen and Frazzini (2008) show that information and shocks transmit between linked firms, creating predictable return patterns. Herskovic (2018) outlines production-network asset pricing: network structure creates priced systematic risk. Gofman *et al*. (2020) show that vertical position in networks affects risk premia. Firms farther from end consumers may have different exposure to shocks and returns.

Recent work links supply chain disruptions more directly to asset pricing. Smirnyagin and Tsyvinski (2022) developed a production-based asset-pricing framework. In this framework, 'supply chain disasters' are rare, large negative shocks. These shocks impact both macro outcomes and asset-pricing moments. This perspective supports the idea that supply constraint measures can proxy for shifts in disaster-like risks. It also helps explain why supply chain stress is associated with changes in expected returns and volatility.

Recent studies use supply-chain pressure indices (such as GSCPI) to examine financial outcomes. Hupka (2022) found that global pressure affects firm leverage during stress. Ginn (2024) linked global supply shocks to financial and equity instability. Bouri *et al*. (2025) showed that supply constraints predict international stock returns and volatility, supporting the idea that supply stress influences higher moments and tail risks. Riaz *et al*. (2025) offer sectoral evidence from China, noting negative links between global supply pressure and sectoral returns under certain conditions.

In sum, the literature suggests supply-chain pressure is a key state variable for financial markets. But we still lack clear evidence on how supply chain stress affects U.S. industry returns, and whether the effects are linear, homogeneous, or regime-dependent and varied across industries. Since supply chain shocks may cluster in time and spread nonlinearly, a regime-based approach can help explain both expected returns and differences in volatility across industries.

Guided by the production-network propagation literature and the finance evidence that disruptions affect both cash flows and risk, the empirical analysis tests the following hypotheses using a regime-based framework and industry portfolio returns:

H1: State dependence in expected returns. The long-run expected return (or 'long-run growth' implied by return dynamics) of industry equity portfolios differs between low- and high-supply-chain-pressure regimes.

This hypothesis reflects the idea that aggregate bottlenecks shift either cash-flow expectations (via costs, shortages, pricing power) and/or discount rates in a state-contingent way (Hendricks & Singhal, 2005b; Smirnyagin & Tsyvinski, 2022; Ginn, 2024).

H2: State dependence in volatility with heterogeneous direction. The conditional volatility of industry equity returns differs across supply-chain-pressure regimes.

For the typical industry, high-pressure regimes are expected to be associated with higher uncertainty and thus higher volatility, but the direction need not be uniform across industries because supply chain pressure can reallocate risk and pricing power across the production network (Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021; Bouri *et al*., 2025). Accordingly, the empirical analysis evaluates both the prevalence of volatility increases and the existence of meaningful exceptions.

H3: Cross-sectional heterogeneity consistent with upstream-downstream exposure. The sign and magnitude of regime-dependent changes in long-run expected returns differ systematically across industries, consistent with differences in production-network position and input dependence.

In particular, upstream or commodity-linked industries may exhibit relatively stronger performance in high-pressure regimes (*e.g*., through price effects or scarcity rents), whereas downstream, input-intensive, and consumer/service industries may exhibit relatively stronger performance in low-pressure regimes (Acemoglu *et al.*, 2012; Herskovic, 2018; Gofman *et al.*, 2020; Gozgor *et al*., 2023).

RESEARCH METHODOLOGY

I used two main data sources: data on supply chain pressure and the market value of the US-listed stocks at the industry level. GSCPI is a measure developed by the Federal Reserve Bank of New York. GSCPI captures *global* supply chain conditions by combining data on shipping costs, delivery times, and backlogs across regions to provide a comprehensive index of GSC conditions. A high index value implies periods of stress in the supply chain.

As for the sectoral stock market returns, I used monthly value-weighted total returns (including dividends) of 49 U.S. industry portfolios – this is public data set available at French (2025). The data sample spans from January 1998 to June 2024. Hence, the sample period included several events that had a profound impact on GSCs: the increasing globalisation of supply chains and the rise of digital and tech-based industries; COVID-19 pandemic supply bottlenecks; geopolitical fragmentation observed following Russia's invasion of Ukraine and China-US tensions. Therefore, this sample allows us to capture structural changes in the relationship between supply chain pressures and equity markets.

I used a Markov switching autoregression (MS-AR) model with time-varying transition probabilities (TVTP) to examine the impact of GSC pressures on equity market returns across different industries. This model captures the dynamic and nonlinear relationships between market returns and supply chain pressures. For more details on this class of models see Hamilton (1989) and Kim and Nelson (2017).

I chose the MS-AR model with TVTP (hereafter MS-AR-TVTP) to understand to what extent GSC pressures account for regime shifts in the equity market and whether these regimes differ from each other. Simple linear models may fail to answer this research question, given that regime changes are inherently nonlinear. This is also the fact shown in Figure 1, which leads to the conclusion that there is no *linear* relationship between supply chain pressures and stock market performance.

The MS-AR-TVTP model addresses these issues by allowing the parameters of the autoregressive process to switch between different regimes, which in this article I interpret as 'low pressure' and 'high pressure' periods. I modelled the transition probabilities between regimes as a logistic function of the GSCPI (Filardo, 1994). This means that as GSC pressures change, the likelihood of switching between regimes changed accordingly. I set the number of regimes to two – this made the interpretation easier (low vs high pressure) and did not change the results. The parameters within each regime, such as the autoregressive coefficients, the constant, and the error variances differed, providing a more flexible modelling approach. For any time series of returns y_t MS-AR-TVTP model can be formulated as follows:

$$y_t = \alpha_{S_t} + \beta_{S_t} y_{t-1} + \varepsilon_{tS_t} \tag{1}$$

in which S_t denotes a state/regime at time t, α_{S_t} is a state-specific constant, β_{S_t} is a state-specific AR(1) coefficient and $\varepsilon_t \sim i.i.d.\ N\left(0, \sigma_{S_t}^2\right)$. Each period, the regime transitioned according to:

$$P(S_t = i | S_{t-1} = j) = \frac{\exp\{x'_{t-1}\beta_{ij}\}}{1 + \exp\{x'_{t-1}\beta_{ij}\}} \tag{2}$$

in which $x_{t-1}$is a vector of GSCPI that determines the transition probabilities from state *j* to *i*. I estimated the model maximum likelihood using the expectation-maximisation algorithm.

For the remainder of this study, I chose AR(1) specification as a baseline for the MS-AR-TVTP model. This parsimonious lag structure provided an intuitive economic interpretation of the model parameters. Long-term expected rate of return in state S_t was given by $\frac{\alpha_{S_t}}{(1-\beta_{S_t})}$. In addition, the AR coefficient β_{S_t} measured the persistence of returns shocks in the state and $\sigma_{S_t}^2$ measured the variability of these shocks. Different combinations of coefficients would correspond to different shapes of the cumulative growth rate of returns. For example, with an AR(1) process, a large positive constant α_{S_t} and a small positive β_{S_t} would correspond to a steep hill, while a lower α_{S_t} would correspond to a hill of milder slope. Zero coefficients would describe a period of no growth, and a negative constant and zero slope would be a collapse period.

RESULTS AND DISCUSSION

Let me begin with descriptive evidence to motivate the nonlinear, regime-based approach. Figure 1 reports correlations between GSCPI and monthly industry portfolio returns. The correlations were modest, suggesting that a linear relationship between supply-chain pressure and sectoral equity returns was weak. This pattern was consistent with the literature, which emphasises that supply shocks may matter most when constraints bind (*e.g.*, through bottlenecks, backlogs, and nonlinear adjustment) rather than continuously and proportionally over time (Acemoglu *et al.*, 2012; Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021). In that sense, the near-zero unconditional correlations in Figure 1 did not evidence that supply chain stress was irrelevant; instead they suggested that its pricing effects may be state dependent, motivating the Markov-switching framework.

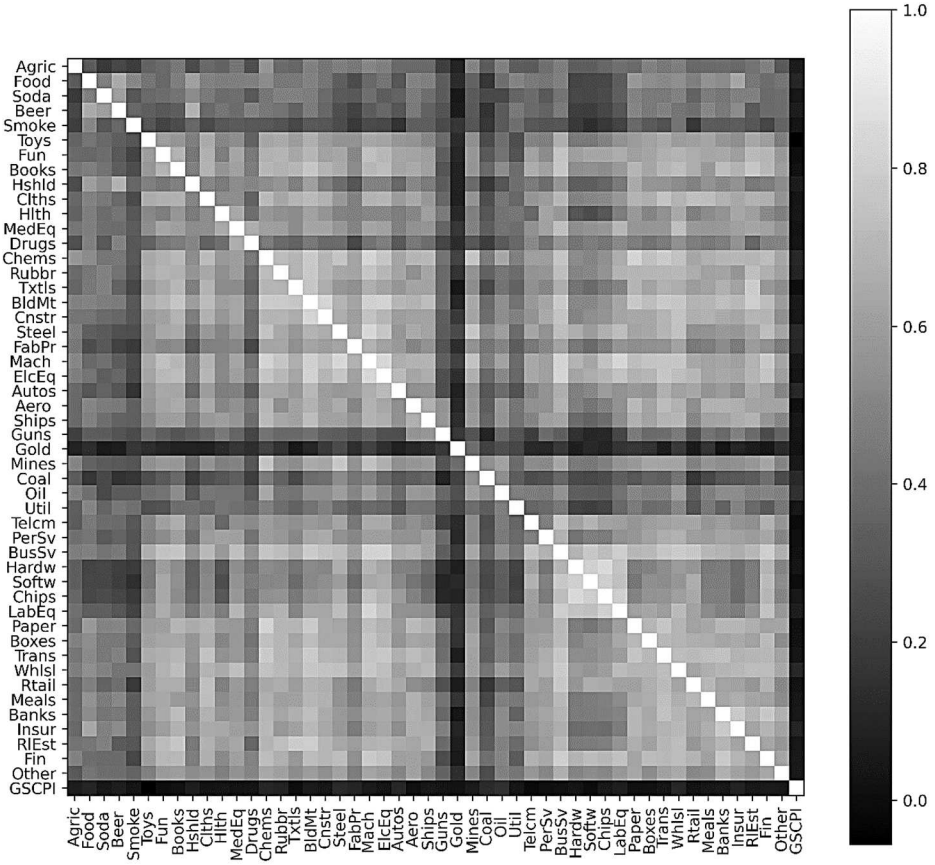

Figure 1. Correlation between the US industry portfolio returns and the GSCPI, 1998-2024
Source: own elaboration.

Figure 2 complemented this by documenting substantial heterogeneity in unconditional mean returns and volatility across the 49 industry portfolios. The cross-section showed a positive association between the unconditional mean and the unconditional standard deviation, consistent with basic risk-return intuition in asset pricing. Table A1 (Appendix) provides summary statistics and confirms pronounced cross-industry dispersion in both central tendency and tail outcomes. These descriptive results set the stage for the article's main question: whether supply chain pressures are associated with systematic changes in industry return dynamics, expected returns, persistence, and volatility, across regimes.

Next, I summarised the regime-specific estimates. Table A2 (Appendix) contains the regime-specific estimates of the MS-AR(1)-TVTP model, and Figures 3-5 summarise the key parameters graphically. For each industry, the model estimates (i) a regime-specific intercept ('Const'), (ii) a regime-specific AR(1) coefficient ('AR(1)'), and (iii) a regime-specific innovation volatility ('SD of residuals'). I interpreted the two regimes as low- and high-pressure supply chain states because the transition probabilities were modelled as a logistic function of the GSCPI.

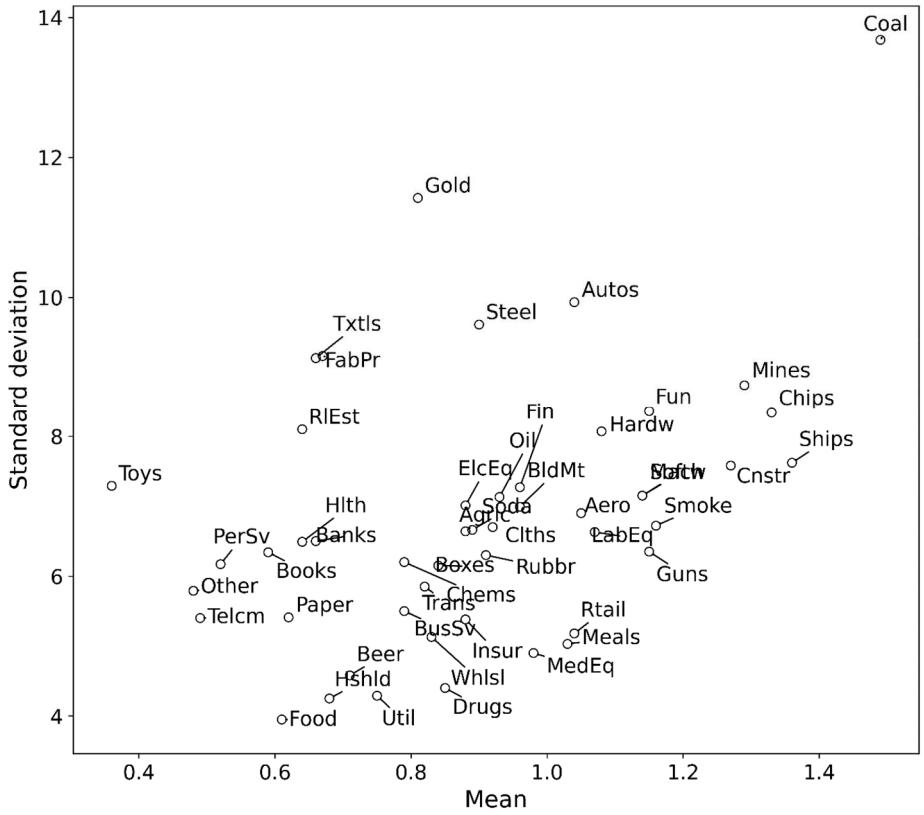

Figure 2. Mean returns and return volatility of the US industry portfolios, 1998-2024
Source: own elaboration.

A clear pattern emerged: several upstream, commodity-linked, and capital-goods industries, including mines, agriculture, steel, and machinery, exhibited higher intercepts in the high-pressure regime. A natural interpretation is that episodes of elevated supply chain pressure often coincide with scarcity conditions and higher input prices, which can raise revenues (or expected margins) for upstream producers and certain capital-goods suppliers, even as they raise costs for downstream users. This interpretation is consistent with production-network logic (Acemoglu *et al.*, 2012; Carvalho *et al.*, 2021) and with evidence that supply chain disturbances can reallocate economic rents and performance across supplier-customer linkages (Barrot & Sauvagnat, 2016). It is consistent with related evidence that global supply-chain stress is connected to commodity-market dynamics (Gozgor *et al.*, 2023).

Conversely, several defensive or rate-sensitive sectors, such as Utilities and Telecom, tended to have higher intercepts in the low-pressure regime. This is consistent with the view that high supply-chain pressure is often associated with upward inflationary pressures and tighter financial conditions (Ascari *et al.*, 2024; Ginn, 2024; Tillmann, 2024), which may be especially adverse for sectors with cash flows discounted at longer horizons and/or those sensitive to interest-rate movements.

Figure 4 compares the AR(1) coefficient across regimes. Interpreting the AR coefficient as capturing the persistence of shocks to industry returns within a regime, the results indicate meaningful heterogeneity in how quickly industries revert after shocks and whether return innovations tend to propagate.

Two patterns were notable. Firstly, some industries displayed greater persistence in the high-pressure regime (*i.e.*, higher AR(1) in the high-pressure state). This is consistent with the idea that when supply bottlenecks bind, adjustment can be slow: backlogs unwind over time, supplier substitution is costly, and shocks can propagate through customer-supplier networks in a persistent manner (Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021). Secondly, other industries exhibit lower persistence or even stronger mean reversion in the high-pressure regime, consistent with rapid repricing and partial reversals when shocks are recognised as temporary and/or when policy and private responses mitigate constraints. This cross-industry heterogeneity in persistence provides

valuable insight, suggesting that supply-chain stress does not merely shift the level of expected returns. It can also alter the time profile of valuation adjustments.

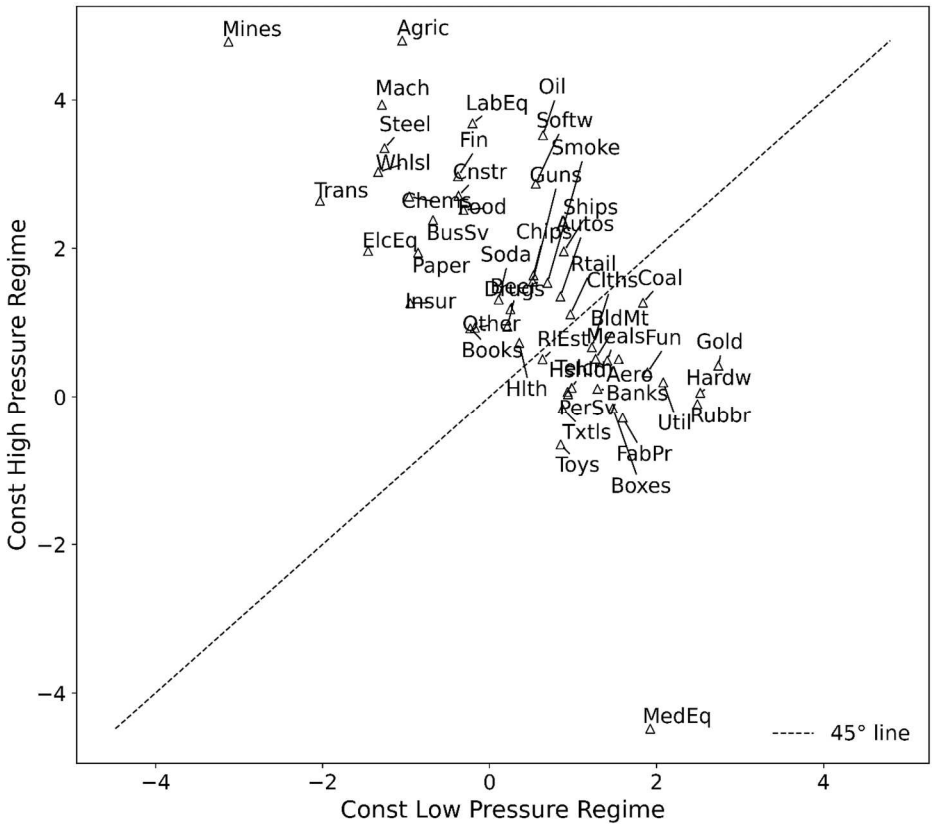

Figure 3. Estimated return intercepts for the US industry portfolios, 1998-2024
Source: own elaboration.

Figure 5 shows the estimated volatility of shocks (innovation volatility) in each regime. For many industries, the high-pressure regime is associated with higher innovation volatility, consistent with the firm-level literature that disruptions elevate uncertainty and equity risk (Hendricks & Singhal, 2003, 2005b; Hendricks *et al.*, 2020) and with more recent evidence that supply bottlenecks help predict the conditional distribution of returns and volatility internationally (Bouri *et al.*, 2025).

Importantly, the volatility effect is not uniform. A nontrivial set of industries exhibits lower innovation volatility in the high-pressure regime. One interpretation is that supply chain stress can compress the dispersion of outcomes for certain upstream sectors when price effects prevail, and cash-flow expectations become more tightly linked to a common factor (*e.g.*, commodity conditions). Another interpretation is that the 'low-pressure' regime, defined with respect to supply-chain conditions, can still contain episodes of financial and macro volatility unrelated to supply chains, which may raise the estimated innovation volatility for specific portfolios. This helps explain why one should treat volatility comparisons across regimes as industry-specific empirical facts rather than imposed by a priori assumptions.

Taken together, Figures 3-5 provide evidence consistent with the article's hypotheses: expected return dynamics and risk are state-dependent and heterogeneous across industries.

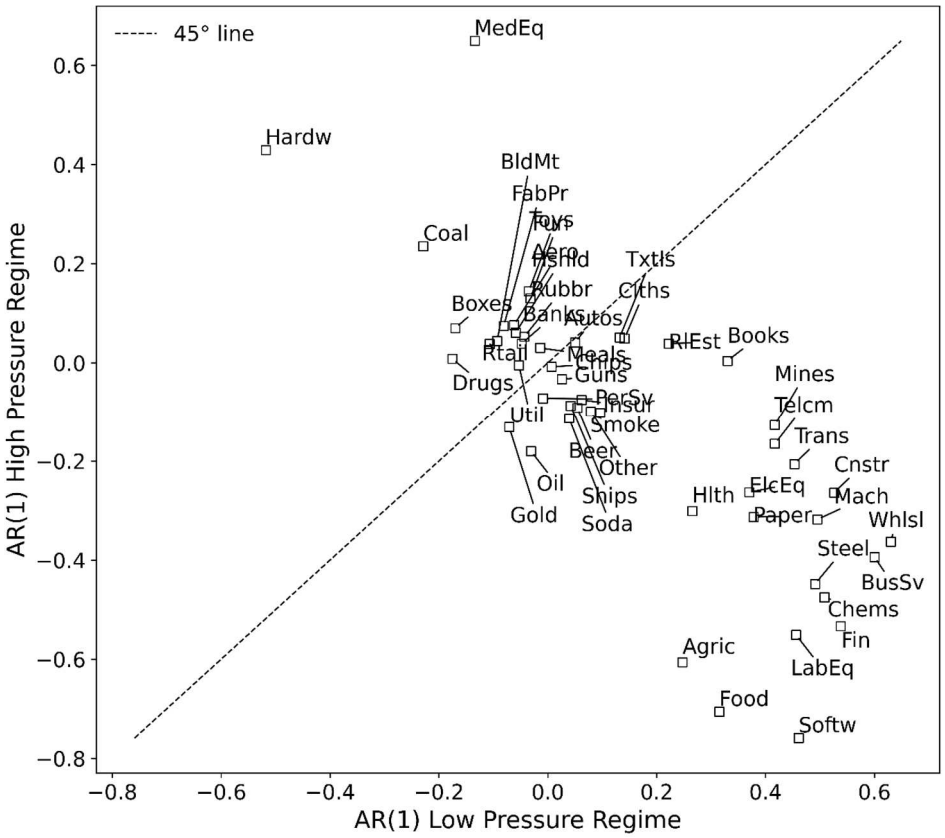

Figure 4. Estimated return persistence for US industry portfolios, 1998-2024
Source: own elaboration.

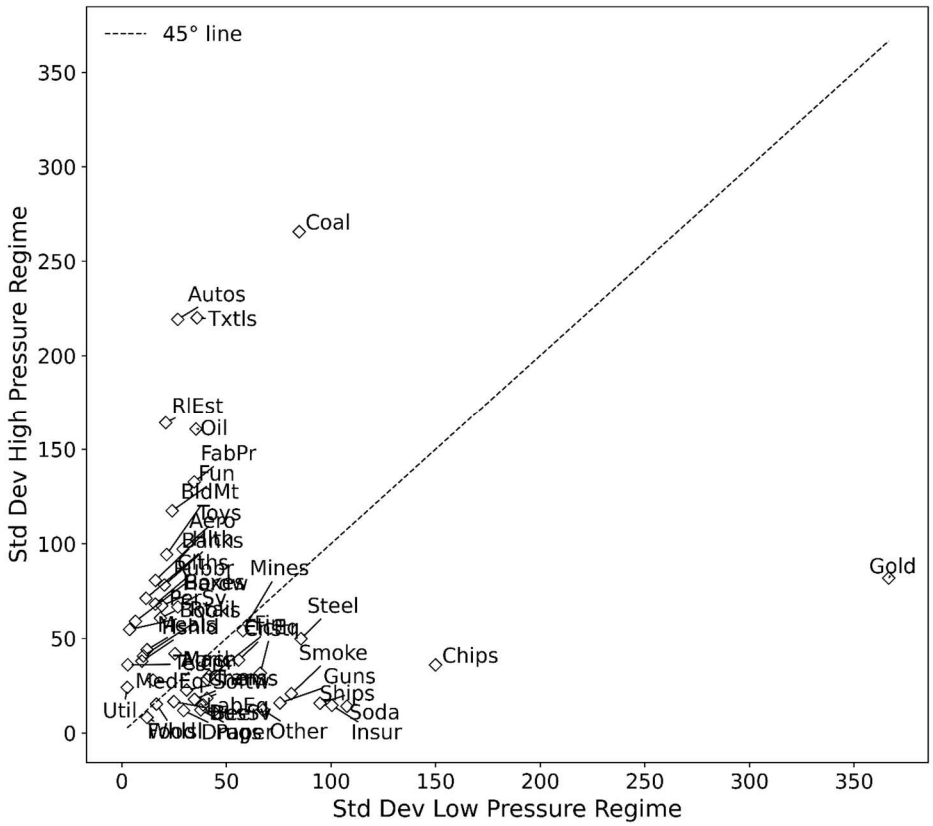

Figure 5. Estimated standard deviation for US industry portfolios, 1998-2024
Source: own elaboration.

Because the model was AR(1) within each regime, it was natural to summarise conditional expected performance using the implied long-run mean return within regime (as reported in Table A2). Figure 6 plots these implied long-run returns for the low- and high-pressure regimes and provides a transparent 'winners and losers' classification. Three results are central:

1. Substantial regime dependence (H1)
   Many industries exhibited economically meaningful differences in implied long-run returns across regimes. This state dependence is consistent with the view that supply chain stress can change both expected cash flows (through costs and shortages) and discount rates (through inflation and financial conditions) in a regime-contingent manner (Ascari *et al.*, 2024; Ginn, 2024; Smirnyagin & Tsyvinski, 2022).
2. Ranking reversals across regimes.
   Several industries that performed relatively well in the high-pressure regime performed relatively poorly in the low-pressure regime, and vice versa. This 'ranking reversal' is precisely the kind of nonlinear cross-sectional behaviour that a linear specification would find it challenging to capture.
3. Cross-industry heterogeneity consistent with production-network exposure (H3).
   Industries that plausibly benefited from scarcity pricing or upstream positioning, such as mines, agriculture, steel, and machinery, tended to exhibit stronger long-run returns in the high-pressure regime. In contrast, a set of sectors performed better in the low-pressure regime, consistent with either downstream input dependence or greater sensitivity to tightening financial conditions in high-pressure episodes. This pattern is consistent with the production-network and network-asset-pricing literature, which emphasises that upstream-downstream positions and network structure shape exposures to real shocks and risk premia (Acemoglu *et al.*, 2012; Herskovic, 2018; Gofman *et al.*, 2020).

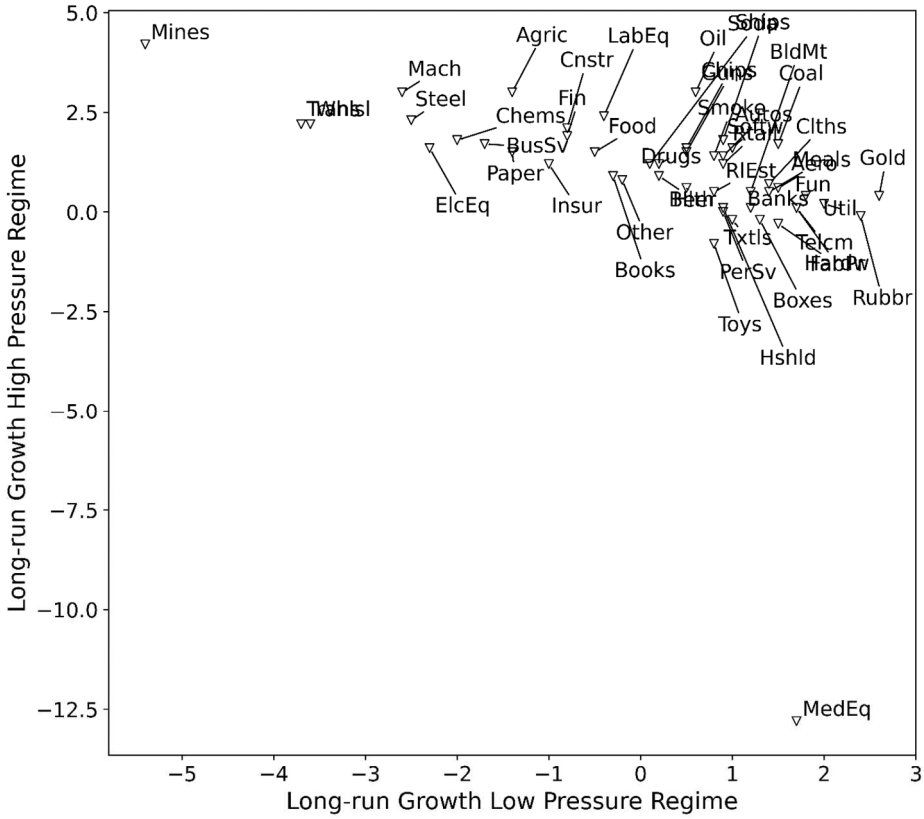

Figure 6. Implied long-run expected returns for US industry portfolios, 1998-2024
Source: own elaboration.

Crucially, these results complement, but also refine, the firm-level event-study literature. Whereas disruption announcements are associated with negative abnormal returns on average (Hendricks &

Singhal, 2003, 2005b), the industry-portfolio evidence here indicates that aggregate supply-chain stress is not uniformly negative across sectors. In an interconnected economy, stress can redistribute profits and risk across the production network, creating both relative winners and losers.

Within the Regime Rate of Return and Standard Deviation

Figure 7 jointly plots implied long-run returns and innovation volatility within each regime, providing a compact summary of how the risk-return trade-off shifts across supply chain states. The low-pressure regime features a relatively tight cluster: many industries combine moderate long-run returns with comparatively contained volatility. In the high-pressure regime, the cross-section becomes more dispersed: some industries pair strong long-run returns with elevated volatility, while others face weaker long-run performance with higher uncertainty. This widening dispersion is consistent with recent evidence that supply chain pressures can influence not only the mean but also higher moments and tail risks of equity returns (Bouri *et al.*, 2025).

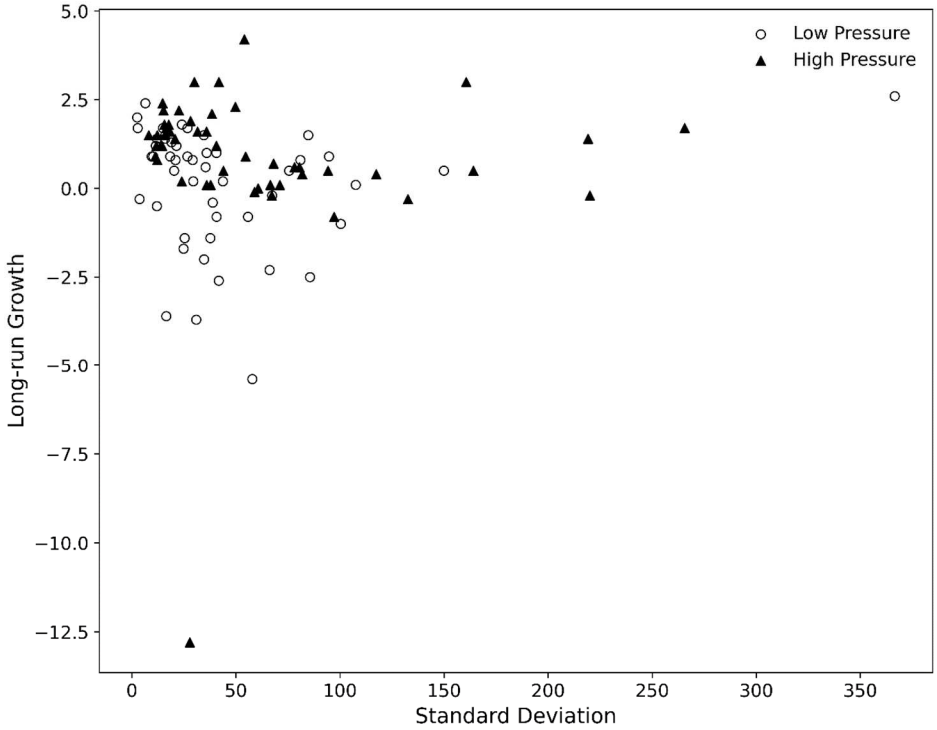

Figure 7. Implied long-run expected returns and volatility of US industry portfolios, 1998-2024
Source: own elaboration.

Figure 8 makes these comparisons more directly interpretable by plotting the differences between regimes in long-run returns and innovation volatility, yielding four economically meaningful quadrants.

1. ΔReturn > 0 and ΔVolatility > 0: industries whose conditional performance improves in high-pressure regimes but at the cost of higher uncertainty. This pattern is consistent with 'scarcity rent' channels in upstream sectors and capital-goods suppliers.
2. ΔReturn > 0 and ΔVolatility < 0: industries whose performance improves while volatility falls under high pressure, suggesting resilience and/or enhanced pricing power that stabilises expectations.
3. ΔReturn < 0 and ΔVolatility > 0: industries that lose under high pressure and become riskier – arguably the clearest 'vulnerable' group from a supply-chain perspective.
4. ΔReturn < 0 and ΔVolatility < 0: industries that underperform in high-pressure regimes but with lower volatility, consistent with a shift in the nature of risk rather than a simple 'more volatility under stress' narrative.

This decomposition is useful because it clarifies why a single blanket statement – 'high supply chain pressure increases volatility' – is incomplete. The empirical evidence supports heterogeneous

volatility responses (H2), which is consistent with production-network propagation and reallocation effects (Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021).

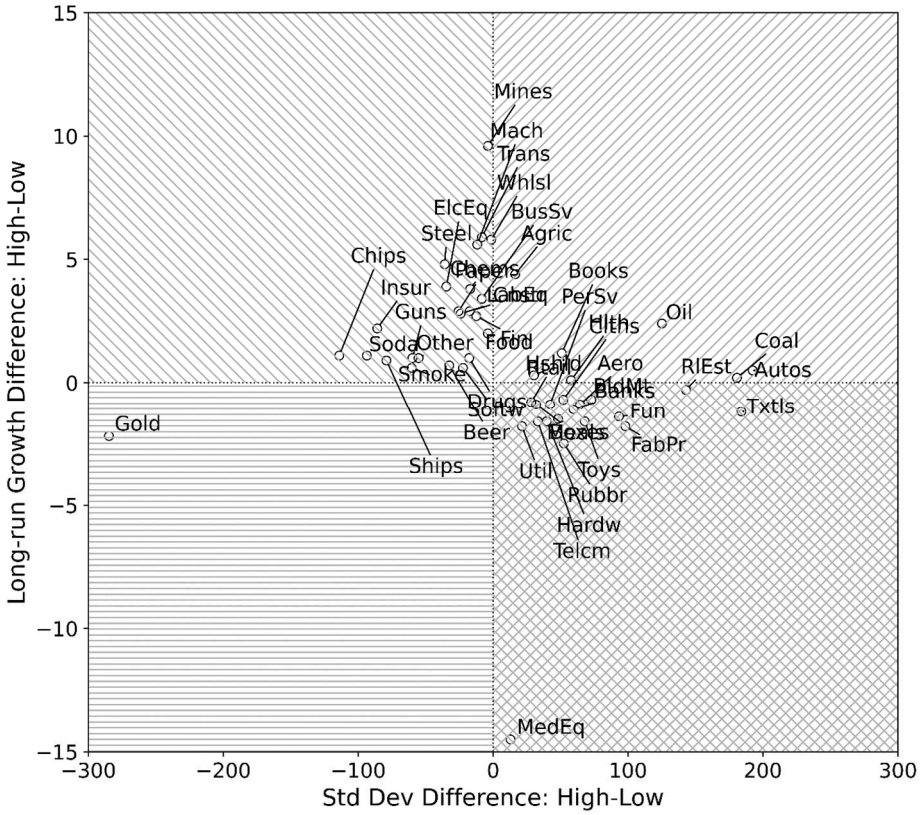

Figure 8. Differences in implied long-run expected returns and volatility between regimes for US industry portfolios, 1998-2024

Source: own elaboration.

The empirical results provide three contributions to existing work.

Firstly, the results show that aggregate supply chain stress is associated with nonlinear, heterogeneous industry dynamics that are not evident in unconditional correlations. This complements macro-finance evidence that supply chain shocks can be destabilising for aggregate output, inflation, and equity returns (Ginn, 2024), by showing that aggregate effects can mask meaningful cross-sectional divergence. In other words, even if a supply chain shock reduces aggregate (or index-level) equity returns, certain industries can still exhibit improved conditional performance.

Second, the 'winners and losers' pattern is consistent with the production-network view, which holds that shocks propagate through supplier-customer relationships and can create asymmetric exposures across vertical positions (Acemoglu *et al.*, 2012; Gofman *et al.*, 2020; Herskovic, 2018). The empirical finding that upstream and commodity-linked industries more often display stronger high-pressure performance is also consistent with evidence that supply chain stress is tied to commodity-price dynamics (Gozgor *et al.*, 2023) and with the broader view that supply constraints can behave like 'disaster-type' shocks with priced implications (Smirnyagin & Tsyvinski, 2022).

Third, the volatility results show that supply chain stress is not a purely 'high-volatility regime' phenomenon across all sectors. While many industries become riskier when pressures rise (consistent with disruption-based increases in equity risk documented by Hendricks & Singhal, 2005b), others exhibit lower innovation volatility in the high-pressure regime, implying that the composition and transmission of uncertainty change across regimes rather than rising uniformly.

Practical Implications

For investors, the data show that the GSCPI is a useful indicator for sectoral risk management. Since industries differ in both regime-dependent expected returns and regime-dependent volatility, a 'one-size-fits-all' approach to hedging supply chain risk is inappropriate. This complements recent evidence that supply chain pressures have predictive content for the conditional distribution of stock returns and volatility (Bouri *et al.*, 2025). A cautious interpretation is warranted: the model identifies conditional patterns rather than causal effects, so the results should be used as inputs into risk monitoring and scenario analysis rather than as mechanical trading rules.

For corporations, the results show that supply chain stress can coincide with large shifts in the market value dynamics of industries. This reinforces the importance of resilience investments (*e.g.*, supplier diversification, inventory and logistics flexibility, and monitoring upstream bottlenecks), which is consistent with the supply-chain resilience literature that emerged after COVID-19 (Ivanov, 2020). The cross-industry heterogeneity documented here suggests that returns aimed at resilience may be particularly high in sectors that fall into the 'ΔReturn < 0 and ΔVolatility > 0' quadrant of Figure 8.

Supply chain pressures have been shown to matter for inflation dynamics and macro-financial conditions (Ascari *et al.*, 2024; Tillmann, 2024; Ginn, 2024). Therefore, from a policy perspective, the industry heterogeneity documented here suggests that monitoring supply-chain indicators may also help identify sector-specific financial vulnerabilities under high-pressure conditions episodes. This does not imply that sector-by-sector intervention is always desirable; rather, it highlights that aggregate supply chain stress can coincide with uneven sectoral effects on risk and valuation, which may be relevant for stress testing and targeted diagnostics.

CONCLUSIONS

In this study, I investigated whether global supply chain pressures, measured by GSCPI, are reflected in the risk and return dynamics of U.S. industry equity portfolios. Using monthly value-weighted returns for 49 industries over January 1998-June 2024, I estimated a two-regime Markov-switching AR(1) model with time-varying transition probabilities driven by the GSCPI (Benigno *et al.*, 2022; Filardo, 1994). The empirical motivation was straightforward: unconditional correlations between the GSCPI and sectoral returns are generally weak, consistent with the view that supply bottlenecks and their financial effects are state dependent rather than linear and constant over time. Thus, a regime-switching framework was well suited to characterise how expected returns, persistence, and volatility change across low- and high-pressure supply-chain states.

The results show that supply chain stress reorders the cross-section of industry performance. In the high-pressure regime, several upstream and commodity- or capital-goods-linked sectors (*e.g.*, mines, agriculture, steel, machinery) exhibit stronger implied long-run expected returns than in the low-pressure regime, while a set of more interest-rate-sensitive or defensive industries (*e.g.*, utilities and telecom) tend to perform relatively better in low-pressure periods. This 'winner-loser reversal' is consistent with production-network logic: disruptions propagate through supplier-customer relationships, but the net equity-market effect depends on whether an industry is positioned to benefit from scarcity pricing or instead suffers primarily from input shortages and cost shocks (Acemoglu *et al.*, 2012; Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021). The findings further strengthen the view that supply constraints can behave like macro shocks, shifting both cash-flow expectations and discount rates, helping explain why supply-chain pressure is associated with meaningful changes in expected returns across states (Ginn, 2024; Smirnyagin & Tsyvinski, 2022).

A second main finding is that the high-pressure regime is typically, though not universally, associated with higher return volatility. This is consistent with firm-level evidence that disruptions increase equity risk and can erode shareholder value (Hendricks & Singhal, 2003, 2005b; Hendricks *et al.*, 2020), as well as macro-finance evidence linking supply chain shocks to deteriorating financial conditions and weaker equity returns (Ginn, 2024). Simultaneously, the volatility response was heterogeneous: for some industries, estimated innovation volatility was not higher under high pressure, and a few show

the opposite pattern. This heterogeneity yields useful information rather than being problematic. It is consistent with the idea that supply-chain stress can reallocate risk and pricing power across the production network, raising uncertainty for some sectors while compressing outcome dispersion for others, rather than functioning as a uniform 'high-volatility state' for the entire market (Barrot & Sauvagnat, 2016; Carvalho *et al.*, 2021). Moreover, the implied long-run growth estimates indicate that high supply-chain pressure pushes a sizable subset of industries toward near-zero or negative long-run performance, highlighting an economically meaningful volatility-growth trade-off: some sectors experience higher risk without compensating improvements in long-run expected returns.

The results contribute to the literature as follows. Firstly, they extend the firm-level disruption literature by showing that aggregate, global supply bottlenecks can generate systematic *cross-industry* divergence in equity outcomes, not just negative average effects for directly disrupted firms (Hendricks & Singhal, 2003, 2005b). Secondly, they complement production-network asset-pricing research by delivering empirical evidence consistent with the view that network position and exposure to upstream bottlenecks shape risk-return dynamics (Herskovic, 2018; Gofman *et al.*, 2020). Thirdly, they demonstrate that treating the GSCPI as a state variable is empirically useful: linear correlations understate the relationship, whereas a regime-dependent approach reveals economically meaningful nonlinearity and heterogeneity. This matters for the interpretation of 'supply chain shocks' in macro-finance settings, where the same aggregate stress can plausibly hurt some sectors while supporting others (Smirnyagin & Tsyvinski, 2022).

Limitations

One should interpret the article's conclusions with several limitations in mind. Firstly, the empirical design is primarily associational: although the regime classification is informed by the GSCPI, the analysis does not claim a fully identified causal effect of supply-chain pressure on returns, and supply-chain stress may co-move with other macro-financial forces (*e.g.*, demand shocks, monetary tightening, commodity cycles). Secondly, the two-regime MS-AR(1) structure is intentionally parsimonious; it captures nonlinear state dependence but may not fully represent richer dynamics (multiple regimes or higher-order persistence) that could matter for some industries. Thirdly, the use of industry portfolios can mask substantial within-industry heterogeneity across firms in exposure, pricing power, and supply-chain organisation.

Several directions for future research occur naturally. One priority is to connect the estimated regime sensitivities to observable industry characteristics (input intensity, import dependence, upstream/downstream position from input-output tables, supplier concentration), providing a sharper mapping from economic mechanisms to empirical heterogeneity. A second extension is to integrate additional indicators of supply-chain tightness (*e.g.*, delivery-time indices, shipping measures, or industry-specific bottleneck proxies) to test whether results are specific to the GSCPI or robust across measurement approaches. Thirdly, firm-level work could unpack within-industry dispersion and test whether firms with greater supplier diversification or resilience investments show systematically different regime responses, thereby linking more directly to the resilience literature. Finally, cross-country replication would clarify how institutional structure, trade exposure, and market composition mediate the financial transmission of global supply-chain stress.

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Appendix A: Additional tables

Table A1 below denotes the average, standard deviation, minimum, maximum, 25th, 50th, and 75th percentiles of each U.S. industry portfolio returns over January 1998–June 2024. Values of GSCPI are in the last row of this table.

Table A2 contains estimated values of model parameters.

Table A1. Summary statistics for monthly United States industry portfolio returns and the GSCPI, January 1998–June 2024

VARIABLE	AVERAGE	STANDARD DEVIATION	MIN	25%	50%	75%	MAX
AGRIC	0.88	6.64	-18.21	-3.27	0.55	4.42	28.56
FOOD	0.61	3.95	-11.12	-1.74	0.82	2.95	17.38
SODA	0.89	6.66	-26.03	-2.19	1.23	4.55	38.9
BEER	0.71	4.58	-19.74	-1.79	0.8	3.54	16.46
SMOKE	1.16	6.72	-24.96	-2.74	1.89	4.92	32.46
TOYS	0.36	7.29	-23.27	-3.8	0.81	4.56	23.14
FUN	1.15	8.36	-32.25	-3.36	1.33	6.06	41.27
BOOKS	0.59	6.34	-24.7	-2.68	0.4	3.69	30.57
HSHLD	0.68	4.25	-14.77	-1.55	0.78	3.23	18.71
CLTHS	0.92	6.7	-22.39	-2.67	1.23	4.66	24.99
HLTH	0.64	6.49	-23.22	-3.44	0.94	4.47	19.95
MEDEQ	0.98	4.9	-19.39	-1.44	1.23	4.48	13.93
DRUGS	0.85	4.4	-11.3	-2.08	1.08	3.86	13.63
CHEMS	0.79	6.2	-21.06	-2.78	1.15	4.38	22.01
RUBBR	0.91	6.3	-20.88	-2.42	1.62	4.08	32.09
TXTLS	0.66	9.13	-36.03	-4.29	1.29	5.53	59.18
BLDMT	0.96	6.99	-31.97	-2.56	1.62	4.72	34.6
CNSTR	1.27	7.58	-32.14	-3.45	1.35	6.3	22
STEEL	0.9	9.61	-32.41	-4.78	0.71	6.53	30.67
FABPR	0.67	9.16	-33.71	-4.82	0.3	6.01	35.79
MACH	1.14	7.15	-29.93	-2.88	1.48	5.62	23.03
ELCEQ	0.88	7.01	-24.82	-2.88	0.93	5.22	22.82
AUTOS	1.04	9.93	-36.42	-4.13	0.89	5.44	49.45
AERO	1.05	6.9	-35.8	-2.21	1.22	5.18	32.53
SHIPS	1.36	7.62	-23.55	-2.71	1.56	5.32	29.33
GUNS	1.15	6.35	-30.08	-2.1	1.27	4.7	25.43
GOLD	0.81	11.42	-33.6	-5.72	-0.02	6.75	79.52
MINES	1.29	8.74	-34.8	-4.72	0.91	7.58	26.99
COAL	1.49	13.68	-40.89	-7.36	1.58	9.88	44.04
OIL	0.93	7.13	-34.66	-2.87	0.79	4.75	32.89
UTIL	0.75	4.29	-12.94	-1.75	1.31	3.56	11.76
TELCM	0.49	5.4	-15.56	-2.45	0.75	3.8	22.11
PERSV	0.52	6.17	-25.3	-3.14	0.63	4.09	18.68
BUSSV	0.79	5.5	-23.25	-2.51	1.37	3.97	18.12
HARDW	1.08	8.07	-33.92	-3.18	1.66	5.76	25.39
SOFTW	1.14	7.15	-22.89	-2.74	1.62	4.96	26.11
CHIPS	1.33	8.34	-31.8	-3.21	2.25	6.4	26.79
LABEQ	1.07	6.63	-23.38	-2.88	1.58	5.08	21.33
PAPER	0.62	5.41	-18.32	-2.74	1.09	3.71	23.44
BOXES	0.84	6.15	-21.47	-2.88	0.97	4.69	18.98
TRANS	0.82	5.85	-17.81	-2.79	1.13	4.47	17.44
WHLSL	0.83	5.13	-21.09	-2.23	1.19	4.27	15.99
RTAIL	1.04	5.18	-14.56	-1.88	1.04	3.94	18.63
MEALS	1.03	5.03	-22.12	-1.99	1.25	4.13	18.67

VARIABLE	AVERAGE	STANDARD DEVIATION	MIN	25%	50%	75%	MAX
BANKS	0.66	6.5	-27.84	-2.89	1.21	4.14	19.85
INSUR	0.88	5.38	-26.98	-1.76	1.38	3.78	23.34
RLEST	0.64	8.1	-36.75	-3.01	1.2	4.44	65.22
FIN	0.96	7.27	-26.2	-3.49	1.4	5.8	19.42
OTHER	0.48	5.79	-23.71	-2.2	0.52	4.1	18.7
GSCPI	0.01	1.01	-1.56	-0.6	-0.25	0.2	4.37

Source: own study.

Table A2. Two-regime MS-AR(1)-TVTP estimates for monthly United States industry portfolio returns, January 1998–June 2024

INDUSTRY	LOW PRESSURE REGIME					HIGH PRESSURE REGIME				
	CONST	AR(1)	SD OF RESIDUALS	LONG-RUN GROWTH	AVG EXPECTED DURATION	CONST	AR(1)	SD OF RESIDUALS	LONG-RUN GROWTH	AVG EXPECTED DURATION
AGRIC	-1.046*	0.247***	25.439***	-1.4%	3.139	4.798***	-0.606***	41.874***	3.0%	1.467
FOOD	-0.312	0.315***	12.074***	-0.5%	3.224	2.519***	-0.706***	8.171***	1.5%	1.450
SODA	0.110	0.039	107.618***	0.1%	1.460	1.311***	-0.113*	14.067***	1.2%	3.174
BEER	0.213	0.054	43.794***	0.2%	1.410	0.948***	-0.091	11.285***	0.9%	3.439
SMOKE	0.694	0.096	81.035***	0.8%	1.643	1.536***	-0.102	20.717***	1.4%	2.556
TOYS	0.852**	-0.035	29.252***	0.8%	3.001	-0.652	0.144	97.172***	-0.8%	1.500
FUN	1.891***	-0.032	24.095***	1.8%	2.108	0.329	0.130	117.412***	0.4%	1.903
BOOKS	-0.230	0.330***	3.763*	-0.3%	1.429	0.924	0.004	54.660***	0.9%	3.329
HSHLD	0.935***	-0.059	9.602***	0.9%	3.428	0.067	0.061	37.917***	0.1%	1.412
CLTHS	1.226***	0.141	16.049***	1.4%	1.820	0.668	0.049	68.092***	0.7%	2.219
HLTH	0.356	0.265***	20.367***	0.5%	3.172	0.728	-0.301*	78.148***	0.6%	1.460
MEDEQ	1.925***	-0.134	14.985***	1.7%	6.841	-4.481**	0.649***	27.917***	-12.8%	1.171
DRUGS	0.250	-0.175*	29.556***	0.2%	1.633	1.181***	0.008	11.817***	1.2%	2.580
CHEMS	-0.962	0.508***	34.753***	-2.0%	1.959	2.699***	-0.475***	17.755***	1.8%	2.042
RUBBR	2.490***	-0.043	6.532***	2.4%	1.666	-0.098	0.053	58.973***	-0.1%	2.502
TXTLS	0.875*	0.132*	35.996***	1.0%	3.953	-0.161	0.051	220.034***	-0.2%	1.339
BLDMT	1.271***	-0.093	21.456***	1.2%	2.699	0.513	0.044	94.267***	0.5%	1.589
CNSTR	-0.372	0.526***	55.862***	-0.8%	1.816	2.709***	-0.264***	38.521***	2.1%	2.225
STEEL	-1.258	0.491***	85.652***	-2.5%	1.905	3.350***	-0.448***	49.786***	2.3%	2.104
FABPR	1.595***	-0.081	34.636***	1.5%	2.047	-0.290	0.074	132.681***	-0.3%	1.955
MACH	-1.289	0.495***	41.836***	-2.6%	1.996	3.936***	-0.318**	30.086***	3.0%	2.004
ELCEQ	-1.455	0.370***	66.230***	-2.3%	1.412	1.966***	-0.263***	31.562***	1.6%	3.426
AUTOS	0.849*	0.050	26.752***	0.9%	2.689	1.352	0.041	219.169***	1.4%	1.592
AERO	1.548***	-0.062	16.115***	1.5%	2.077	0.509	0.076	80.596***	0.6%	1.928
SHIPS	0.890	0.042	94.759***	0.9%	2.123	1.960***	-0.087	15.673***	1.8%	1.890
GUNS	0.518	0.026	75.615***	0.5%	1.678	1.556***	-0.033	15.821***	1.5%	2.475
GOLD	2.741	-0.071	366.569***	2.6%	1.193	0.421	-0.131**	81.832***	0.4%	6.176
MINES	-3.127***	0.417***	57.925***	-5.4%	1.765	4.785***	-0.127	54.067***	4.2%	2.308
COAL	1.838**	-0.229**	84.814***	1.5%	1.972	1.268	0.235**	265.573***	1.7%	2.029
OIL	0.640*	-0.031	35.478***	0.6%	9.057	3.524*	-0.180	160.674***	3.0%	1.124
UTIL	2.081***	-0.053	2.614***	2.0%	1.432	0.195	-0.005	24.022***	0.2%	3.316
TELCM	0.984**	0.417***	2.868*	1.7%	1.373	0.121	-0.165*	35.987***	0.1%	3.681
PERSV	0.940***	-0.009	18.469***	0.9%	2.195	0.036	-0.072	60.673***	0.0%	1.837
BUSSV	-0.677	0.600***	24.899***	-1.7%	1.985	2.382***	-0.394***	16.518***	1.7%	2.015
HARDW	2.524***	-0.518***	26.793***	1.7%	1.763	0.054	0.429***	66.581***	0.1%	2.311
SOFTW	0.554	0.461***	40.677***	1.0%	2.415	2.871***	-0.759***	18.325***	1.6%	1.707
CHIPS	0.526	0.007	149.972***	0.5%	1.410	1.637***	-0.008	35.941***	1.6%	3.436
LABEQ	-0.204	0.456***	38.912***	-0.4%	2.629	3.683***	-0.551***	14.810***	2.4%	1.614
PAPER	-0.856	0.378**	37.764***	-1.4%	1.816	1.942***	-0.313***	12.184***	1.5%	2.226
BOXES	1.476***	-0.170**	19.116***	1.3%	2.748	-0.157	0.070	67.268***	-0.2%	1.572
TRANS	-2.031	0.453**	30.996***	-3.7%	1.634	2.641***	-0.206**	22.644***	2.2%	2.577
WHLSL	-1.334**	0.630***	16.580***	-3.6%	2.015	3.029***	-0.363***	15.221***	2.2%	1.985
RTAIL	0.968***	-0.107	10.340***	0.9%	1.854	1.112**	0.038	40.649***	1.2%	2.171
MEALS	1.410***	-0.014	12.105***	1.4%	2.470	0.489	0.030	43.975***	0.5%	1.680

INDUSTRY	LOW PRESSURE REGIME					HIGH PRESSURE REGIME				
	CONST	AR(1)	SD OF RESIDUALS	LONG-RUN GROWTH	AVG EXPECTED DURATION	CONST	AR(1)	SD OF RESIDUALS	LONG-RUN GROWTH	AVG EXPECTED DURATION
BANKS	1.293***	-0.048	11.594***	1.2%	1.972	0.107	0.039	71.134***	0.1%	2.028
INSUR	-0.949	0.062	100.449***	-1.0%	1.187	1.263***	-0.075	14.558***	1.2%	6.353
RLEST	0.635	0.222***	21.018***	0.8%	3.270	0.508	0.039	164.065***	0.5%	1.441
FIN	-0.377	0.538***	40.758***	-0.8%	2.305	2.971***	-0.533***	28.274***	1.9%	1.766
OTHER	-0.175	0.079	67.452***	-0.2%	1.593	0.933***	-0.099	12.198***	0.8%	2.686

Source: own study.

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Acknowledgements and Financial Disclosure

Not applicable.

Use of Artificial Intelligence

The author declares that Grammarly was used for proofreading.

Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Published by Krakow University of Economics – Krakow, Poland

International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.04

Unitary Patenting in the EU: A comparative study of population- and R&D-based efficiency indicators and procedural preference

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ABSTRACT

Objective: The article aims to identify, appreciate, and assess the human resources efficiency, cost efficiency, and procedural preferences of EU member states covering Unitary Patent registration via the Unitary Patent System (UPS) and enforcement before the Unified Patent Court of Appeal (UPCoA) in 2024 and 2025.

Research Design & Methods: Based on a robust framework, academic, and empirical background, we selected seven-years delay and identified and visualized data about inhabitants and Gross domestic expenditures on R&D (GERD) in EU member states in 2017-2024 along with data about Unitary Patents granted and litigated before the UPCoA in 2024 and 2025. Following the matrix triad – human resource efficiency, cost efficiency, and procedural preferences – we addressed eight research questions (RQ1-RQ8) based on data extracted from the Eurostat database, European Patent Office (EPO) dashboard, and UPCoA collection via descriptive analyses (RQ1-RQ4), regression analysis (RQ5-RQ6), and features, and thematic identification (RQ7-RQ8).

Findings: The cohorts of the most human resources efficient, and of the most cost-efficient traditional EU member states, in Unitary Patenting overlap and include Sweden, Denmark, Finland, and Italy. Belgium, France, and Spain record very low efficiency, France, and Spain, while EU members joining since 2024 perform poorly. Our micro-longitudinal study found no dramatic trend changes. Emerging procedural preferences favour larger subjects with individuals mastering English. The exploration of data about the first two years of Unitary Patenting points to the leading role of Scandinavia and leaving behind Mediterranean states, except Italy, and newer EU member states, in particular Romania, and Bulgaria. The position of Germany is precarious and that of France – definitely bad.

Implications & Recommendations: European competitiveness needs Unitary Patents, ideally as many as possible, at the lowest cost, and with robust enforcement. The EU member states that excel in this should be studied carefully to model the progress in other EU member states. Specifically, we should closely observe Scandinavia to learn how to do it, while Spain, France, and especially Bulgaria and Romania to learn how not to.

Contribution & Value Added: This pioneering multi-disciplinary, holistic, and complex study confirms the importance of patents and shows that trusting in the size of the gross domestic product (GDP) and population, albeit GDP per capita helps little to predict efficiency in receiving Unitary patents. The investing-inventing-patenting-innovating process entails many unpredictable factors and variables, and AI can only partially help with that, while we may still identify the best approaches. There are EU member states with a full UPS membership, with no agricultural focus, and with a lean, not overly regulatory, pragmatic, and responsible approach, in which the investing-inventing-patenting-innovating process developed uninterrupted but respected and driven by the private sector. The creative culture of these states stems from specific national mentality further supported by a good grasp of the English language.

Article type: research article

Keywords: Unitary patent; GERD; efficiency; patenting; enforcement; procedural preferences

JEL codes: K29, K 41, O32, O34, O44, O52, O57, Z13

Received: 2 March 2026 Revised: 5 May 2026 Accepted: 13 May 2026

Suggested citation:

Beneš, M., Hála, M., MacGregor, R.K., & MacGregor Pelikánová, R. (2026). Unitary Patenting in the EU: A comparative study of population- and R&D-based efficiency indicators and procedural preference. *International Entrepreneurship Review,* 12(2), 65-84. https://doi.org/10.15678/IER.2026.1202.04

INTRODUCTION

For over three decades, competitiveness, intellectual property (IP), and sustainable growth anchor the EU's top priorities (Rubáček & MacGregor Pelikánová, 2025). Both European Commissions led by Ursula von der Leyen understood that the prosperity and functioning of the single internal market depends on smart, sustainable competitiveness generated by innovations (Decyk, 2025), which requires investment (Das, 2020), external and internal knowledge (Zygmunt, 2025), and protection (Fedajev *et al.*, 2025). Consequently, the EU policies, and law championed investment in Research and Development (R&D) (MacGregor Pelikánová, 2019) and the protection of inventions by European patents (EP) granted, under the European Patent Convention (EPC), through the European Patent Office (EPO) (Nicolai, 1971; Potužáková & Öhm, 2018). However, the famous Paris convention on industrial property protection from 1883 allows and underpins not only the EPC but also other concurring treaties, such as the Patent Cooperation Treaty (PCT), which the World Intellectual Property Organization administers (WIPO).

After decades of struggles (Kaesling, 2013), the EU reached a milestone on 1st June 2023, by launching the Unitary Patent System (UPS), allowing for a multi-jurisdictional alternative to the continuation of EP – the Unitary Patents (UP) (MacGregor Pelikánová *et al.*, 2025). The UPS rests on (i) Regulation No 1257/2012 on the establishment of the unitary effect conferred by a EP; (ii) Regulation No 1260/2012 which governs linguistic and translation requirements and (iii) Agreement on a Unified Patent Court from 19th February 2013 (UPCA) establishing the Unified Patent Court (UPC), comprising the Court of First Instance with central, regional, and local divisions, and the Court of Appeal in Luxembourg (UPCoA) (MacGregor Pelikánová & Beneš, 2023).

From the substantive perspective, the Eurostat database, and EPO dashboard supply data about the annual total number of UP granted to subjects from each and every EU member state in 2024 and 2025 as well as data about the population, GDP, GDP per capita, and even Gross domestic expenditure on R&D (GERD) in these jurisdictions in 2017-2024. From the procedural perspective, the Unified Patent Court (UPC) judgments repository supplies data about final decisions regarding UP disputes by UPCoA, about *rei judicata* disputes important to parties, showing which disputes mattered most to the parties and how they ended.

Certainly, patents do not exclusively protect inventions destined to become innovations (Ashrafi & Easmin, 2023). At the same time, more than a century of experience confirms the relevance and significance of patent protection and the correlation between the number of patents and economic growth (MacGregor Pelikánová, 2019; Saikia *et al.*, 2023), competitive advantage (Garncarz & Michalik, 2025) arguably even the sustainable development (Decyk, 2025; Bieńkowska *et al.*, 2025) with value creation (Malla & Zdziarski, 2025), and even cultural particularities (Zygmunt & Dvouletý, 2024). Undoubtedly, the patent regime par excellence among EU subjects, above all EU businesses, remains the EP with its special 2023 extension, the UP. Therefore, if the EU intends to compete genuinely in the 21st century, then Europeans must engage aggressively, effectively, and efficiently in the invest-invent-patent-innovate process. This calls for deeper engagement regarding the understanding of the inventing-patenting dynamics, in particular the appreciation of the involved efficiency. Consequently, the objective of this study was to explore the European human resources efficiency, cost efficiency, and procedural preferences based on EP by projecting this triad onto eight intra-related research questions.

The uniqueness, novelty, and data transparency of UP creates an exceptional chance to fill the pre-existing gap, regarding the patenting efficiency, and particularism in general as well as in the context of the UPS with EP. Namely, we can exploit a completely new emerging opportunity in observing UPS operation, along with national preferences and performance. In particular, permitting us to identify, appreciate, and assess the human resources efficiency, cost efficiency, and procedural preferences of EU member states regarding the Unitary Patents registration via the UPS and their enforcement via the UPCoA in 2024 and 2025. It exposes how efficient EU member states prove in generating and defending UP, and where the concentration runs highest of UP (a lot of UP per million inhabitants, *i.e.* a low number of inhabitants per UP) at the lowest cost (low GERD per UP) and which UP spark serious legal battles. In this context, the term efficient means 'doing things right' as opposed to effect, which means 'doing right

things.' Conse-quently, the starting point – our first premise – holds that obtaining UP proves positive, pro-competitive, and pro-sustainable to get as many UP as possible (because this is effective and *conditio sine qua non* for a large bulk of innovations), thus maximising the count per capita and per investment/cost (GERD) marks efficiency. Our second premise follows from the empirical observation that the investing–inventing–patenting–innovating process runs long (takes years) and risky (Asad *et al.*, 2024).

LITERATURE REVIEW

Nowadays, the investing-inventing-patenting-innovation line underpins progress (Decyk, 2025), development (Hall, 2024), and growth (De Rassenfosse *et al.*, 2013; De Rassenfosse & Palangkaraya, 2023), as revealed by history (Moser, 2013; Saikia *et al.*, 2023) and confirmed by the EU presence (Fedajev *et al.*, 2025) and emerging indices (Dziallas & Blind, 2019). Numerous publications refer to it, albeit often in a superficial manner, ignoring the patenting determination, significance, and justification in the context of various patent regimes entailing and demanding costs, disclosure, time, and more (Das, 2020). Plainly, prior studies are merely intuitively indicative and pass on a deeper exploration of patenting efficiency based on the labour and financial demands and costs with the inherent delay factor and particularism of national drives, preferences, and enforcement attitudes. However, there are new data to overcome such a pre-existing gap and address the mentioned key determinants, especially for UP within the UPS as an extension of the EP within the EPS, provided a proper conceptual and literature review is established. Such a review must address the patenting determination and significance, patenting justification, patenting regimes, and the built-in delay factor.

Patenting Determination and Significance

Human ideas about resolving various issues, overcoming obstacles, and doing new or better things (effective) in a new or better way (efficient) emerge from various products of human minds entailing various technological strategies (Beneito, 2023) such as creative works protected by copyright or confidential solutions protected by trade secret (Crass *et al.*, 2019). Although all these intellectual property assets stem from creative activities of the human mind, they differ in nature, and protection mechanisms (MacGregor Pelikánová, 2019). A significant subset comprises solutions of a technical problem called inventions, and they typically obtain a temporary, territorial monopoly protection title called patent (MacGregor Pelikánová, 2019). Namely, new inventive solutions of technical problems typically prove hardest to reach. Such inventions demand time, resources, and effort (Dvouletý & MacGregor Pelikánová, 2025) but also an out-of-the-box thinking and multi-disciplinary, cross-cultural, and sectorial collaboration (Van Tulder & Keen, 2018). Once achieved, patents protect them (De Rassenfosse *et al.*, 2013; De Rassenfosse & Palangkaraya, 2023) and turned into innovations (Ashrafi & Easmin, 2023).

The EU requires innovations grounded in inventions to secure sustainable prosperity and competitiveness, see Political Guidelines 2024-2029 with their European Prosperity Plan. Ursula von der Leyen opened her Political Guidelines 2024-2029 by stating that 'Europe has always been a continent of industry, enterprise, and innovation' (Political Guidelines 2024-2029, p. 6). She also stated that R&D requires financing (Nunes *et al.*, 2012), that we should measure innovation, and innovativeness by the number of patents granted (Prędkiewicz & Prędkiewicz, 2014), and that the EU needs a unified patenting regime (MacGregor Pelikánová *et al.,* 2025).

Therefore, following the logic triad investing-inventing-protecting (Koellinger, 2008), EU member states, and EU subjects must ensure that a sufficient share of their GDP and creative potential flows into R&D and that they deploy these efforts and funds effectively and efficiently to yield as many inventions as possible – inventions that attract patent protection which authors then convert into innovations (Barabino, 2019). Given the inherent risk features (Asad *et al.*, 2024), needed efforts, and financing requirements, and the length of the inventing-patenting process, only a few R&D endeavours produce patented inventions for transformation into innovations (Ashrafi & Easmin, 2023). However, innovations supply the key to competitive advantage (Garncarz & Michalik, 2025; Bigos & Wach, 2021), and sustainable progress. They reflect national, industrial, and even a firm's culture (Zygmunt & Dvouletý, 2024) and can be pivotal for the 'value proposition' at the intersection of value creation, capture and

delivery (Malla & Zdziarski, 2025). Plainly, without investment, creative skills, and both internal and external knowledge (Zygmunt, 2025) no inventions arise and, without inventions, no patents appear and innovation cannot flourish. Hence, Europeans should engage in inventing, with both their skills and resources, and should patiently and systematically work towards patents and innovations (Barabino, 2019) and the EU policies that law should support (Rubáček & MacGregor Pelikánová, 2025).

Nevertheless, since the very beginning of the modern recognition of the significance of inventions for innovation and progress by Joseph Schumpeter, the visionary of creative destruction, Joseph Schumpeter (Schumpeter 1934 &2003; Śledzik, 2013), and of the 'change as opportunity' entrepreneurship guru, Peter Drucker (Drucker, 2015), patent protection providing temporary, territorial exclusivity has drawn criticism. Such temporary, territorial monopolies arguably slow progress, lead to abuses, and breed massive unfairness. Therefore, for decades or even centuries, scholars have closely scrutinised patent justifications by drawing on various philosophical streams to assess the justice and justification regarding patents while national – often culturally based – approaches have evolved (MacGregor Pelikánová, 2019).

Patenting Justification

The discourse about the (lack of) justification for patents typically opens with Aristotle's distributive (appreciative) justice, which advances the concept of deserved rewards, see diagonal conjunction positive justice for unequals – physicians versus farmers (Jagannathan, 2019). This generates the distinction between property in distribution and property in use, following Augustine, Gregory the Great and Thomas Aquinas, who recognise private property but reject its unjust use for one's own benefit (Lopata, 1973). Hobbes's social contract demands political consensus authority, see the Faustian deal for patent protection (Lopata, 1973). Locke's labour theory explains the acquisition of exclusive title to property in the context of the natural law duty to preserve mankind, since the inventor must preserve himself and the results of his own exclusive work: patenting inventions (Lustig, 1991). Kant's deontological approach does not perceive the human enjoyment as a justification, see Kant´s categorical imperative (Baynes, 1989). As a matter of fact, Hobbes, Locke, and Kant stand as contract theorists: for Hobbes, such consent rests on rational self-interest; for Locke, on a natural right to self-preservation and the guarantee of absolute property rights; and for Kant, on a moral obligation to institutionalise property rights (Baynes, 1989). Classical utilitarianism opposes classical contractarianism (Gourevitch, 1975), meaning that consequentialism pursues benefit maximisation, or as Bentham's utilitarianism puts it: 'The interest of the community then is, what? The sum of the interests of the several members who compose it' (Gunn, 1968). This translates into the necessary incentive for R&D and planning with return of the interest via patents. In contrast, Hegel's intellectual property theory views property as an extension of personality, see Hegelian personification and mirror dualism of the author and his work (Priya, 2008). The cooperation by even citizens within a 'moral judgement in equilibrium' (Gourevitch, 1975) leads to Rawls's semi-egalitarian system, namely genuine cooperation (Fritsch *et al.*, 2020) and the political conception of justice for all, including inventors. Namely, Rawls's social justice theory argues that individual's views of justice in organizational contexts have a significant impact on both behaviours and outcomes (Beugr, 2002) and stresses the critical importance of fair reward allocation (Dahanayake *et al.*, 2018), *i.e.* organisational justice comprises distributive justice and procedural justice and shapes individuals' motivation and perceived equity (Rahman, 2024), including inventors. In addition to these leading philosophical justifications, additional streams in ethics and legal science support patent protection – be it directly or indirectly – due to entrepreneurship (Drucker, 2015) and other concerns, including sustainability (Balcerzak & MacGregor Pelikánová, 2020). Recent justifications arise from the concept of sustainability complemented by particular inventions and innovations, the public interest technology (Abbas *et al.*, 2024) and convincing propositions about cross-sectorial collaboration and partnership (Van Tulder & Keen, 2018). This basically means solving public problems in the public interest (Michael & Abbas, 2020) while preserving resources and avoiding waste (Marikyan & Papagiannidis, 2024) and naturally such a pro-multi-stakeholder endeavour (Lashitew *et al.*, 2020;

MacGregor Pelikánová *et al.*, 2024) fully aligns with priorities advanced both by current policies and law (Marikyan & Papagiannidis, 2024).

Furthermore, these justifications face ongoing attack from the idea of abolishing private property entirely, including intellectual property assets such as patented inventions, which Karl Marx advanced through his surplus-versus-added-value approach (Marx, 1969), explained by the socialisation of the means of production and distribution of common goods on the basis of need (Lopata, 1973), which still surface in the 21st century. Despite all empirical experience, particularly the catastrophic economic record with the abolition of the patent protection (the Netherlands 1869-1912), voices still call for reducing or even eliminating the protection of R&D cooperation (Fritsch, 2020) and of resulting inventions. Nevertheless, the prevailing position remains clear: the law must protect inventions and the typical legal title for that temporary, territorial, negative-absolute monopoly remains the patent.

Patenting Regimes

A patent grants its holder a legal title to exclude others in the given jurisdiction from using the patented invention without the permission of the patent owner during a fixed time period, for up to 20 years. Consequently, every patent carries a temporary, territorial nature and demands a *sui generis* strategy (Appio *et al.*, 2022). Pursuant to the conventional approach, national law establishes a national patent regime that produces such national patents for transposition into national innovations (Dziallas & Blind, 2019). Since the 19th century, governments have facilitated the obtaining of more national patents via international patenting regimes. Hence, although a patent remains essentially national, valid in one jurisdiction (national patenting regime), through recognition and harmonisation under international treaties (international patenting regimes), applicants can co-ordinate the simultaneous acquisition of several national patents and so exploit the patents-innovation link (Moser, 2013). The most important international patenting regimes for Europeans are based on PCT and EPC.

The PCT was signed in 1970 in Washington and is administered by WIPO in Geneva, which now counts 157 member states. The EPC was signed in 1973 in Munich, and it operates under the Council of Europe, now counting 39 member states (Nicolai, 1971). All 27 EU member states belong to both the PCT and the EPC. The EPC and PCT systems compete with each other which, drawing from a national patent application and a 12-month national phase, permit an international examination and search phase of 18-24 months, which yields a title convertible into a bundle of mutually independent national patents which holders maintain and defend independently and separately.

Unitary Patents and Unitary Patent System: Seven Years Built-in Delay

For decades, the EU has pursued unified trademark and patent regimes (Kaesling, 2013; MacGregor Pelikánová & Beneš, 2023). In 2016, Regulation 2015/2424 delivered this for trademarks transforming the Community Trade Mark into a truly unified European Trademark. However, the original enthusiastic push for unified patents via the UPS collapsed, amid underestimated opposition driven by several factors (EU law reach, language regimes, judicial review, jurisdictions, fees and their distributions, etc.), which spawned several cases the CJEU decided. Spain launched the especially salient C-146/13 and C-147/13 seeking to annul both key UPS implementing regulations: (i) Regulation No 1257/2012 on the establishment of the unitary effect conferred by a EP and (ii) Regulation No 1260/2012 which governs linguistic administration and translation requirements. Their rejection sealed Spain's decision to stay out of the UPS as much as feasible (MacGregor Pelikánová & Beneš, 2023), *i.e.* not signing the UPCA. Ultimately, a less ambitious regime emerged, *i.e.* on 1st of June 2023, the EU launched the UPS as a sub-option, co-operating with the EPC, allowing an EP to become one UP valid across several jurisdictions, replacing a bundle of national patents (MacGregor Pelikánová *et al.*, 2025). The UPS streamlines complex registration and management procedures, removes validation, saves resources, and delivers uniform patent protection in 18 EU member states (UPS states).

Although both Regulations apply across the entire EU, the UPCA – the third EPS pillar – governs unified judicial enforcement, with the UPCoA at the apex, which 18 EU member states have signed and ratified (UPCA A states). Six states have signed it without ratifying (Cyprus, Czech Republic,

Greece, Hungary, Ireland, Slovakia – UPCA B states). Three states have not yet signed the UPCA (Croatia, Poland, Spain – UPCA C states).

Procedurally, EPO keeps accepting requests based on national patent applications to move to the international phase, once the national phase concludes, and, if successful, grants the European Patent (MacGregor Pelikánová & Beneš, 2023). Importantly, the European Patent acts not as a patent per se but as a title issued by a centralised proceeding which lets the applicant, via validation, acquire a bundle of national patents. The UPS lets European Patent holders, instead of validating to obtain a bundle, request a truly regional patent, the Unitary Patent, automatically valid in 18 EU member states (EU member states enrolled in enhanced co-operation regarding Unitary Patents) and, and, hopefully, in the other six EU member states. Hence, after a two-to-four-year research process, the applicant files a national patent application that enters a national phase (12 months) and an international phase with the EPO (18-24 months). Thereafter, the successful applicant secures the European Patent and may either convert it into a set of separate national patents or opt for a Unitary Patent, requiring future payment of only one annual renewal fee and the management of only one regional patent covering (so far) 18 EU member states. Empirical observation and prior arguments confirm that, although the inventing-patenting length always remains individual and specific (Dvouletý & MacGregor Pelikánová, 2025), the process takes at least five years, and an invention rarely becomes a European Patent or Unitary Patent after more than nine years (the patent issues earlier or not at all) (MacGregor Pelikánová & Beneš, 2023; MacGregor Pelikánová *et al.*, 2025). We therefore adopt a 7-year delay, *i.e.* if successful, R&D – with its human-resource and cost demands – yields a Unitary patent after 7 years. We therefore match GDP, GERD, inhabitants, and other Y1 data against data on Unitary Patents granted in Y8 (Das, 2020).

RESEARCH METHODOLOGY

Drawing on the robust framework and the academic and empirical background, we extended the recently developed methodological approach to patenting efficiency using indices that involve GERD per capita and patent counts (Dziallas & Blind, 2019) with the seven-year delay (MacGregor Pelikánová *et al.*, 2025), and applied it to fresh data about UP granted for both completed UPS operating years, *i.e*. 2024 and 2025.

Namely, the data from Eurostat about the number of inhabitants in 2017 and 2018 and about GERD in 2017 and 2018 for all 27 EU member states we extracted, tabulated, recalculated, and further processed alongside data extracted from the EPO dashboard about UP granted in 2024 and 2025 to subjects from all 27 EU member states. These data target the human-resource efficiency and cost efficiency of EU member states and their subjects to get UP and we now complement them with a fresh set of data on all UPCA decisions.

This methodological framework necessarily remains complex and partly heterogenous given the inherent features of the investing–inventing–patenting–innovation process, the intangibility of involved assets, and the variability of the delay effect. Consequently, a snowball of intra-related dynamics affects the systematically employed battery of methodology tools as well as the data regarding the so far only two completed years of UPS.

Consequently, this methodology mirrors the available data and patenting particularism, and aligns with recent trends and innovation indices (Ujwary-Gil, & Florek-Paszkowska, 2025). These selected and processed data on inhabitants, GERD in EU member states in 2017-2024, along with data about UP granted and litigated before the highest UPS court, UPCA, in 2024 and 2025, support the matrix triad – human resource efficiency, cost efficiency and procedural preferences – which we projected onto eight research questions (RQ1-RQ8) and addressed through descriptive analysis with trends indications (RQ1-RQ4), regression analysis with cluster indications (RQ5-RQ6) and thematic analysis with procedural preferences indications (RQ7-RQ8). We add a gloss and comparison against AI findings. The dynamic juxtaposition and visualization of the processed data let us identify procedural preferences and even key features of EU member states belonging to the top cohort.

Descriptive Analysis of Human Resources and Costs Efficiency With Trends Indications

The EPO dashboard https://www.epo.org/en/about-us/statistics/statistics-centre#/unitary-patent is used to extract data about UP in 2024, in 2025 and in 2025 versus 2024 (Table 1) (EPO, 2026). The UPC overview (UPC, 2026) is used to indicate the UPS membership of each EU member state (A full – UPCA in force; B partial – UPCA to be ratified; C out – no UPCA signed) (Table 2). The data included in these two Tables, along with their per capita recalculation, allows one to address four research questions regarding the human resources efficiency and its development and regarding the cost efficiency and its development.

RQ1: What is the Unitary Patenting efficiency of EU member states, based on human capital, *i.e.* what is the Inhabitants/UP index in EU member states (human resources efficiency)?

RQ2: How has the Unitary Patenting efficiency of EU members, based on human capital, evolved in 2024-2025, *i.e.* how has the Inhabitants/UP index changed in EU member states from 2024 to 2025 (human resources efficiency)?

RQ3: What is the Unitary Patenting efficiency of EU member states, based on financial expenses, *i.e.* what is the GERD/UP index in EU members states (cost efficiency)?

RQ4: Who has the top Unitary Patenting efficiency of EU members, based on costs, evolved in 2024-2025, *i.e.* how the GERD/UP index has changed in EU member states from 2024 to 2025?

Related processing and response generating to each of these four research questions is visualized by graphs (Figures 1-4). Such a descriptive analysis with trends indications is further advanced by regression analysis.

Regression Analysis of Human Resources and Cost Efficiency With Cluster Indications

Recognizing the seven years delay effect and development 2017-2024 versus 2018-2025, we developed two separate linear regression models, while for each we used GERD in EUR per capita seven years earlier as the independent variable and UP per million inhabitants as the dependent variable. These models address the following two research questions (RQ5-RQ6).

RQ5: What is the linear regression model of Inhabitants/UP index (human resource efficiency) and GERD/UP index (cost efficiency) while considering Inhabitants and GERD from 2017 and UP from 2024?

RQ6: What is the linear regression model of Inhabitants/UP index (human resource efficiency) and GERD/UP index (cost efficiency) while considering Inhabitants and GERD from 2018 and UP from 2025?

The descriptive and regression analysis provides predominantly quantitative data on human-resource and cost efficiency but conceals the dynamics of daily operation and about the real interest and commitment.

Thematic Analysis With Procedural Preferences Indications and Further Gallops Indications With the AI Double check

An obvious litigation triage offsets this, *i.e*. Unitary Patents that pass full UPS judicial review and reach *rei judicata* at the UPCoA qualify as Unitary Patents that matter (RQ7). Such thematic analysis and exploration rest on objective data extracted from the mentioned database, such as the register number, the name of parties, and the proceeding language employed. Together with the propositions we generated for prior questions, (RQ1-RQ6), this yields not only procedural preferences, and specific indices but generally thematic features for the top cohort of the EU member states regarding Unitary Patenting (RQ8).

RQ7: What are the shared features of unitary patenting enforcement before the UPCoA?

RQ8: What are the shared features of Unitary Patenting efficiency and commitment leaders, *i.e.* what is common for the most human resources efficient, and most cost efficient and most enforcement commitment EU member states regarding Unitary Patenting?

RESULTS AND DISCUSSION

As suggested, we present the results and discussion in three batches – descriptive analysis with trends indications (RQ1-RQ4), regression analysis of human resources and cost efficiency with clusters indications (RQ5-RQ6) and thematic analysis with enforcement (and further) preferences, double-checked by AI, with further cluster indications.

Descriptive Analysis With Trends Indications

We begin by determining how many European Patents the EPO granted to subjects from each and every EU member state in each of the two full years of the UPS operation, in 2024 and 2025 (Table 1.).

Table 1. Unitary Patents in 2024, in 2025 and in 2025 as opposed to 2024

Unitary Patents	2024	2025	2025v2024
European Union – 27 countries (from 2020)	14760	16548	112%
Belgium	527	576	109%
Bulgaria	11	20	182%
Czechia	73	81	111%
Denmark	660	728	110%
Germany	5277	5951	113%
Estonia	28	32	114%
Ireland	246	279	113%
Greece	24	42	175%
Spain	463	554	120%
France	1895	2195	116%
Croatia	5	10	200%
Italy	1670	1869	112%
Cyprus	15	30	200%
Latvia	12	25	208%
Lithuania	19	38	200%
Luxembourg	64	58	91%
Hungary	36	44	122%
Malta	19	20	105%
Netherlands	952	1090	114%
Austria	710	722	102%
Poland	116	186	160%
Portugal	103	122	118%
Romania	10	12	120%
Slovenia	54	50	93%
Slovakia	24	24	100%
Finland	499	554	111%
Sweden	1248	1236	99%

Source: own study based on EPO dashboard.

Generally, Unitary Patents continue to gain popularity and the EU-wide annual increase from 2024 to 2025 reaches 112%. A radical increase appeared only among subjects from EU member states (Bulgaria, Greece, Croatia, Latvia) that recorded very low results in 2024, *i.e.* their elevated Unitary Patent count so far represents only a small correction of prior very poor results. No EU member state fell below 90% and so we can propose that no dramatic changes have emerged in the Unitary Patents subjects obtained in 2024 and 2025. Examining UPCA involvement (A, B, C) and the ratio of Unitary Patents in 2024 and 2025 against the population (inhabitants) and investment (GERD) seven years earlier, (2017 and 2018) yields more specific information on the relationship between Unitary Patents and available population and financial resources seven years ahead (Table 2).

Table 2. Inhabitants and GERD in 2017 and in 2018 v Unitary Patents in 2024 and in 2025

Country	A	B	C	2024UP	Inh2017/ UP2024	GERD2017/ UP2025	2025 UP	Inh2018/UP2024 in mill EUR	
European Union 27 countries (from 2020)				14 760			16 548		
Belgium	x			527	21 540	23	576	19 789	23
Bulgaria	x			11	622 683	35	20	337 871	21
Czechia		x		73	144 915	47	81	130 988	49
Denmark	x			660	8710	13	728	7941	12
Germany	x			5277	15 638	19	5951	13 912	18
Estonia	x			28	46 987	11	32	41 223	11
Ireland		x		246	19 509	15	279	17 404	13
Greece		x		24	448 675	85	42	255 742	52
Spain			x	463	100 426	30	554	84 197	27
France	x			1895	35 256	27	2195	30 536	24
Croatia			x	5	815 754	85	10	401 434	50
Italy	x			1670	35 968	14	1869	32 069	14
Cyprus		x		15	57 992	7	30	29 287	4
Latvia	x			12	162 510	11	25	77 375	7
Lithuania	x			19	150 478	20	38	74 374	11
Luxembourg	x			64	9229	11	58	10 379	12
Hungary		x		36	270 552	46	44	220 765	47
Malta	x			19	24 178	3	20	23 742	4
Netherlands	x			952	17 943	17	1090	15 762	15
Austria	x			710	12 356	16	722	12 219	16
Poland			x	116	327 353	42	186	204 176	32
Portugal	x			103	100 432	25	122	84 719	23
Romania	x			10	1 964 395	94	12	1 627 790	85
Slovenia	x			54	38 257	15	50	41 338	18
Slovakia		x		24	226 473	31	24	226 797	31
Finland	x			499	11 029	12	554	9951	12
Sweden	x			1248	8009	13	1236	8188	13

Source: own study based on Eurostat and EPO dashboard (EPO, 2026).

This focused overview shows that the Unitary Patenting efficiency, while considering the population (inhabitants) and financial investment (costs) at the estimated average beginning of the inventive process (seven years prior), remains broadly consistent within each state, yet dramatic differences appear between states, as prior similar studies on R&D versus patenting have suggested (Potužáková & Öhm, 2018; Ujwary-Gil & Florek-Paszkowska, 2025). *Prima facie*, the largest bulk of population and investment per Unitary Patent appears in Romania, while the smallest bulk falls to the Scandinavian trio (Sweden, Denmark, and Finland) and in very small states with a high risk of statistics impairment, given the particularism of their economy coupled with their small size (Cyprus, Latvia, Luxembourg). Visualisation helps us appreciate the human resources efficiency of Unitary Patenting while linking 2017 inhabitants and 2024 Unitary Patents and 2018 inhabitants and 2025 Unitary Patents.

Figure 1 shows the index 'Inh versus UP' changes from 2024 to 2025, with states sorted from most to least efficient in 2024. Figure 1 confirms the Scandinavian trio's leadership followed by Austria and all European communities creating states – Germany, France, Italy, Benelux. EU member states with the lowest concentration of Unitary Patents per inhabitants lie among agriculture-oriented South-Eastern states – Romania, Croatia, Bulgaria, Greece, Poland, and Hungary (RQ1). *Prima facie*, no dramatic trend changes appear but, to double-check, we visualise the dynamics in Figure 2.

Comparing 2017-2024 versus 2018-2025, the human resources efficiency appears to be increasing for almost all states (blue) and generally no dramatic changes occur (RQ2). Namely the drop occurred only in Sweden, Luxembourg, Slovakia, and Slovenia (red), but did not exceed 20 %. In contrast, the

biggest increase in the human resources efficiency achieved 40-50%, and it was in the Southern and Eastern states with generally not impressive Unitary Patenting results. Plainly, trends remain and changes are rather moderate adjustments. This invites the consideration of cost efficiency (see Figure 3) and its development (see Figure 4).

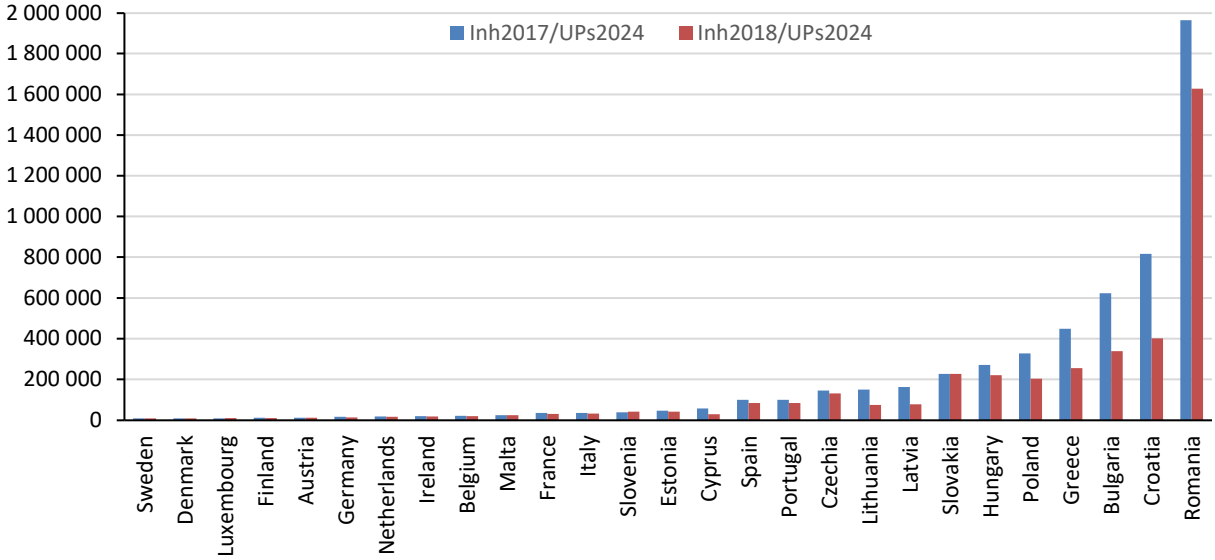

Figure 1. Human resource efficiency – Inhabitants 2017/2018 v Unitary Patents in 2024/2025 – static
Source: own elaboration based on Eurostat and EPO dashboard.

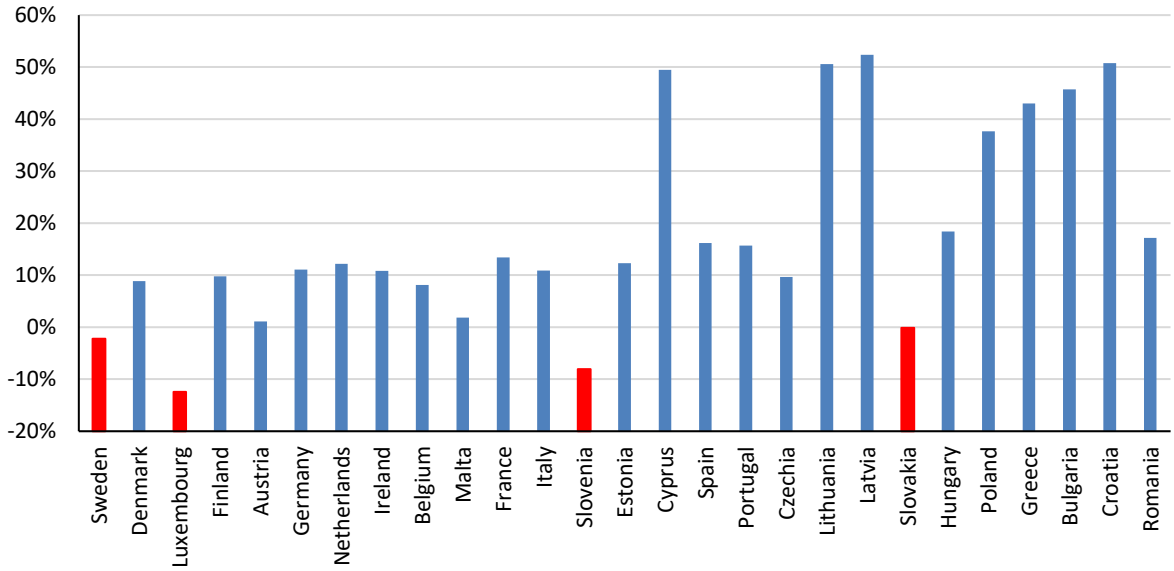

Figure 2. Human resource efficiency – Inhabitants 2017/2018 v Unitary Patents in 2024/2025 – trend dynamics aka Improvement in the Index Inhabitants v UP
Source: own elaboration based on Eurostat and EPO dashboard.

Figure 3 shows the index 'GERD versus UP' in 2024 to 2025. The EU member states are sorted from the most efficient to the least efficient one in 2024. Cost efficiency rises (*i.e.* the index decreased) in most countries. Furthermore, the lowest efficiency in both GERD 2017/UP2024 and GERD2018/UP2025 appears in Romania, fully matching prior studies on innovation differences among EU member states (Decyk, 2025). Moreover, the least cost-efficient EU member states – namely Czech Republic, Greece, Hungary, Slovakia, Croatia, Poland, Spain, and until 2024, Romania – neither hold full UPS membership nor have ratified the UPCA (RQ3). Therefore, we suggest that the starting cost-

efficiency stood markedly worse for reluctant, late, or non-joining UPS member states. And what about the development of cost efficiency, in particular in EU member states for which the literature expected or even proclaimed improvement, such as Slovakia, Romania, or Spain (Garncarz & Michalik, 2025)?

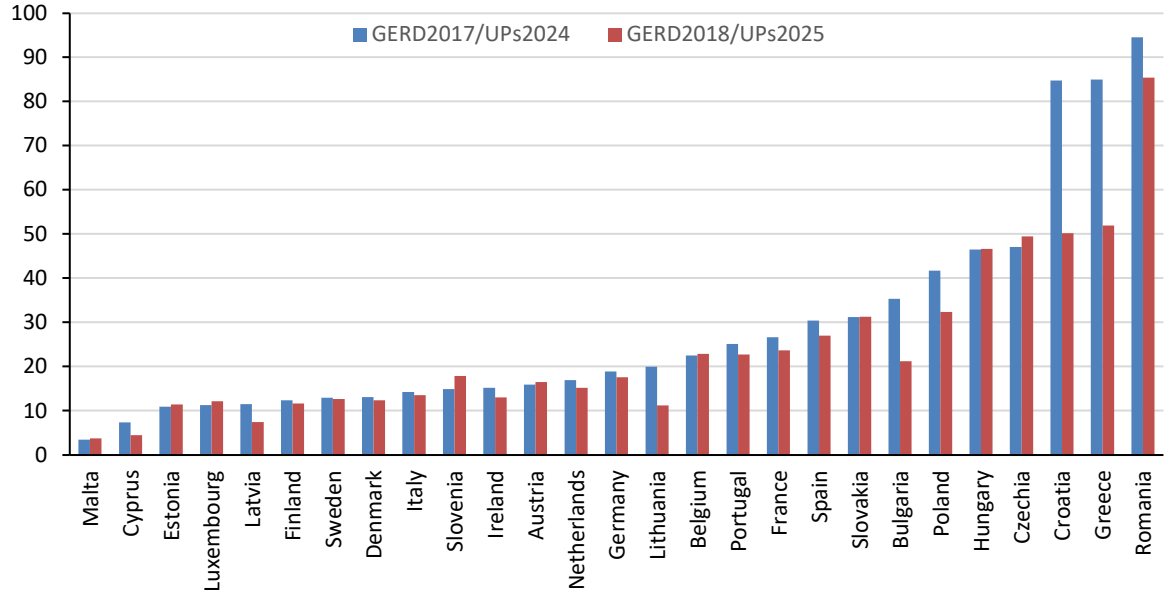

Figure 3. Cost efficiency – GERD 2017/2018 v Unitary Patents in 2024/2025; static
Source: own elaboration based on Eurostat and EPO dashboard.

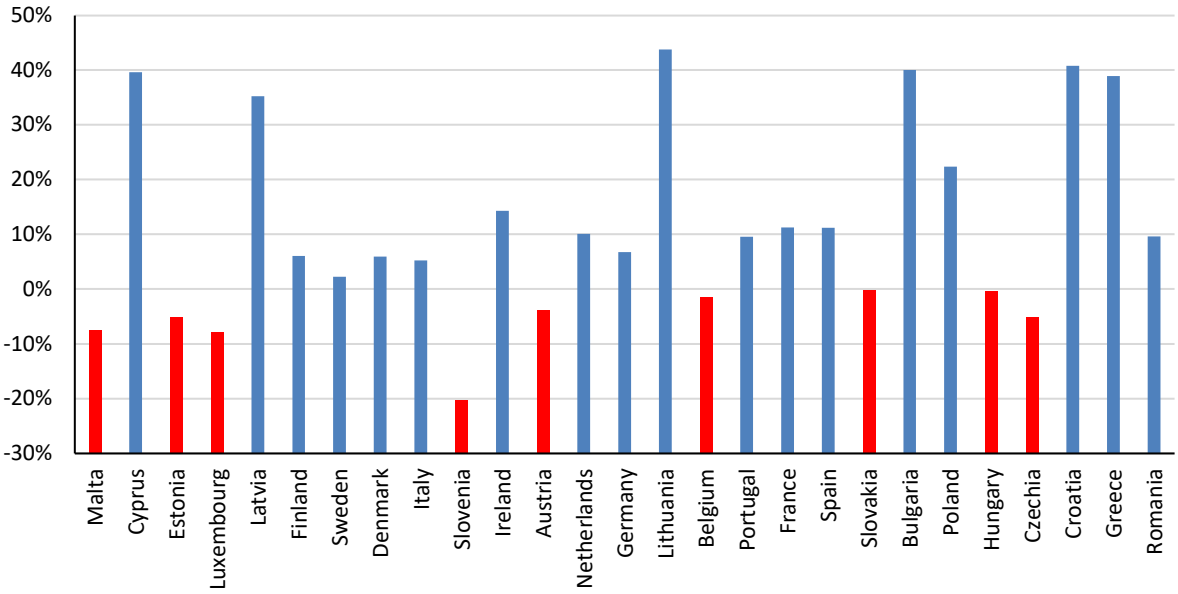

Figure 4. Cost efficiency – Inhabitants 2017/2018 v Unitary Patents in 2024/2025 – trend dynamics aka Improvement in the Index GERD v UP
Source: own elaboration based on Eurostat and EPO dashboard.

Figure 4 shows the percentage changes in this efficiency. EU member states where cost efficiency rose appear in blue again and, where it fell, in red. Improvements arose predominantly in smaller EU member states with unimpressive cost efficiency, *i.e.* they fell by up to 30% and rose by up to 45% (RQ4). This descriptive analysis grounds the following regression analysis.

Regression Analysis With Cluster Indications

We developed two linear regression models separately, for both 2017-2024 and 2018-2025. We used GERD in EUR per capita seven years earlier as the independent variable. and UP per million inhabitants as the dependent variable. Both models prove highly statistically significant. The R-squared of the first model exceeds 90%, while the second model falls just below this benchmark, see Figure 5 for RQ5 and Figure 6 for RQ6.

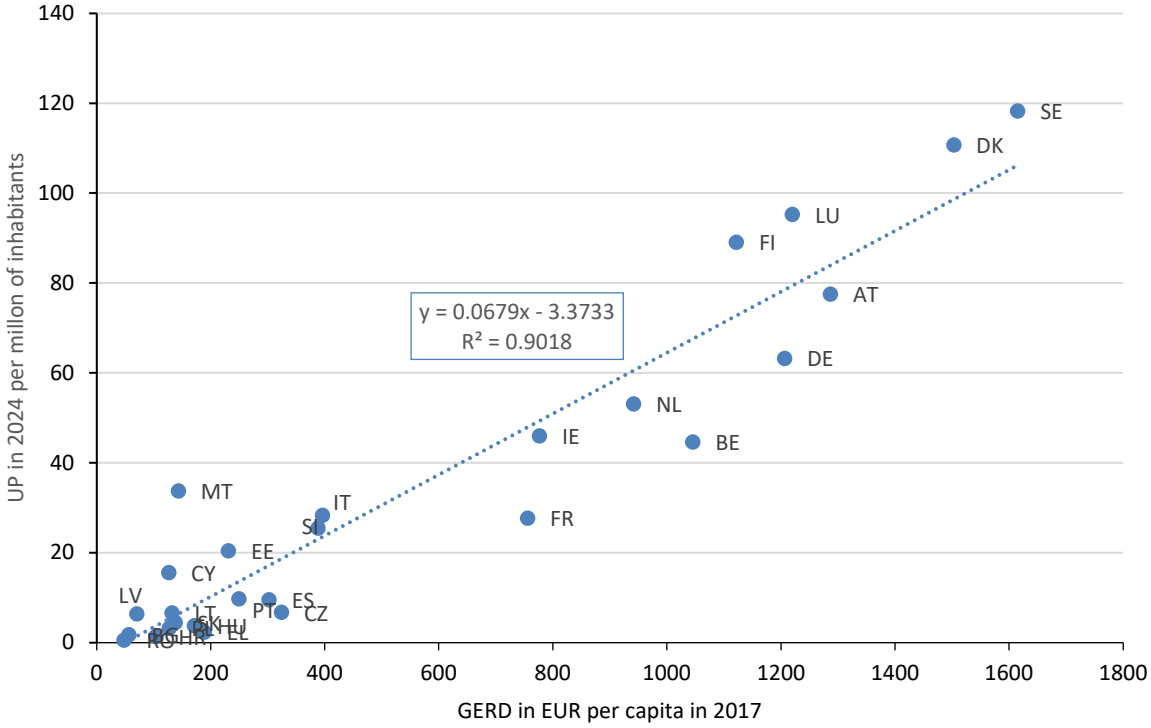

Figure 5. Linear regression model: UP in 2024 per million of inhabitants v GERD in EUR per capita in 2017
Source: own elaboration based on Eurostat and EPO dashboard.

The first linear regression model of combined human resources and cost efficiency for Unitary patenting 2017v 2024, *i.e.* Inhabitants 2017/UP 2024 index (human resource efficiency) and GERD 2017/UP 2024 index (cost efficiency) confirms Scandinavia's leadership, followed by Austria and, partly, the original six EC states, as France, and Belgium underperform while Italy outperforms them (RQ5) (see Figure 5). This aligns with prior studies (Scellato, 2007). For comparison, we should now examine the second linear regression model (see Figure 6).

The second linear regression model of combined human resources and cost efficiency for Unitary patenting 2018 versus 2025, *i.e.* Inhabitants 2018/UP 2025 index (human resource efficiency) and GERD 2018/UP 2025 index (cost efficiency), reconfirms Scandinavia's leadership followed by Austria and only partly the original six EC states, as France and Belgium underperform while Italy outperforms them (RQ6) (see Figure 6).

However, we argue that Unitary Patenting must move beyond plain numbers and recognise the dramatic differences between Unitary Patents: some patents prove critical for innovations while others lie forgotten and unused at the bottom of a desk drawer. A key indicator of truly valuable and innovation-driving patents lies in the determination to protect and enforce them by litigating until the *rei judicata* decision by the top instance – the UPCoA. These procedural preferences form an integral part of the Unitary Patenting efficiency assessment.

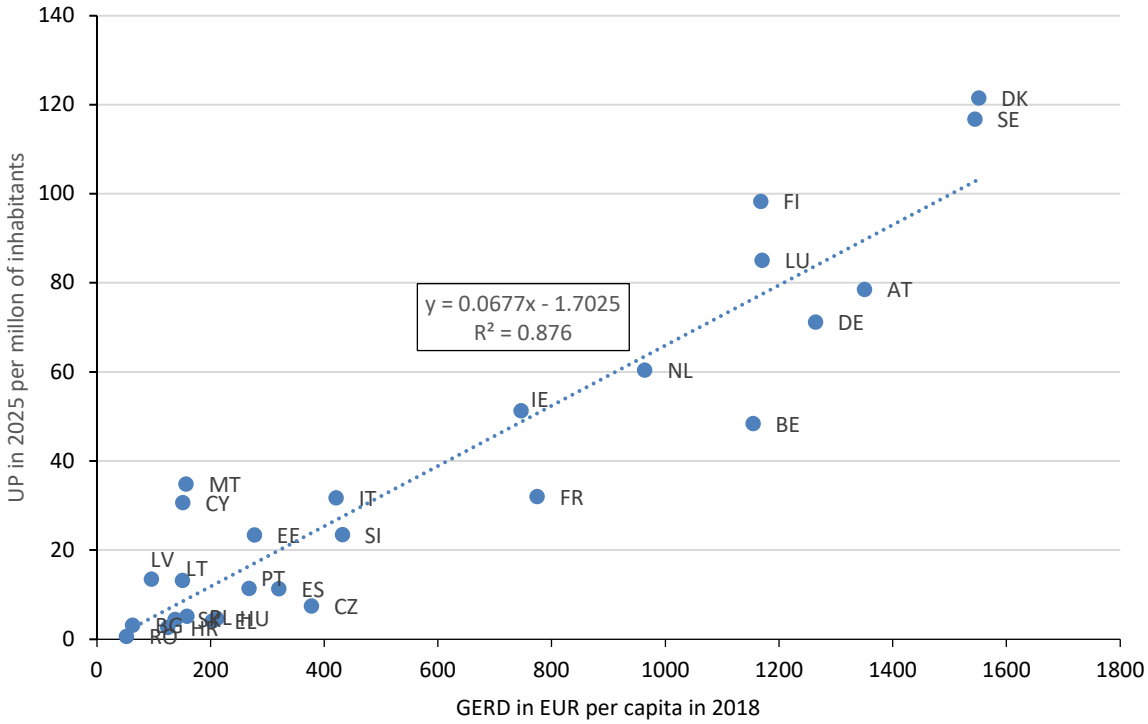

Figure 6. Linear regression model: UP in 2025 per million of inhabitants v GERD in EUR per capita in 2018
Source: own elaboration based on Eurostat and EPO dashboard.

Thematic Analysis With Procedural Preferences Indications and AI Double Check

Table 3 summarises all final judgements by the appeal instance of the UPS, *i.e.* the UPCoA, until the 9th of January 2026, and shows that only two of these 82 proceedings did not run in English, see Table 3.

Table 3 reveals not only English language's total dominance but also German language's clear second position – with 30 out of the 82 proceedings – along with the absence of any clear third position. Specifically, based on the data available so far, patent holders enforce Unitary Patents in English, German, and occasionally in Italian, Danish, and Dutch – with the same litigants often appearing, with typical plaintiffs (JUUL Labs, Volkswagen AG) and typical defendants emerging (NJOY Netherlands B.V., Xiaomi). Recalling the principal controversies around the UPS, this delivers a clear answer: subjects insist on enforcing Unitary Patenting in English and German. Thus, it obviates any third language and makes the entire debate about French, Italian, and Spanish appear obsolete (RQ7).

From this emerges a proposition on shared features Unitary Patenting efficiency and commitment leaders, *i.e.* the descriptive analysis, regression analysis and thematic procedural exploration imply that subjects managing to get the most Unitary Patents while having the lowest human resources and cost demands are typically from EU member states which (RQ8):

1. are full UPS members (category A);
2. have consistently recognized the importance of innovations and justification of patents;
3. take the lean, consistent and not over-regulatory approach;
4. leave the R&D and patenting predominantly to private parties with a minimal involvement of the state;
5. are not focusing on agriculture;
6. ave joined the EU before 2004;
7. their population masters English and German.

These propositions echo prior studies on the importance of proper framework, attitude, and financing (Appio *et al.*, 2022; Beneito, 2023; Decyk, 2025; MacGregor Pelikánová *et al.*, 2025), while foregrounding the predominance of private patenting, the negative impact of a stronger state involvement, and the lin-

guistic primacy of English and German, *i.e.* signalling the growing redundancy of the French-Spanish patenting discourse and other 'historical-cultural' disputes (MacGregor Pelikánová & Beneš, 2023). Such propositions carry very serious consequences at the state level, for policy, and at the business level, for managerial strategy, naturally inviting further verification, development, and refinement.

Table 3. UPCoA final judgments until 9th January, 2026

DateSort ascending	Registry number/Order reference	EN	DE	Oth
09 January 2026	UPC_CoA_328/2025, APL_16780/2025	1	0	0
09 January 2026	UPC_CoA_237/2025, APL_13193/2025	1	0	0
09 January 2026	UPC_CoA_257/2025, APL_14348/2025	1	0	0
29 December 2025	APL_4383/2025, UPC_CoA_71/2025	1	0	0
24 December 2025	App_20809/2025, UPC_CoA_523/2024	1	0	0
23 December 2025	UPC_CoA_691/2025	1	0	0
22 December 2025	UPC-COA-0000886/2025	1	0	0
19 December 2025	App_35643/2025	1	0	0
09 December 2025	APL_366/2025	1	0	IT
27 November 2025	UPC_CoA_70/2025	0	1	0
27 November 2025	PC-CoA-001/2025	0	1	0
25 November 2025	UPC_CoA_528/2024	1	0	0
25 November 2025	UPC_CoA_529/2024	1	0	0
25 November 2025	UPC_CoA_464/2024, UPC_CoA_457/2024…	1	0	0
05 November 2025	APL_64022/2024	1	1	0
05 November 2025	APL_64706/2024	1	1	0
03 October 2025	UPC_CoA_19/2025	1	1	0
03 October 2025	UPC_CoA_683/2024	1	1	0
03 October 2025	UPC_CoA_534/2024	1	1	0
02 October 2025	UPC_CoA_774/2024	1	1	0
02 October 2025	UPC_CoA_764/2024	1	1	0
01 October 2025	UPC_CoA_681/2025	1	0	0
13 August 2025	APL_24205/2025	1	0	0
12 July 2025	APL_55849/2024	1	0	0
09 July 2025	APL_23093/2025	1	0	0
09 July 2025	APL_23095/2025	1	0	0
03 July 2025	APL_12280/2025	1	0	0
03 July 2025	APL_8639/2025	1	1	0
26 June 2025	APL_36389/2024	1	0	0
23 June 2025	APL_14947/2025	1	0	0
20 June 2025	APL_20694/2025	1	0	0
06 June 2025	APL_57918/2024	1	1	0
04 June 2025	APL_13146/2025	1	0	DK
02 June 2025	APL_8790/2025	1	1	0
30 May 2025	APL_68523/2024	1	1	0
01 May 2025	APL_64374/2024	1	0	0
14 April 2025	APL_8326/2025	1	0	0
11 April 2025	APL_9191/2025	1	0	0
26 March 2025	APL_31428/2024	1	1	0
04 March 2025	APL_51115/2024	1	0	0
14 February 2025	APL_39664/2024	1	0	0
12 February 2025	APL_58177/2024	1	0	0
10 January 2025	APL_54646/2024	1	0	0
09 January 2025	APL_46747/2024	1	0	0
20 December 2024	APL_40470/2024	1	0	0
20 December 2024	APL_40553/2024	1	0	0
10 December 2024	APL_593120/2023	1	1	0

DateSort ascending	Registry number/Order reference	EN	DE	Oth
03 December 2024	APL_32012/2024	1	1	0
21 November 2024	APL_50205/2024	1	0	0
21 November 2024	APL_44633/2024	1	0	NL
12 November 2024	APL_596007/2023 & APL_596892/2023	1	0	0
12 November 2024	APL_596007/2023	1	0	0
04 October 2024	APL_83/2024	1	1	0
25 September 2024	APL_21143/2024	1	1	0
25 September 2024	APL_21143/2024	1	1	0
24 September 2024	APL_32350/2024	1	1	0
24 September 2024	APL_32345/2024	1	1	0
24 September 2024	APL_32347/2024	1	1	0
18 September 2024	APL_30169/2024	1	1	0
18 September 2024	APL_30168/2024	1	0	0
18 September 2024	APL_38206/2024	1	0	0
18 September 2024	APL_38948/2024	1	0	0
17 September 2024	APL_25919/2024	1	0	0
17 September 2024	APL_26889/2024	1	0	0
17 September 2024	APL_25922/2024	1	0	0
16 September 2024	APL_33746/2024	1	0	0
05 September 2024	APL_24598/2024	1	1	0
05 September 2024	APL_12739/2024	1	1	0
03 September 2024	APL_21943/2024	1	1	0
06 August 2024	APL_21602/2024	1	0	0
06 August 2024	APL_10370/2024	1	1	0
06 August 2024	APL_24585/2024	1	1	0
23 July 2024	APL_20002/2024	1	0	0
04 June 2024	APL_9578/2024	1	0	0
28 May 2024	APL_3507/2024	1	0	0
13 May 2024	APL_8/2024	1	1	0
17 April 2024	APL_12116/2024	1	1	0
03 April 2024	APL_588422/2023	1	0	0
03 April 2024	APL_588425/2023	1	0	0
03 April 2024	APL_588423/2023	1	0	0
03 April 2024	APL_588420/2023	1	0	0
03 April 2024	APL_588426/2023	1	0	0
Total		80	30	

Source: own study based on UPCoA collection.

To complement these propositions, and as we previously discussed in similar cases (Balcerzak, & Valaskova, 2024; Rubáček & MacGregor Pelikánová, 2025), we placed RQ8 as a prompt to AI – ChatGPT – which produced the following suggestions:

- early ratification and political commitment to the UPC/UP system;
- high innovation capacity and frequent patent use;
- legal and administrative readiness, including professional ecosystems that support cross-border patent management;
- economic incentives to reduce costs and complexity;
- policy alignment with broader EU IP objectives.

To elicit an even more specific AI answers, comparable to our findings above, we asked AI to identify the most efficient states, which led to the following:

- Nordic countries (Denmark, Sweden, Finland) show above-average uptake relative to population, indicating efficient use of the UPS;

- large EU innovators (Germany, Netherlands) generate high absolute volumes and also show solid relative performance;
- smaller states with strong innovation ecosystems often convert a higher share of their European patents into Unitary Patents, reflecting effective utilisation.

These replies do not contradict our propositions above yet remain markedly more superficial and partly misleading, see, for example, the overstatement of Germany, the neglect of France's poor position, and the disregard of Italian particularities (Scellato, 2007) and high success rates (MacGregor Pelikánová *et al.*, 2025; Rubáček & MacGregor Pelikánová, 2025).

CONCLUSIONS

Unitary Patents continue to gain ground steadily across the EU, in particular in the 18 full UPC member states (UPCA category A) yet dramatic differences persist in human-resource efficiency and cost efficiency among EU member states, while GDP and population size, on their own, do not matter.

The descriptive analysis reveals that the Unitary Patenting efficiency of EU member states, based on human capital (human-resource efficiency), has shifted little (RQ2) and points to the leadership of the Scandinavian trio followed by Austria and all six states creating originally European communities: Germany, France, Italy, Benelux. Meanwhile, the EU member states with the lowest concentration of Unitary Patents per inhabitants lie among agriculture-oriented South-Eastern states such as Romania, Croatia, Bulgaria, Greece, Poland, and Hungary (RQ1). Results regarding Unitary Patenting efficiency among EU member states, based on financial expenses (cost efficiency), look very similar: no dramatic change has emerged so far (RQ4) and the cost-efficiency leaders broadly match those as in the case of human resources efficiency (RQ3).

What confirms Scandinavia's leadership followed by Austria and only partly the original six EC states (RQ5, RQ6) are regression analyses of human resources efficiency and cost efficiency with two separate linear models for Unitary Patenting 2017 versus 2024 – *i.e.* the Inhabitants 2017/UP 2024 index (human resource efficiency) and the GERD 2017/UP 2024 index (cost efficiency) – and for Unitary Patenting 2018 versus 2025, *i.e.* the Inhabitants 2018/UP 2025 index (human resource efficiency) and the GERD 2018/UP 2025 index (cost efficiency). Notably, France and Belgium underperform as Italy outperforms them, while most non-full UPCA members trail far behind. Both models reach high statistical significance and confirm that no dramatic changes have emerged in the longitudinal perspective and that broadly the same EU member states excel in both human-resources and cost efficiency (RQ5, RQ6).

The thematic analysis regarding enforcement before the UPCoA shows a strong commitment to enforcing Unitary Patents by large businesses (often the same) preferring English and German proceedings and showing no interest in any other languages, including French (RQ7). An advanced analysis, AI-double-checked, suggests the features of Unitary Patenting efficiency leaders and absolute size (population and GDP) clearly does not matter. Instead, seven features characterise Unitary Patenting efficiency leaders: full UPS membership (1), consistent patent justification and recognition (2), lean approach (3), private-party-led with minimal state involvement (4), industrial rather than agricultural focus (5), membership in the EU before 2004 (6), and mastering English and German languages (7).

Naturally, this study faced two principal inherent limitations. Firstly, the investing-inventing-patenting-innovation dynamics are extremely challenging for the selection and employment of conventional methodology tools. Consequently, the employed matrix triad and implied research questions built upon recently established methodologic strategies, but certainly are not conclusive and require further testing and improving, in particular regarding new patenting indexing and modelling. Secondly, due to the existence of the UPS only since 2023, the full annual data sets regarding Unitary Patents cover only 2024 and 2025. Naturally, in the future this limitation should be overcome with data about Unitary Patents in the following years. Furthermore, this improved and extended data set could help with the double checking of the appropriateness of the use of the seven-years delay and with the refinement of the indication of the efficiency leaders, which should definitely be respected and followed by other EU member states that should inspire future EU as well as national policies and law.

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Acknowledgements and Financial Disclosure

This article is the result of Metropolitan University Prague research project no. 110-2 'Economic studies, International Business and Financial Management' (2026) funded by the Institutional Fund for the Long-Term Strategic Development of Research Organisations.

Use of Artificial Intelligence

We prepared the manuscript without the use of any AI/GAI.

Conflict of Interest

The authors declare that they conducted the research without any commercial or financial relationships that could imply a potential conflict of interest.

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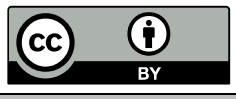

Published by Krakow University of Economics – Krakow, Poland

International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.05

Core-periphery structures in global agricultural gross and value added trade networks

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ABSTRACT

Objective: This study aimed to identify and explain the structural differences of global agricultural trade networks, depending on the trade metric applied *i.e.*, gross exports (EXGR) versus domestic value-added embedded in foreign final demand (FFD_DVA). By applying the core-periphery framework, we evaluated the degree of hierarchy, structural coherence, and temporal stability of core-periphery patterns within trade relationships between countries from 2011 to 2020.

Research Design & Methods: The analysis employed social network analysis (SNA) techniques, incorporating both the discrete and continuous versions of the core-periphery model, to identify structural roles within agricultural trade networks. The study relied on OECD TiVA data for value-added trade flows and constructs directed, weighted trade networks for EXGR and FFD_DVA separately. We calculated key SNA metrics, such as the final fitness index, coreness scores, the Gini coefficient, and heterogeneity.

Findings: The FFD_DVA network showed a much stronger fit to the ideal core–periphery structure than the EXGR network. China and the United States consistently formed the core, although their relative positions varied by metric. The FFD_DVA network became more stable over time and more hierarchical, confirming that value-added measures better reflect the structure of global agricultural trade.

Implications & Recommendations: Value-added metrics should be prioritised in assessing trade dependencies and risks, as they reveal structural patterns not visible in gross flows. Policy makers and researchers should apply value-added diagnostics to better identify vulnerabilities and understand the organisation of global agri-food supply chains.

Contribution & Value Added: The study offers a rare direct comparison of EXGR and FFD_DVA networks using identical core–periphery methods. It introduces a compact, multi-metric framework for analysing trade structures and demonstrates the added value of incorporating value-added data into agricultural trade research.

Article type: research article

Keywords: social network analysis; core-periphery model; value-added trade; agricultural trade network; global value chains

JEL codes: F14, F12, D85, L14

Received: 10 December 2025 Revised: 6 March 2026 Accepted: 27 March 2026

Suggested citation:
Brózda-Wilamek, D., & Nacewska-Twardowska, A. (2026). Core-periphery structures in global agricultural gross and value added trade networks. *International Entrepreneurship Review,* 12(2), 85-100. https://doi.org/10.15678/IER.2026.1202.05

INTRODUCTION

International trade in agricultural products plays a vital role in the global economy (Wood *et al.*, 2018). Agricultural production is inherently dependent on natural factors such as climate and soil conditions, leading to an uneven spatial distribution of output throughout the world (Ray *et al.*, 2015). Simultaneously, the demand for agricultural goods is also asymmetrically distributed due to demographic, cultural, and economic differences (D'Amour & Anderson, 2020; Distefano *et al.*, 2018). This structural imbalance creates a strong rationale for trade, making agricultural exchanges a key mechanism for meeting global food and raw material needs.

This study builds on the world systems theory (Wallerstein, 1974), which conceptualises the world economy as a hierarchically organised system composed of core, semi-peripheral, and peripheral zones. These zones differ in terms of their roles in production, control over capital and technological flows, and levels of integration into the global market. To operationalise this framework, we applied the core-periphery model developed by Borgatti and Everett (1999), which allows the identification of structurally cohesive cores and weakly integrated peripheries within a given network. We used both categorical and continuous approaches to the model to capture idealised binary structures and graded centrality profiles, respectively.

Moreover, we applied this approach to investigate global agricultural trade networks and explore the extent to which they exhibit core-periphery characteristics. Importantly, we compared two distinct representations of trade: gross export flows (EXGR) and domestic value added in foreign final demand (FFD_DVA). Although gross exports are a standard metric in trade analysis, they can overstate the role of intermediary countries and obscure structural dependencies (Johnson, 2014). Despite growing recognition of these limitations, existing network-based studies of agricultural trade rarely compare gross and value-added representations using identical methodological frameworks, leaving uncertainty as to how trade measurement affects observed core–periphery structures. In contrast, scholars increasingly acknowledge value-added-based measures, particularly domestic value added in foreign final demand (FFD_DVA) for their capacity to reveal more durable, functionally integrated, and hierarchically organised trade relationships (Guilhoto *et al.*, 2022). This distinction is especially relevant for the global agri-food system marked by intersectoral linkages, regional production specialisation, and power asymmetries along supply chains (Bialowas & Budzynska, 2022).

The primary objective of this study was to identify and explain the structural differences in global agricultural trade networks, depending on the applied trade metric, gross exports versus domestic value-added embedded in foreign final demand. Specifically, we aimed to evaluate the degree of hierarchy, structural coherence, and temporal stability of the core-periphery patterns within these networks using social network analysis (SNA) techniques. We addressed the following research questions:

RQ1: Which countries consistently occupy core positions in global agricultural trade networks based on EXGR and FFD_DVA data between 2011 and 2020?

RQ2: To what extent do the EXGR and FFD_DVA networks exhibit characteristics of an ideal core-periphery structure in terms of coherence and hierarchical stratification?

To what extent does the value-added-based representation of trade (FFD_DVA) differ from the gross exports-based network (EXGR) in capturing hierarchical and durable economic relationships? The novelty of this study manifests itself on several levels. Firstly, it offers a rare direct comparison between two representations of the global agricultural trade network, based on gross exports (EXGR) and value added in foreign final demand (FFD_DVA), using identical network analysis techniques. This ensures that observed structural differences were attributable solely to differences in trade measurement. Second, the analysis applied both discrete (blockmodeling) and continuous (coreness scores) core-periphery models in parallel, allowing for a multidimensional interpretation of network hierarchies, an approach rarely adopted in existing research. Thirdly, we used data from the OECD TiVA database, which, despite its increasing popularity, remains underused in structural network research on the agricultural sector. By integrating advanced network methodologies with a modern value-added trade framework, this article contributes to a dynamic yet still niche field of inquiry.

The remainder of the article is structured as follows. Section 2 reviews the relevant literature on core-periphery structures in trade networks and value-added trade measurement. Section 3 outlines the data sources, methodology, and operationalisation of the network models. Section 4 presents the results of the core-periphery analyses based on EXGR and FFD_DVA data and discusses their implications in light of the research questions and hypotheses. Finally, Section 5 concludes with a summary of contributions, limitations, and future research directions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The agricultural sector plays a key role in international trade, shaping global food security, production diversity, and economic interdependence. Trade is crucial for countries with limited resources, particularly in the Global South, where imports of staple crops introduce both stabilising and destabilising effects (D'Amour & Anderson, 2020). Although trade helps reduce distributional inequalities, it also increases vulnerability to production shocks in exporting regions. Despite comparative advantage theories, many countries maintain diverse agricultural outputs for resilience and cultural reasons (Nelson *et al.*, 2016). Agricultural trade networks have become denser and more interconnected, increasing systemic exposure to cascading disruptions (Burkholz & Schweitzer, 2019). Globalisation further intensifies this by homogenising production patterns (Aguiar *et al.*, 2020). Understanding these interactions is essential to improving the resilience of global agri-food systems.

Core-periphery structures help explain persistent global economic inequalities and trade asymmetries. Rooted in world system theory (Wallerstein, 1974) and extended by dependency and structuralist approaches (Hryniewicz, 2014; Thomas, 2013), the framework highlights constraints on peripheral economies. Empirical operationalisation often follows Borgatti and Everett's model (1999), which detects cohesive cores and loosely connected peripheries (Chandra & Joba, 2015; Long *et al.*, 2019; Nordlund, 2018; Yu & Ma, 2020; Zhu *et al.*, 2023). Other models include spatial concentration theories (Akamatsu *et al.*, 2012) and game-theoretic frameworks (Su & Marbach, 2023). Network-based studies employing ERGM reveal hierarchical trade structures influenced by economic size and distance (Lewin *et al.*, 2013; Solanes *et al.*, 2025; Zhao, 2021). Core exporters maintain strong reciprocal ties (Smith & Sarabi, 2022), while peripheral countries remain marginalised. Applications from the EU and Asia highlight how integration and industrial policy reshape hierarchies (Antras & Chor, 2019; Fang *et al.*, 2023; Pascariu & Tiganasu, 2017). In global value chains, core countries dominate high-value segments, while peripheral regions face structural constraints and dependence (Chávez-Bustamante *et al.*, 2023; Long *et al.*, 2019). Borgatti and Everett's model (1999) is particularly useful in identifying strategic actors and vulnerabilities in trade networks (Long *et al.*, 2019; Zhu *et al.*, 2023).

Studies of agricultural trade increasingly use network analysis to capture hierarchical structures and spatial inequalities. Scholars model networks as directed weighted graphs based on trade flows (Torreggiani *et al.*, 2018). Centrality measures help identify core actors: betweenness (Ercsey-Ravasz *et al.*, 2012), and composite indices combining degree, eigenvector, and closeness (Qiang *et al.*, 2020; Dong *et al.*, 2024). Community-detection algorithms reveal clusters of closely connected countries (Dong *et al.*, 2024; Torreggiani *et al.*, 2018). Together, these methods highlight concentration and interdependence in global agri-food systems.

Value-added (VA) trade data address the limitations of gross trade by revealing the true economic contribution of countries and sectors. This is particularly relevant in agriculture, where GVCs differ from manufacturing due to perishability and regulatory diversity (Flaig & Greenville, 2021; Zdráhal, 2024). Agriculture contributes around 35% of VA in final consumption (Greenville *et al.*, 2017), and agricultural exports display higher domestic VA shares than processed foods. Furthermore, VA data shows that much agricultural value is embedded in foreign final demand, often indirectly through foreign processors, and key hubs such as China, the US, and Germany dominate global agri-food GVCs (Greenville *et al.*, 2019). Regional trade agreements also reveal deeper integration when measured in VA terms, as shown for AfCFTA (Fusacchia *et al.*, 2022), RCEP (Wei *et al.*, 2024), and APEC (Flaig & Greenville, 2021). In SSA, VA analysis identified stronger-than-expected GVC participation and significant tariff effects (Balié *et al.*, 2019). Environmental inequalities also emerged, with exporters like Brazil and China bearing disproportionate ecological costs (Zhai *et al.*, 2024). Differences between gross and VA trade can substantially alter comparative advantage assessments (Zdráhal, 2024). Building on prior empirical evidence showing that value-added trade measures better reflect structural integration and hierarchical positioning in global value chains, this study tests two key hypotheses:

H1: The FFD_DVA network demonstrates a higher degree of fit to the ideal core-periphery model (as measured by the final fitness index) than the EXGR network.

H2: The core structure of the FFD_DVA network is more temporally stable than that of the EXGR network over the 2011–2020 period.

In general, the literature shows that agriculture is central to global trade and economic interdependence. Core-periphery theory and VA trade analysis offer essential tools for understanding structural inequalities and real economic contributions in agri-food systems. These approaches reveal hidden dependencies, environmental burdens, and integration dynamics, underscoring the need for refined analytical frameworks – an agenda central to this study.

RESEARCH METHODOLOGY

We used data from the OECD trade in value added (TiVA) database, which provides detailed information on international trade flows broken down by value added. This data set enabled the trace of the value added embodied in exports and imports across countries and industries, capturing complex global production chains and the role of intermediate goods and services in trade.

To compute value added embodied in trade flows, we analysed the standard inter-country input-output approach (Folfas, 2024). Firstly, we constructed a global matrix of technical coefficients A, representing the direct intermediate input requirements in all countries and industries. Based on this matrix, we calculated the global Leontief inverse $\mathrm{B} = (\mathrm{I} - \mathrm{A})^{-1}$ to capture the total (direct and indirect) production needed to satisfy final demand. For each country i, we derived a vector of value-added coefficients v_i, while f_j denoted the vector of final demand in country j. We then obtained value-added exports from country i to country j using the standard formula

$$VAX_{ij} = v_i B f_j, \tag{1}$$

which measures the amount of domestic value added generated in i to meet the final demand in j. This methodology enabled us to identify the true domestic content of exports and the decomposition of global production chains into their underlying value-added components.

The TiVA database covered 62 economies and included data disaggregated into 35 sectors based on the ISIC Rev. 4 classification, making it a valuable source for analysing global value chains and the real origin and destination of economic value in cross-border trade. For this study, we restricted the analysis to Section A (ISIC Rev. 4 divisions 01–03), which included agriculture, forestry, and fishing. This sectoral scope comprised crop and animal production (including mixed farming and related service activities), forestry and logging (including the production of roundwood and non-wood forest products), as well as fishing and aquaculture (United Nations, 2008).

We employed social network analysis (SNA), which is rooted in graph theory, matrix algebra, and statistics. This research method provides a robust framework for examining relational properties and dependencies that would be undetectable when viewed in isolation (Borgatti *et al.*, 2024). In international trade analysis, SNA facilitates the visualisation of trade networks as comprehensive structures, revealing previously unnoticed indirect trade connections (Yang *et al.*, 2016). The networks in SNA function as systems, with entities acting as nodes and their relationships as edges, providing deep insights into their structure and dynamics. Empirical research typically represents these networks as graphs, with nodes represented as circles and edges as straight lines connecting them (Nerurkar *et al.*, 2022).

Similarly to the studies by De Benedictis *et al.* (2014) and Nacewska-Twardowska and Brózda-Wilamek (2024), in this study, we represented the global trade system as a valued, directed network $G = (V, E)$, where the set of nodes V corresponded to countries and the set of edges E denotes bilateral trade relationships. Each directed edge $(i, j) \in E$ was assigned a non-negative weight c_{ij}, defined as exports from country i to country j. Thus, the full network can be expressed as an $n \times n$ weighted adjacency matrix $C = [c_{ij}]$, where $c_{ij} > 0$ indicates the existence and intensity of a trade flow, and $n = |V|$ denotes the total number of countries included in the network. These networks, constructed separately for EXGR and FFD_DVA, capture the asymmetry and intensity of international trade flows.

Consequently, while the EXGR weights capture the gross monetary volume of trade flows, the FFD_DVA weights reflect the contribution of domestic value added to the final demand abroad. This distinction allows the value-added network to better approximate the underlying production dependencies and long-term economic links between countries. To ensure comparability across years and network representations, we constructed all networks using identical node sets. Network density and edge distributions were allowed to vary endogenously, reflecting structural changes in global agricultural trade over time rather than methodological artefacts. The core-periphery model by Borgatti and Everett constitutes a foundational concept in SNA, designed to identify and differentiate core nodes, highly connected actors central to the network, from peripheral nodes, which are more loosely connected and structurally marginal (Borgatti & Everett, 1999). This model has found widespread application in analysing global trade networks, particularly in studies grounded in world-systems theory, which posit a hierarchical organisation of international economic relations (Kick & Davis, 2001).

In the literature, we may identify two main methodological approaches to detect the structures of the core-periphery. The first focuses on the classical framework introduced by Borgatti and Everett (1999), which has been extended by scholars such as Nordlund (2018) and Clark and Beckfield (2009). The second strand emphasises algorithmic refinements and alternative classifications, designed to classify countries as part of the core or the periphery (Boyd *et al.*, 2010; Elliott *et al.*, 2020; Kostoska *et al.*, 2020).

In this study, we based the identification of core-periphery structures on the seminal model proposed by Borgatti and Everett. There are two distinct approaches to identifying core-periphery structures by Borgatti and Everett (1999):

1. Categorical (discrete) model – it uses combinatorial optimisation to partition nodes into core and periphery sets such that core-core ties are maximised, and periphery-periphery ties are minimised.
2. Continuous model – it calculates the coreness of each node by modelling the existence (strength) of ties between pairs of nodes as a function of the coreness of each.

These models are particularly relevant for analysing trade networks, in which some countries serve as economic hubs while others play peripheral roles. In this study, both the discrete and continuous variants of the core-periphery model are applied using UCINET, a specialised software for SNA.

In this study, we employed the categorical core-periphery model implemented in UCINET to classify countries into two distinct structural roles, core and periphery, within global agricultural trade networks. The methodological approach began by generating initial partitions using eigenvector centrality measures and multiple randomised starting configurations. We then iteratively refined these preliminary assignments through a hill-climbing optimisation algorithm that maximises the correlation between the observed adjacency matrix and an idealised block model structure. In this ideal configuration, the core countries are densely interconnected, while the peripheral countries exhibit minimal or no interconnectivity. The final binary classification reflects the configuration that yields the highest structural fit, thereby exposing hierarchical patterns in international trade architecture (Borgatti *et al.*, 2002). To assess the quality of this partitioning, we computed the final fitness statistic, which quantifies the degree of correspondence between the empirical network and the ideal core-periphery model. Higher values of the fitness index (ranging from 0 to 1) indicate a stronger structural fit (Chandra & Joba, 2015).

A straightforward assessment of how closely the observed structure approximates the ideal one is provided by the equations listed below (Borgatti & Everett, 1999).

$$\rho = \sum_{i,j} c_{ij}\delta_{ij}, \qquad \boldsymbol{\delta}_{ij} = \begin{Bmatrix} 1 \text{ if } k_i = \text{CORE or } k_j = \text{CORE} \\ 0 \text{ otherwise} \end{Bmatrix} \tag{2}$$

in which:

c_{ij} - the presence or absence of a tie in the observed data;
k_i - the class core or periphery that actor i is assigned to;
δ_{ij} - the ideal core-periphery pattern;
ρ - final fitness.

The final fitness is perfect when the observed matrix C (the matrix of c_{ij}) and the ideal matrix Δ (the matrix of δ_{ij}) are the same. The larger ρ, the closer the network is to a core–periphery structure.

Importantly, this methodological framework directly supports the objectives of the study by enabling a systematic comparison of hierarchical trade architectures based on two contrasting trade metrics, EXGR and FFD_DVA. By applying the same algorithmic procedure to both representations, we can evaluate which network better approximates the ideal core-periphery structure (based on the final fitness index), thereby empirically testing H1. Moreover, by repeating the model across the 2011–2020 time series, we could assess the temporal consistency of the core membership, facilitating the verification of H2 regarding the stability of the core in FFD_DVA-based networks. Thus, the use of the categorical core-periphery model and the associated final fitness statistic was essential to address the central research questions of this study.

To complement the binary classification of countries into core and periphery, we also employed the continuous core-periphery model, which provides a more refined and scalable evaluation of structural positioning in global agricultural trade networks. Rather than assigning countries to discrete categories, this method estimates a coreness score for each country (ranging from 0 to 1) that indicates the extent to which a country occupies a central, trade-integrated role within the network. We computed these scores by identifying a coreness vector whose outer product best approximates the observed adjacency matrix, thereby preserving the directionality and intensity of trade relations (Borgatti *et al.*, 2024; Borgatti & Everett, 1999; Borgatti *et al.*, 2002).

This approach assumed that one can explain the network structure by a latent one-dimensional hierarchy, where each node i is assigned a non-negative coreness score $k_i \geq 0$. The model posits an ideal pattern matrix $\Delta = [\delta_{ij}]$, where the expected tie intensity between nodes i and j is defined as:

$$\delta_{ij} = k_i k_j \tag{3}$$

This implies that strong ties occur primarily between nodes that are both close to the core (high $k_i$and k_j), while ties between peripheral countries are weak.

We estimated the coreness vector $K = (k_1, k_2, \ldots, k_n)$ by maximising the correspondence between the observed adjacency matrix C and the ideal structure Δ. Following Borgatti and Everett (1999), we achieved this by maximising the Pearson matrix correlation between C and Δ, or equivalently, by minimising the sum of squared errors:

$$\sum_{i,j} (c_{ij} - k_i k_j)^2 \tag{4}$$

The continuous model is particularly well-suited to the analysis of directed and weighted networks and allows for detailed comparisons across countries and over time.

In addition to coreness values at the node level, the model generated several global diagnostic indicators that provided a multidimensional assessment of the network structure. The Gini coefficient measured the inequality in the distribution of coreness scores; values approaching 1 suggested a highly hierarchical system dominated by a small group of central actors, while values closer to 0 indicated structural egalitarianism (Yu & Ma, 2020). The composite Gini-based core-periphery index builds on this by integrating inequality and topological fit, thereby reflecting how closely the empirical network resembles the idealised core-periphery model (Borgatti *et al.*, 2024). Finally, the heterogeneity index quantified the spread of coreness scores across the network, capturing the degree of polarisation between structurally central and peripheral countries (Yu & Ma, 2020).

This methodological extension played a critical role in achieving the central aim of the study, *i.e.*, identifying and explaining structural differences in global agricultural trade networks based on EXGR and FFD_DVA. By providing continuous and scalable measures of coreness and systemic inequality, this approach enabled a more precise and comparative assessment of structural dominance and integration. In operational terms, the analytical procedure linked specific network indicators to the tested hypotheses as follows. Specifically, it facilitated the empirical testing of H1 by comparing (i) the final fitness index obtained from the categorical core–periphery model and (ii) the global ine-quality measures (Gini coefficient and composite core-periphery index) derived from the

continuous model across the EXGR and FFD_DVA networks. A higher fitness value and stronger hierarchical differentiation in FFD_DVA, relative to EXGR, constituted direct empirical evidence in support of H1. Moreover, by examining the temporal dynamics of coreness dispersion and polarisation through the heterogeneity index, as well as the year-to-year consistency of core membership and coreness rankings, it directly supported the evaluation of H2, which posits that the FFD_DVA network exhibited greater structural stability over time. Stability is assessed through a longitudinal comparison of (i) changes in core composition in the categorical model and (ii) variation in coreness scores and heterogeneity indices in the continuous model over the 2011–2020 period. Together, these metrics enabled a robust and nuanced investigation into the hierarchical organisation and resilience of international trade structures under alternative trade representations.

We supplemented the analysis with data visualisation. We used Gephi and the ForceAtlas2 layout algorithm to create spatial representations of global trade flows (Jacomy *et al.*, 2014). In the ForceAtlas2 layout, we conceptualised the network as a physical system in which nodes behave like charged bodies pushing one another apart, while edges operate as springs pulling their incident nodes closer (Brinkmann *et al.*, 2017; Gorgol & Salwa, 2025). The algorithm repeatedly updates node coordinates until the forces reach equilibrium. For connected pairs of nodes, attraction grows proportionally with their separation distance,

$$F_a(n_1, n_2) = d(n_1, n_2). \tag{5}$$

In turn, repulsive forces scale with the degrees of both nodes and decline with distance.

$$F_a(n_1, n_2) = k_r \frac{(\deg(n_1)+1)(\deg(n_2)+1)}{d(n_1, n_2)}, \tag{6}$$

A commonly used alternative, the LinLog mode, replaces the linear attraction with a logarithmic form,

$$F_a(n_1, n_2) = \log\big(1 + d(n_1, n_2)\big), \tag{7}$$

which enhances the separation of communities and makes modular structures more distinct. The algorithm also integrates several practical adjustments, including gravitational pull that stabilises low-degree nodes,

$$F_g(n) = k_g(\deg(n) + 1), \tag{8}$$

penalisation of hubs, avoidance of node overlap, and the treatment of weighted edges.

Node movements follow the combined effect of all forces, moderated by an adaptive speed parameter:

$$\Delta(n) = s(n)F(n). \tag{9}$$

The local speed depends on a 'swinging' measure, defined as

$$swg^{(t)}(n) = \left|\left|F^{(t)}(n) - F^{(t-1)}(n)\right|\right|, \tag{10}$$

which captures instability in the direction of motion. It serves to regulate step size,

$$s(n) = \frac{k_s s(G)}{1+s(G)\sqrt{swg(n)}}. \tag{11}$$

In turn, global speed reflects the balance between effective traction and total swinging,

$$s(g) = t \cdot \frac{tra(G)}{swg(G)}, \tag{12}$$

For larger networks, ForceAtlas2 relies on the Barnes–Hut approximation to estimate repulsion, reducing the computational complexity to $O(n\ log\ n)$. One may quantify the overall quality of the layout using the Noack's measure,

$$Q(p) = \frac{1}{Q_{Noack}(p)}. \tag{13}$$

Through this combination of force formulations, adaptive optimisation, and computational shortcuts, ForceAtlas2 delivers stable and interpretable layouts suitable for medium- and large-scale graphs, while maintaining an interactive, continuous visualisation process.

RESULTS AND DISCUSSION

Data Analysis

We employed both categorical and continuous core-periphery models to analyse the hierarchical structure of global agricultural trade networks measured by EXGR and FFD_DVA. In the first step, the analysis spanned the period from 2011 to 2020. We conducted it using UCINET's combinatorial optimisation algorithm, which iteratively maximises the correlation between the empirical adjacency matrix and the idealised block model. The model identified countries as either part of the core, characterised by dense mutual interconnections. or as peripheral actors, marked by weak or absent interconnectivity. We used the final fitness statistic, a correlation-based indicator, to assess the structural fit of the observed network to the ideal core-periphery configuration. Table 1 presents the results of this classification, highlighting both the temporal stability of core memberships and the comparative fitness levels of the two types of networks.

Table 1. The results of discrete core-periphery models for EXGR and FFD_DVA networks in 2011-2020

Year	Core/periphery class memberships		Final fitness	
	EXGR	FFD_DVA	EXGR	FFD_DVA
2011	CHN USA	CHN USA	0.639	0.823
2012	CHN USA	CHN USA	0.667	0.850
2013	CHN USA	CHN USA	0.659	0.866
2014	CHN USA	CHN USA	0.675	0.853
2015	CHN USA	CHN USA	0.668	0.824
2016	CHN USA	CHN USA	0.673	0.841
2017	CHN USA	CHN USA	0.654	0.843
2018	CAN CHN USA	CHN USA	0.658	0.799
2019	BRA CHN USA	CHN USA	0.547	0.779
2020	CHN USA	CHN USA	0.652	0.851
Average 2011-2020	–	–	0.649	0.833

Note: *Fitness measure: CORR.
Source: own study using UCINET 6 software.

The results of the categorical modelling approach (Table 1) indicate that the FFD_DVA network exhibited a consistently higher fit to the ideal core-periphery structure compared to the EXGR network. The final fitness index, representing the correlation between the empirical and ideal core-periphery matrices, averaged 0.833 for FFD_DVA versus 0.649 for EXGR during the 2011–2020 period. This significant and persistent difference is consistent with H1, which posited that the value-added-based trade network more closely approximated an idealised core-periphery structure.

Both networks identified China (CHN) and the United States (USA) as the consistent core actors, which corresponds to their enduring centrality in global agricultural trade. However, the EXGR network displayed occasional fluctuations, with Canada (CAN) and Brazil (BRA) entering the core in 2018 and 2019, respectively. These episodic shifts indicate greater variability in core composition within the EXGR network over time. In contrast, the FFD_DVA network displays a more precise and more durable bifurcation between the core and periphery, associated with stronger structural integration within global value chains. This is consistent with H2, which contends that the core structure of the FFD_DVA network is more temporally stable than that of the EXGR network.

These findings are partially consistent with previous research. Dong *et al.* (2024) identified three persistent trade communities, each dominated by key core countries: Germany in Europe; the United States and China in North America and East Asia, respectively; and Brazil representing a central actor in the Global South. These regional hubs formed stable cores within the modular structure of agricultural trade networks. Similarly, Torreggiani *et al.* (2018) observed that China, the United States, and Brazil recurrently occupied central positions in multiple commodity-specific clusters, particularly in the trade of soy, cereals, and meat. Their multilayer network analysis demonstrated that despite differences between

products, certain countries consistently held structurally advantageous positions within trade communities. Furthermore, Ercsey-Ravasz *et al.* (2012) identified a clearly defined core within the international agricultural trade network, composed of seven countries selected based on betweenness centrality and degree. The United States and China were among these structurally central economies.

In the second step, the continuous core-periphery model (Table 2) reinforced the structural contrasts between the two networks by assigning each country a degree of coreness along a continuous scale. In the EXGR network, the United States retained the highest average coreness score (0.706), indicating its role as a dominant agricultural export hub. Brazil (0.408) and Canada (0.232) followed, demonstrating their relatively strong positions as global suppliers. In particular, Brazil's core quality rose steadily from 0.338 in 2011 to 0.485 in 2020, corresponding to its expanding influence in global agri-food markets. However, China exhibited a relatively peripheral role in the EXGR network, with an average coreness score of just 0.175. Although it did not rank among the top exporters, China's position improved moderately over the decade, rising from 0.145 in 2011 to over 0.20 by 2020. This upward trend was consistent with a gradual increase in China's participation in gross agricultural exports, potentially driven by expanded new trade agreements and diversified sourcing strategies. Nonetheless, its relatively low coreness in the EXGR network suggests that, in terms of sheer export volumes, China functions more as a processing or transit economy rather than a primary exporter of agricultural raw goods.

In contrast, the FFD_DVA network presents a markedly different pattern. China emerged as the unequivocal core country, with an average coreness of 0.808, far surpassing other nations. This centrality reflects China's deeply embedded position in global agricultural value chains – not just as an exporter but as a key node in the transformation, processing and redistribution of agricultural products. Meanwhile, the position of the United States appeared considerably less central (average: 0.297), suggesting that much of its agricultural trade may consist of primary commodities with less embedded domestic value added.

Moreover, the continuous model points to a regional shift in trade centrality, with increasing coreness scores for countries such as India, Indonesia, and Thailand. This trend indicates an ongoing reconfiguration of the global agricultural trade landscape, in which emerging Asian economies are increasingly integrated into high-value food production and distribution segments.

The observed patterns are broadly consistent with previous studies. Qiang *et al.* (2020) analysed the long-term developments in agricultural trade networks and found that the most influential countries, measured by node strength, shifted over time. In 1986, the dominant hubs included the United States, Japan, France, Germany, and the USSR. By 2016, the core had expanded to include China, Brazil, India, Argentina, and Canada, illustrating the increasing multipolarity of global agricultural trade.

The structural coherence of the FFD_DVA network was also reflected in higher values for the Gini coefficient (0.675 vs. 0.651 for EXGR), composite core-peripheries (0.440 vs. 0.267), and heterogeneity index (0.060 vs. 0.042). These metrics suggest that the FFD_DVA network exhibit greater internal differentiation, more evident hierarchical stratification, and stronger central-peripheral distinctions than the EXGR network. These findings support H1, which proposed that the FFD_DVA network would more closely approximate the idealised core-periphery structure than the EXGR network.

Furthermore, such findings also support H2, which posited that the value-added-based trade structure would exhibit greater temporal and structural stability. Indeed, while the core of the EXGR network proved susceptible to short-term disruptions, the FFD_DVA network remained consistently structured around a stable set of central actors, particularly China.

First and foremost, the core-periphery analysis results underscore the analytical superiority of value-added-based trade networks. The consistently higher final fitness scores and more pronounced stratification indices observed in the FFD_DVA model suggest that this representation provides a more clearly differentiated depiction of the hierarchical nature of global trade. The presence of a well-defined and persistent core, dominated by China and the United States, alongside a differentiated periphery, indicates that value-added flows are associated with more stable structural patterns than gross trade flows. Moreover, the continuous model offers a more nuanced understanding of international trade positioning. Countries are no longer classified as either core or periphery, but instead as-

sessed along a gradient of influence and integration. This allows for more granular evaluations of each country's strategic role within the evolving architecture of global trade.

Table 2. Level of coreness scores and coreness coefficients for EXGR and FFD_DVA networks in 2011–2020 (top 10 countries)

Variables	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average 2011-2020
EXGR networks											
USA	0.755	0.736	0.721	0.736	0.698	0.735	0.700	0.667	0.639	0.673	0.706
BRA	0.338	0.361	0.382	0.377	0.418	0.358	0.424	0.474	0.463	0.485	0.408
CAN	0.218	0.224	0.237	0.246	0.258	0.236	0.230	0.242	0.234	0.199	0.232
CHN	0.145	0.144	0.149	0.157	0.188	0.196	0.186	0.178	0.205	0.202	0.175
FRA	0.193	0.176	0.191	0.168	0.173	0.152	0.144	0.160	0.163	0.137	0.166
NLD	0.177	0.166	0.173	0.159	0.162	0.170	0.160	0.149	0.175	0.160	0.165
ESP	0.145	0.144	0.162	0.163	0.176	0.183	0.175	0.171	0.176	0.154	0.165
AUS	0.155	0.188	0.186	0.155	0.147	0.162	0.180	0.136	0.122	0.123	0.155
VNM	0.092	0.088	0.093	0.103	0.126	0.137	0.146	0.151	0.162	0.162	0.126
RUS	0.122	0.140	0.108	0.140	0.107	0.088	0.109	0.126	0.133	0.106	0.118
gini coefficient	0.652	0.65	0.652	0.655	0.656	0.655	0.654	0.649	0.64	0.651	0.651
composite 'gini-based core / peripheriness'	0.264	0.244	0.254	0.274	0.287	0.306	0.271	0.245	0.267	0.261	0.267
heterogeneity	0.044	0.042	0.042	0.044	0.042	0.043	0.042	0.04	0.036	0.041	0.042
FFD_DVA networks											
CHN	0.742	0.769	0.797	0.843	0.881	0.839	0.793	0.797	0.800	0.818	0.808
USA	0.347	0.324	0.337	0.300	0.247	0.280	0.299	0.290	0.264	0.278	0.297
IND	0.320	0.283	0.272	0.218	0.196	0.225	0.257	0.258	0.284	0.252	0.257
BRA	0.236	0.222	0.221	0.200	0.179	0.201	0.241	0.244	0.222	0.238	0.220
IDN	0.159	0.143	0.131	0.119	0.116	0.134	0.156	0.152	0.146	0.140	0.140
CAN	0.113	0.111	0.112	0.096	0.099	0.109	0.120	0.109	0.105	0.095	0.107
ESP	0.097	0.089	0.095	0.089	0.087	0.109	0.118	0.120	0.119	0.101	0.102
THA	0.101	0.097	0.091	0.084	0.083	0.098	0.114	0.117	0.120	0.100	0.101
VNM	0.075	0.078	0.077	0.081	0.083	0.104	0.117	0.123	0.130	0.130	0.100
FRA	0.110	0.097	0.087	0.083	0.074	0.074	0.086	0.097	0.090	0.078	0.088
gini coefficient	0.675	0.683	0.682	0.681	0.694	0.681	0.668	0.662	0.656	0.668	0.675
composite 'gini-based core / peripheriness'	0.433	0.434	0.463	0.461	0.438	0.437	0.441	0.432	0.414	0.447	0.440
heterogeneity	0.051	0.054	0.061	0.068	0.082	0.066	0.055	0.054	0.053	0.06	0.060

Source: own study using UCINET 6 software.

These findings have significant implications for economic policy and international trade research. Analyses relying solely on gross export data may overemphasise countries that operate as trade intermediaries while underestimating those embedded more deeply in value-generating processes. In contrast, value-added trade metrics highlight structural interdependencies of global economic interdependence and provide a more accurate lens to assess power and influence within global supply chains.

Visual Analysis

Figure 1 illustrates the global agricultural trade network in 2011 and 2020, using gross export flows and domestic value added embodied in foreign final demand. The ForceAtlas2 layout positions the nodes to visualise the core–periphery structures: node colour reflects weighted degree centrality, and node size corresponds to coreness. Following earlier studies (Gorgoni *et al.*, 2018; Smith & Sarabi, 2021), we applied a coreness threshold of 0.05 to highlight the most central countries and reduce visual clutter. This facilitated a clear identification of dominant actors while omitting peripheral nodes with limited structural relevance.

Moreover, ForceAtlas2 enabled a meaningful comparison between network types and years. The spatial placement of countries and the density of their ties provide a readable representation of structural change, for example, by comparing the EXGR and FFD_DVA networks within a given year or tracing their evolution between 2011 and 2020.

In 2011, the EXGR centred strongly on the United States, forming a classic unipolar core–periphery pattern. By 2020, the structure appears more decentralised: Brazil, Canada, and China gain coreness, producing a more multipolar configuration and signalling a redistribution of trade influence.

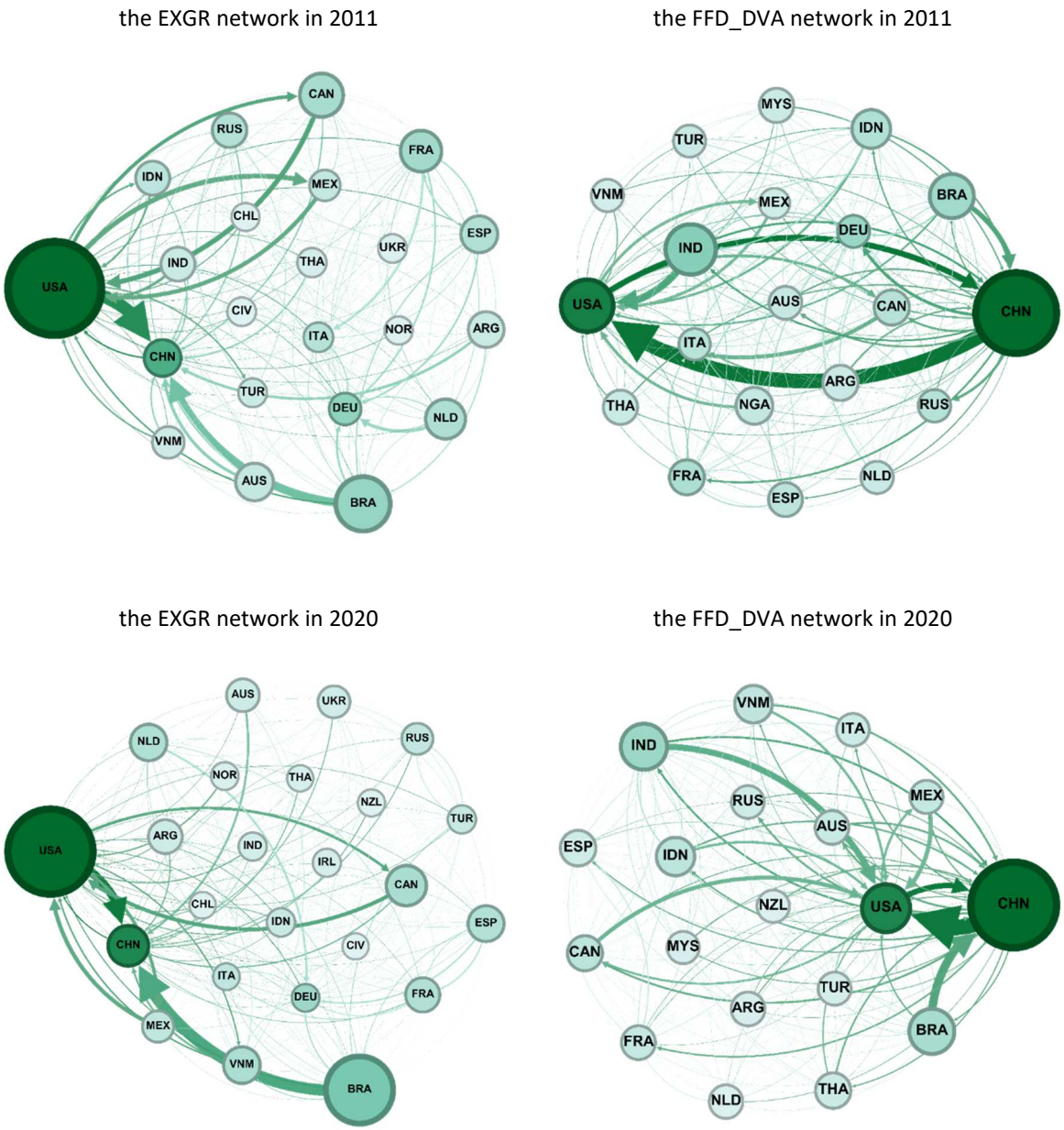

Figure 1. Global agricultural trade network in 2011 and 2020 based on gross export flows and domestic value added embodied in foreign final demand

Source: own elaboration in Gephi software.

Furthermore, the 2011 FFD_DVA network already displays a more balanced core, with both China and the United States occupying central positions. China appears more prominent than in the EXGR, reflecting its role as a hub in global value chains. By 2020, China had become the primary core actor, absorbing value added from most major economies, while the United States had re-

mained important but less dominant. Countries such as Brazil and India strengthened their semi-peripheral roles. The denser and more cohesive structure supports the interpretation of FFD_DVA as a more stable representation of long-term trade relations.

Comparisons among metrics revealed substantial structural differences. In 2011, EXGR displayed a unipolar network dominated by the USA, whereas FFD_DVA showed a more distributed configuration in which China and other emerging economies (*e.g.*, India, Indonesia) played greater roles due to their participation in intermediate production. By 2020, EXGR shifted toward multipolarity, while FFD_DVA became more hierarchical and internally coherent. This provides empirical support for H1 (better fit of the FFD_DVA network to the core–periphery model) and H2 (greater temporal stability of the value-added structure).

CONCLUSIONS

This study offered evidence that value-added-based representations of trade provide an alternative and structurally differentiated framework for analysing the core-periphery structures of global agricultural trade networks. Through a comparative analysis of gross export (EXGR) and domestic value added in foreign final demand (FFD_DVA) networks from 2011 to 2020, we demonstrated that the FFD_DVA network aligns more closely with the theoretical ideal of a core-periphery configuration. Notably, the FFD_DVA network exhibited consistently higher fitness indices, greater structural coherence, and increased inequality in coreness distributions, which are hallmarks of a hierarchically stratified and functionally integrated global trade system.

The empirical results further validated our hypotheses. Firstly, the stronger fit of the FFD_DVA network with the idealised core-periphery model confirmed that value-added trade measures are more effective at capturing enduring economic relationships. Secondly, the temporal analysis revealed greater stability of core membership in the FFD_DVA network, suggesting that value-added flows reflect more deeply rooted trade interdependencies than those captured by gross exports, which appear to be more susceptible to short-term fluctuations.

Despite the significant insights offered by this study, we must acknowledge several limitations. Firstly, the value-added trade data employed were based on estimations, which introduced a degree of uncertainty and may have affected the results' accuracy. The analysis relied on multi-regional input-output tables, which are susceptible to aggregation bias and inconsistencies in reporting across countries and sectors. Another limitation lies in the restricted temporal scope of the data set, which may have limited the findings' generalisability. It is also important to note the absence of a formal statistical test to assess the fit of the core-periphery structure. As Borgatti and Everett (1999) note, although the model may appear to closely approximate network structures, there is no guarantee that such a fit could not have occurred by chance, particularly in the absence of a well-established null model for comparison.

Despite its limitations, the study contributes to the growing body of literature advocating the use of value-added metrics in the analysis of global trade networks. By demonstrating that FFD_DVA-based networks are more clearly differentiated in terms of hierarchical structures and temporal stability, the findings challenge the continued reliance on gross export data in structural trade analysis. Moreover, applying both discrete and continuous core-periphery models offers a methodological framework that can be replicated across other sectors or temporal scopes, thereby opening new avenues for comparative network research in international political economy, regional integration, and global value chains.

The practical implications are equally significant. For policymakers and trade analysts, adopting a value-added lens is essential to accurately diagnose structural dependencies and identify strategic trade partners. Gross export data may obscure the true nature of economic influence, especially in complex global supply chains. Conversely, FFD_DVA metrics highlight patterns of value creation offering a more precise basis for assessing trade vulnerabilities and leverage points in negotiations.

Future studies may expand on this research by exploring core-periphery structures across different sectors of the global economy, such as high-tech industries, energy, or services, to assess how sector-specific characteristics influence the durability and hierarchy of trade relationships. Moreover, incorporating additional network measures, such as betweenness centrality, modularity, or structural role

indices, could offer a more nuanced understanding of countries' positions and functions within trade networks. Finally, a more in-depth regional and geopolitical perspective (*e.g.*, EU. ASEAN. MERCOSUR. or Global North vs. Global South) would allow for the identification of structural divergences within trade blocs and help assess the impact of economic integration on network positioning.

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Acknowledgements and Financial Disclosure

The study was conducted without any external funding.

Use of Artificial Intelligence

We have used Grammarly, Writefull and ChatGPT for proofreading the text to eliminate grammar and spelling errors.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.06

Entrepreneurial leadership in Polish small and medium-sized enterprises through appreciative inquiry: Evidence from qualitative interviews

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ABSTRACT

Objective: The objective of this article is to identify and understand the strengths-based mechanisms through which entrepreneurs enact entrepreneurial leadership in post-transition economies. We know that entrepreneurship research in post-transition economies often diagnoses barriers and deficits. However, we know far less about the strengths-based mechanisms through which entrepreneurs enact entrepreneurial leadership. In, this study, we explored entrepreneurial leadership in Polish small and medium enterprises through an appreciative inquiry lens, focusing on enabling experiences, resources, and aspirations.

Research Design & Methods: We conducted eighteen semi-structured appreciative inquiry interviews with entrepreneurs (owners and owner-managers) from three Polish regions and three sectors (services, trade, and technology). We transcribed and analysed interviews (June-July 2025) using a hybrid thematic analysis (deductive-inductive) supported by NVivo, with attention to the discovery and dream phases of the appreciative inquiry cycle.

Findings: We identified five interconnected mechanisms of entrepreneurial leadership: (1) resilience-as-learning after failure and crisis; (2) a gradual shift towards greater community legitimacy of entrepreneurship, although not uniformly across sectors; (3) relational leadership built through networks that often compensate for uneven formal institutional support; (4) proactive, place-based institutional co-creation with local stakeholders; and (5) future orientation towards innovation and sustainability, which is most visible in large-city and technology contexts.

Implications & Recommendations: For educators and support organisations, appreciative inquiry offers a practical way to cultivate reflective, opportunity-oriented leadership competences. For local and national policymakers, the results indicate that strengthening peer networks and creating accessible, place-sensitive support infrastructures can amplify existing entrepreneurial strengths.

Contribution & Value Added: The study advances entrepreneurial leadership scholarship by proposing a micro-meso-macro framework that links psychological resources, social capital, and institutional co-creation in a post-transition context. Methodologically, it demonstrates how appreciative Inquiry complements deficit-oriented entrepreneurship research by making visible the generative narratives and practices through which entrepreneurs sustain and develop their ventures.

Article type:	research article
Keywords:	appreciative inquiry; entrepreneurial leadership; Poland; qualitative interviews; social capital; resilience
JEL codes:	L26, O17, Z13, I25, O31

Received: 25 July 2025 Revised: 10 March 2026 Accepted: 19 March 2026

Suggested citation:
Wójcik-Chodorowska, J., Sułkowski, Ł., & Seliga, R. (2026). Entrepreneurial leadership in Polish small and medium-sized enterprises through appreciative inquiry: Evidence from qualitative interviews. *International Entrepreneurship Review,* 12(2), 101-113. https://doi.org/10.15678/IER.2026.1202.06

INTRODUCTION

Poland's post-1989 transition created a dynamic entrepreneurial landscape, but entrepreneurial opportunities and leadership practices remain uneven across regions, sectors, and settlement types. Existing research documents institutional frictions, socio-cultural ambivalence towards entrepreneur-

ship, and the continuing fear of failure in Poland. However, the dominant analytical emphasis remains deficit-oriented. Consequently, we still have an incomplete understanding of the enabling mechanisms through which Polish entrepreneurs sustain opportunity-oriented leadership in everyday practice. To address this gap, we applied appreciative inquiry as a strengths-based theoretical lens and qualitative interviewing strategy. Rather than evaluating appreciative inquiry as an organisational intervention, we used it to elicit entrepreneurs' narratives of peak experiences, resources, and aspirations, thereby complementing problem-centred accounts with evidence on what works, for whom, and under what local conditions. The objective of the study was twofold: (1) to identify the strengths-based mechanisms that constitute entrepreneurial leadership in Polish small and medium enterprises; and (2) to specify how these mechanisms are embedded in, and sometimes reshape, local institutional and community contexts in a post-transition economy. We addressed the following general research question (GRQ): What factors, attitudes, and positive experiences shape entrepreneurial leadership in Polish enterprises when analysed through an appreciative inquiry lens?

To operationalise the GRQ, we examined five interrelated dimensions: (RQ1) resilience and positive attitudes; (RQ2) changing social perceptions of entrepreneurship; (RQ3) social networks and cooperation; (RQ4) adaptation to, and co-creation of, institutional and regional conditions; and (RQ5) orientation towards innovation and sustainability. Based on eighteen interviews with entrepreneurs from three regions and three sectors, the article contributes (a) a contextualised account of entrepreneurial leadership in Poland, (b) a micro-meso-macro framework linking psychological resources, social capital, and institutional co-creation, and (c) practical implications for entrepreneurship education and place-sensitive policy design.

The remainder of the article is organised as follows: the next section reviews the literature and develops the analytical framing, followed by the methodology, results and discussion, conclusions.

LITERATURE REVIEW

Entrepreneurial Leadership in Poland: Empirical Context and Analytical Themes

After the collapse of communism in 1989, Poland embarked on a major transformation towards a market economy (Smuniewski *et al*., 2021). In the course of this change, there was a marked increase in entrepreneurial activity and people began to take advantage of new market opportunities in the developing capitalist system (Organisation for Economic Co-operation and Development (OECD), 2010). Existing research indicates that social values and systemic factors have significantly shaped the development of entrepreneurship in Poland, while also contributing to regional and demographic differences in entrepreneurial behaviour (Rogalska, 2018; Zarębski *et al*., 2022). Poland's transition to a market economy opened space for widespread small-firm entrepreneurship. Still, regional disparities and institutional frictions continue to shape the contemporary entrepreneurial ecosystem. Large urban centres are characterised by high activity, also in the area of emerging innovations, while smaller cities lag behind due to limited capital, weaker access to knowledge networks and less developed infrastructure (Rogalska, 2018; Sułkowski & Ulatowska, 2025). Studies of Polish entrepreneurship point to uneven local development conditions, cautious social perceptions of private business ownership, and persistent administrative and regulatory burdens that can discourage opportunity exploitation (Rogalska, 2018; Godlewska & Morawska, 2020; OECD, 2025; Żuk & Żuk, 2021). Such deficit-oriented diagnoses are indispensable, but they can understate the enabling resources through which entrepreneurs lead, learn, and create value in everyday practice. Therefore, in this article, we organise the literature around five mechanisms of entrepreneurial leadership that correspond to our research questions and that one can investigated productively through a strengths-based lens.

Psychological resilience and failure learning are central to entrepreneurial leadership (RQ1). Research on Polish entrepreneurs indicates that responses to failure are often characterised by renewed opportunity seeking and confidence, even when prior initiatives collapse (Wójcik & Ciszewska-Mlinarič, 2020). During the COVID-19 shock, micro- and small-entrepreneurs also mobilised resilience as a behavioural capacity to adapt, improvise, and continue operating under uncertainty (Pyrkosz-Pacyna *et al.*, 2021). More broadly, positive psychological resources (*e.g.*, optimism

and resilience) can strengthen entrepreneurial creativity and innovation (Li *et al.*, 2022), thereby shaping how leaders frame risk and motivate others.

Socio-cultural legitimacy is another relevant mechanism (RQ2). While attitudes towards entrepreneurship in Poland have gradually improved since the early transition period, research suggests a continuing 'cultural lag' whereby entrepreneurs may be recognised economically but still evaluated ambivalently in social terms (Osowska, 2019; PARP, 2022; Wójcik & Ciszewska-Mlinarič, 2020; Żuk & Żuk, 2021). These perceptions matter for entrepreneurial leadership because legitimacy affects the willingness of families, employees, partners, and local communities to support entrepreneurial initiatives.

Entrepreneurial leadership is also enacted relationally through social capital (RQ3). Internal social capital within firms (trust, reciprocity, shared norms) and external networks (peers, partners, mentors, investors) provide access to resources, market opportunities, and emotional support (Markowska-Przybyła, 2022; Ziemiański, 2018). In Poland, where formal support infrastructures may be uneven, relational ties can compensate for institutional gaps and facilitate cooperation and resource sharing (Żukowska, 2025; Zygmunt, 2025).

Institutional context and place-based support further shape entrepreneurial leadership (RQ4). Entrepreneurship tends to flourish when regulatory and policy environments are enabling, and bureaucracy and policy instability can constrain it (Audretsch *et al.*, 2021). In Poland, local governments can act as institutional entrepreneurs by fostering public-private partnerships, incubators, and collaborative initiatives, although such engagement varies across localities (Derlukiewicz *et al.*, 2021; Xing *et al.*, 2018; Godlewska & Morawska, 2020). This highlights the relevance of entrepreneurial leaders not only as firm-level decision-makers but also as actors who may co-create local ecosystems.

Finally, innovation and sustainability orientation increasingly enter entrepreneurial leadership agendas (RQ5). Entrepreneurial strategies in peripheral regions depend on multi-dimensional innovation capacities and local resource configurations (Zarębski *et al.*, 2022). At the same time, socio-cultural factors can shape how entrepreneurs interpret climate and sustainability agendas, producing both engagement and scepticism (Żuk & Żuk, 2021). Thus, understanding when entrepreneurs integrate innovation and sustainability into leadership practices therefore requires attention to sectoral and local context.

Appreciative Inquiry as a Strengths-based Lens in Entrepreneurship Research

The concept of appreciative inquiry originated in the 1980s in the United States, and posits that instead of analysing what is working wrong in an organisation, it makes sense to focus on what is working well, and build on that to further develop the organisation (Cooperrider & Srivastva, 1987). The concept of appreciative inquiry emphasises that every organisation or social system has hidden forces that, when uncovered, can trigger breakthrough change. Rather than focusing on a detailed analysis of failures and their sources, appreciative inquiry supports stakeholders in a collective insight into what works best, identifying opportunities, strengths and successes (Bushe, 2013). This creates positive energy and a collective commitment to move forward based on existing strengths (Cooperrider & Srivastva, 1987; Cooperrider *et al*., 2008).

Appreciative Inquiry emerged as an alternative to problem-centred organisational diagnosis, proposing that one can mobilise change and learning by systematically exploring what works well and why (Cooperrider & Srivastva, 1987; Cooperrider *et al.*, 2008). Rather than treating failures as the sole or primary analytical entry point, appreciative inquiry emphasises strengths, peak experiences, and development potential as resources for understanding and shaping social systems.

Appreciative inquiry is grounded in social constructivism, which conceptualises organisational reality as produced and reproduced through language and interaction (Berger & Luckmann, 1966; Bushe, 2011). Therefore, as an inquiry strategy, appreciative inquiry lies on generative questions that invite participants to articulate values, successful practices, and desired futures (Cooperrider & Whitney, 2005).

Appreciative inquiry perspective aligns with broader streams of positive organisational scholarship that study enabling conditions such as resilience, virtuousness, and high-quality relationships (Cameron *et al.*, 2003; Cameron & Caza, 2004). For entrepreneurship research, this alignment is theoretically consequential, because entrepreneurship is inherently opportunity-oriented, yet empirical studies often privilege barriers, deficits, and failure (Woodfield *et al.*, 2017).

Researches have used appreciative inquiry both as a research tool and as a change methodology (Michael, 2005; Reed, 2007). A common critique is that a purely 'positive' orientation may underplay structural problems or silence negative experiences (Grant & Humphries, 2006). To address this concern, strengths-based inquiry can treat difficulties as part of the narrative context while analysing how entrepreneurs cope, learn, and mobilise resources- an approach particularly relevant in post-transition settings where constraints and opportunities coexist.

In the Polish context, an appreciative inquiry lens is suitable for two reasons. Firstly, it complements existing Polish entrepreneurship research by making visible the micro-level resources (mindsets and learning), meso-level resources (networks and legitimacy), and macro-level resources (institutional co-creation) that enable entrepreneurial leadership. Second, by combining the discovery and dream phases, appreciative inquiry- informed interviews can elicit both retrospective accounts of successful practices and prospective visions of ecosystem development, which are directly relevant for education and policy design. The next section details how we operationalised appreciative inquiry in the research design.

RESEARCH METHODOLOGY

We adopted a qualitative design informed by appreciative inquiry to explore the enabling mechanisms of entrepreneurial leadership in Polish small and medium enterprises. We used appreciative inquiry as an inquiry strategy to elicit narratives of strengths, achievements, resources, and aspirations, while allowing challenges to surface as contextual elements discussed in relation to coping and learning.

In this study, we treated appreciative inquiry not only as a sensitising perspective but as a qualitative research methodology that structures the entire research process, in line with its classic conceptualisation as a philosophy of change and an approach oriented towards uncovering an organisation's 'positive core' (Cooperrider & Whitney, 2005). Accordingly, we designed and conducted the in-depth interviews in the spirit of appreciative inquiry, using generative, strengths-based questions.

We chose qualitative interviewing because entrepreneurial leadership is embedded in meaning-making, relationships, and context, which are difficult to capture through purely variable-based measurement. To avoid treating appreciative Inquiry as a 'positivity filter,' we used appreciative prompts to open narratives and then employed follow-up questions that explored how entrepreneurs dealt with constraints, crises, and institutional barriers.

We conducted eighteen semi-structured interviews with entrepreneurs (owners and owner-managers) representing the service, trade, and technology sectors. Interviews took place in June-July 2025 and we conducted them in the hybrid format: eight interviews were conducted face-to-face and ten online via MS Teams, depending on respondents' preferences and availability.

We used purposeful maximum-variation sampling to capture heterogeneity across (a) sectors, (b) regions (Śląskie, Małopolskie, Mazowieckie), and (c) settlement size. We included the three settlement-size categories (small, medium and large cities) to probe whether leadership narratives vary across different local ecosystems. The study does not aim at statistical representativeness but at analytic generalisation through rich, context-sensitive evidence.

We based the respondents selection on the following criteria:

1. Position: holding a managerial position (both as a formally employed director and as an owner-founder acting as a director) or a managerial position in the company selected for the study.
2. Sector: employment/ownership/co-ownership in one of the three selected sectors: services, trade, technology.
3. Tenure: at least one year of experience in the current firm and managerial role.
4. Location: firm located in a small city (less than 20 000 inhabitants), a medium-sized city (20 000-100 000), or a large city (100 000 and more inhabitants) (Statistics Poland, 2010, p. 1).

The interview guide was exploratory and strengths-based. Each interview started with appreciative prompts (Discovery), for example: 'Tell us about a moment when you felt most engaged and proud as an entrepreneur.' We then invited respondents to describe enabling relationships, resources, and practices, and to articulate desired futures (Dream) for their firms and local business environments.

This design leverages appreciative inquiry not only to collect data but also to stimulate reflection about successful practices and transferable lessons. In line with methodological guidance on appreciative interviewing, the protocol balances open, generative questions with probes that clarify concrete actions, contextual conditions, and the meaning respondents attribute to their experiences (Michael, 2005).

We informed all participants about the study purpose, the voluntary nature of participation, and the right to withdraw at any time. We recorded the interviews only after obtaining informed consent. Moreover, we anonymised transcripts by assigning respondent codes (R1-R18) and removing identifying details. Because appreciative interviewing may amplify 'success narratives,' we remained reflexive about our own research interests in positive organisational change. During interviews and analysis, we actively attended to boundary conditions, counterexamples, and references to difficulties, treating them as analytically relevant when they informed coping strategies or revealed ecosystem constraints.

We transcribed, stylistically edited, and translated interviews into English. Translation focused on semantic equivalence, and we checked all quotations included in the manuscript against the original transcripts to preserve meaning.

We applied a hybrid thematic analysis (Braun & Clarke, 2006) supported by NVivo. Firstly, we developed a deductive coding frame from the entrepreneurial leadership and appreciative inquiry literatures (*e.g.*, resilience, legitimacy, networks, institutional co-creation, innovation orientation). Secondly, inductive coding captured emergent patterns and context-specific expressions of these concepts. We iteratively clustered codes into candidate themes, reviewed against the full dataset, and refined until we achieved a coherent thematic structure.

To enhance credibility and transparency, we maintained an audit trail of coding decisions and analytic memos that documented how interpretations were derived from the data. In the results section, we present verbatim quotations as illustrative evidence and provide short thematic summaries to distinguish empirical description from interpretation. We presented the general research question and five specific research questions in the Introduction; they guided both the interview protocol and the analytical categorisation of findings. Although the interviews were strengths-oriented, difficult topics were not excluded. When participants raised challenges (*e.g.*, bureaucracy, crises, market shocks), follow-up questions explored how they responded, what resources they mobilised, and what they learned. This approach allows one to analyse strengths in relation to constraints rather than in isolation. Interview duration ranged from 55 to 130 minutes (mean approximately 90 minutes), producing approximately 27 hours of recorded material.

Given the qualitative design, we do not claim statistical representativeness; instead, we offer the findings as analytically generalisable mechanisms that can inform theory building and hypothesis generation for future quantitative research. By combining an appreciative lens with systematic thematic analysis, the study captures not only the obstacles Polish entrepreneurs face but also the resources and practices through which they sustain entrepreneurial leadership. This complements problem-centred research by providing evidence on enabling mechanisms that can be strengthened through education, support programmes, and local policy.

RESULTS AND DISCUSSION

Research Results

This section reports five empirically grounded mechanisms of entrepreneurial leadership that emerged from the interviews. To improve analytical clarity, we (a) defined each mechanism as it appeared in participants' narratives, (b) provide illustrative quotations, and (c) end each subsection with a short thematic summary. We develop interpretation and links to prior literature in the Discussion section.

Resilience-as-learning: Reframing Failure and Sustaining Entrepreneurial Action

One of the dominant themes was the role of a positive attitude in dealing with the risks that accompany entrepreneurship. Many participants told stories of difficult moments, such as business failures or economic crises (including those related to the COVID-19 pandemic), which they overcame by focusing on solutions and trusting their own skills. Rather than focusing on mistakes, they

highlighted the lessons they had learned in difficult situations and the new opportunities they had discovered as a result.

Entrepreneurs frequently narrated setbacks (*e.g.*, failure of an early venture, the COVID-19 shock, or market crises) as experiences that strengthened their capacity to lead. Across interviews, respondents described resilience less as an 'enduring hardship' and more as learning-oriented reframing followed by renewed action. For example, one entrepreneur from the retail industry recounted how the failure of the first company he was involved in setting up did not discourage him, but became an experience from which he learned in subsequent professional activities. He put it this way: 'This failure provided me with a treasure trove of knowledge from which I drew for many years (...). This experience allowed me to build another business that had a stronger foundation (...). I already felt more mentally resilient to failure' (R1). Similarly, another respondent emphasised deliberate learning from setbacks: 'I tried not to give up and to learn from each failure, I tried to turn it into something valuable for me as a person managing a team and building the reputation of the company' (R7).

Participants in the interviews often described failures as 'turning points, ''breakthrough moments' or 'turnarounds,' indicating a belief that any failure can become an impetus for innovation and personal and entrepreneurial development. Participants linked this resilience-as-learning mechanism to leadership practice: by normalising failure as part of entrepreneurship, they reported greater readiness to take calculated risks and to encourage experimentation. An entrepreneur from the retail industry pointed out: 'Failure is intrinsic to entrepreneurial activity and should be assumed at the very beginning (...); then it will not have a paralysing and demotivating effect (...), but on the contrary- it will enhance effectiveness, innovation and a sense of agency' (R2).

Thematic summary: resilience appears as a leadership resource when one reframes setbacks into actionable learning that sustains agency and experimentation.

Legitimacy Shift: Changing Social Perceptions and Community Embeddedness

Another theme was the perceived transformation of the social climate for entrepreneurship in Poland and the growing support from local communities and city dwellers. Many participants noted that the perception of entrepreneurship by their immediate environment (family, friends, business partners) has improved significantly over the last 10-15 years. In the past, family discouraged risky ventures characterised by a high level of professional and financial uncertainty, preferring rather stable employment, mainly in companies that were stable and well established in the market.

A second mechanism concerns the perceived shift in the entrepreneurship's social legitimacy. Many respondents contrasted earlier scepticism, often voiced by family members who preferred stable employment- with a more supportive climate in recent years. Respondents narrated legitimacy in concrete terms: trust, repeat patronage, and community recognition that reinforced entrepreneurs' motivation to lead locally embedded firms.

Entrepreneurs from small cities (less than 20 000 inhabitants) emphasised that the local community supports their companies by using their offer. In small cities, entrepreneurs particularly emphasised community trust as a resource that stabilises demand and legitimises the firm's presence. One respondent from the service industry described this as follows: 'the townspeople have a lot of trust in the brand that I have managed to create, develop, and maintain. They often use my services, even though competition in the market is already quite high. The trust closest to the community is a big reason for me to be happy' (R8). Another entrepreneur in the same sector from a medium-sized city (20-100 000 inhabitants) indicated that: 'the inhabitants of the city and its surroundings are the vast majority of my customers' (R10).

Simultaneously, legitimacy was not universal. Several respondents reported that novel or non-standard ventures initially triggered distrust or were treated as 'unrealistic, 'especially when they departed from familiar industry templates. A technology entrepreneur described early scepticism towards an appreciative inquiry related tool: 'The companies we worked with (...) were quite dismissive (...), were thought to be the result of personal fascination rather than market needs' (R5). Another respondent described how an unconventional initiative in a service outlet produced surprise before it was gradually accepted (R15).

Thematic summary: a legitimacy shift is visible in everyday support and trust, yet boundary conditions persist for unusual and innovation-driven initiatives.

Network Bricolage: Cooperation, Trust, and Relational Leadership

Interviewees also frequently raised the issue of the networking and relationships's role, considered as an important organisational resource. Interview participants treated this aspect multidimensionally, going beyond mere support. In the interviews, they emphasised that systems of social relations influence the development of their companies and provides support for them in crisis situations. A third mechanism is network bricolage: entrepreneurs actively assembling relational resources (peer ties, partnerships, employee relations) to solve problems, access markets, and sustain leadership under uncertainty. Networking was not described as 'optional' but as a core capability that substitutes for scarce resources and accelerates learning.

Respondents emphasised that cooperation and peer support were crucial during crises. One entrepreneur recalled: 'The professional contacts I was able to acquire helped me to get my business out during the COVID-19 pandemic (...) without mutual cooperation and help, many of the businesses would not have survived' (R3). Networks also enabled internationalisation and strategic partnerships: 'Thanks to my network of foreign contacts, I was able to attract several important customers from neighbouring countries' (R4). Respondents framed local cooperation as both efficiency and community building: 'Cooperation with local companies is very important (...) It saves time (...) but also builds relationships, organises joint events, builds community' (R17). Only three respondents reported consistent institutional support for networking and cooperation. By contrast, several expressed that institutions are 'detached from reality' or overly focused on formalities (R2; R9). The qualitative data obtained suggest that social networks compensate for institutional deficiencies in Poland. Relational leadership was also visible inside firms: entrepreneurs repeatedly highlighted that interpersonal relationships and trust 'build the company' (R7) and that 'we work with people, not companies' (R11).

Thematic summary: networks function as a multi-purpose leadership resource, supporting survival, growth, trust-building, and cooperation, particularly where formal support infrastructures are perceived as weak or uneven.

Institutional Co-creation: Place-based Leadership and Uneven Formal Support

The interviews also revealed how regional and local factors influence entrepreneurial leadership, particularly the ability to adapt to change. This is clearly visible in the form of a difference in perspectives between entrepreneurs from large (100 000 or more inhabitants) and small cities (less than 20 000 inhabitants).

A fourth mechanism concerns how entrepreneurs interpret and engage with their local institutional and regional environments. Respondents often contrasted leadership demands in large cities (speed, flexibility, competitive intensity) with those in small towns (embeddedness, proximity, long-term trust).

Entrepreneurs from large cities emphasised agility and anticipatory adaptation: 'In a big city, everything happens faster. The market, customer expectations, competition. As a company, we have to be flexible and ready for constant change' (R2); 'Change is constancy. This is the definition of 21st-century entrepreneurship. Change is inevitable and an agile leader must be able to react before the competition overtakes them' (R5).

In small cities, leaders more often stressed relational proximity: 'I don't chase every novelty. Here it is more important to be close to people, to know their needs and to act honestly' (R7).

Some large-city respondents described local government initiatives (*e.g.*, innovation competitions, entrepreneurship events) as sources of recognition that strengthen leadership confidence and visibility. However, entrepreneurs outside large cities more often described limited access to such initiatives and instead reported bottom-up engagement with local authorities.

Respondents narrated this bottom-up engagement as a form of institutional co-creation: entrepreneurs proposing solutions, building partnerships, and seeking to improve the local ecosystem. As one respondent stated: 'We act bottom-up and consciously (...) if we don't activate, nothing will change' (R3). Another entrepreneur similarly noted: 'Instead of complaining, we started to look for partners in the office and propose concrete solutions' (R11).

Thematic summary: entrepreneurial leadership in Poland includes not only firm-level action but also place-based efforts to adapt to, and sometimes reshape, local institutional conditions.

Innovation and Sustainability Orientation: Future Visions With Sectoral and Local Boundaries

A fifth mechanism concerns future orientation towards innovation and sustainability. Many respondents, especially technology entrepreneurs and those operating in large cities, reported that leadership increasingly requires aligning competitiveness with responsible production and long-term societal value. For example: 'Customers (...) are increasingly asking not only about the price, but also whether the product is manufactured in a responsible manner' (R18); 'Sustainable development is now an obligation (...) but also an opportunity to gain a competitive advantage' (R5); 'We invest in innovations that make business sense and environmental sense' (R12).

Retail entrepreneurs additionally described innovation as a response to globalised consumer expectations: 'Customers travel around the world (...) they expect to be able to buy such goods in [our city] as well' (R17). Another respondent observed that competitive reference points are increasingly European or global rather than local (R6). Importantly, respondents did not frame innovation only in financial terms: one entrepreneur highlighted combining modern solutions with 'real benefits for people' (R1).

Boundary conditions were also visible. Service-sector entrepreneurs in small towns rarely articulated leadership in sustainability or innovation terms, instead prioritising liquidity and local trust.

Thematic summary: innovation and sustainability are salient leadership themes in technology-intensive and metropolitan contexts, but they are less central in small-town service settings where immediate market stability dominates.

Discussion

This section interprets the five mechanisms in relation to existing entrepreneurship and entrepreneurial leadership research, and it discusses boundary conditions and alternative interpretations. We structured the discussion along a micro-meso-macro logic: psychological resources (micro), relational and community resources (meso), and institutional co-creation (macro).

Micro-level: resilience-as-learning. The resilience narratives from our interviews are consistent with research showing that Polish entrepreneurs often respond to failure by renewing opportunity search rather than withdrawing (Wójcik & Ciszewska-Mlinarič, 2020). Our contribution is to specify the mechanism through which this occurs in leadership practice: entrepreneurs reframed setbacks into actionable lessons and used this reframing to normalise experimentation for themselves and their teams. Simultaneously, the appreciative framing may foreground 'successful coping' and under-represent experiences where failure leads to exit; this is addressed as a limitation and motivates comparative and longitudinal research (Pyrkosz-Pacyna *et al.*, 2021).

Meso-level: legitimacy and social capital. The findings add nuance to accounts of Poland's changing entrepreneurial culture by showing how people experience legitimacy in concrete everyday interactions, customer trust, peer recognition, and family support, while distrust persists for unconventional initiatives. This duality aligns with studies that note both improving perceptions and continued socio-cultural ambivalence (Osowska, 2019; Żuk & Żuk, 2021). Network bricolage further illustrates how entrepreneurs assemble relational resources to compensate for uneven formal support structures, echoing evidence on the importance of social capital in Polish enterprises (Markowska-Przybyła, 2022; Żukowska, 2025).

Macro-level: institutional context and co-creation. Our results resonate with work portraying local government as an institutional entrepreneur that can foster regional entrepreneurship through collaboration and place-based initiatives (Xing *et al.*, 2018; Derlukiewicz *et al.*, 2021). We extend this literature by showing that entrepreneurs also act as ecosystem co-creators: especially outside metropolitan areas, they described bottom-up engagement with authorities and partners to improve local conditions. This suggests that entrepreneurial leadership in post-transition contexts may include a civic dimension, leading beyond the firm by shaping enabling environments (Godlewska & Morawska, 2020).

The interviews indicate that sustainability and innovation increasingly inform leadership narratives in technology-intensive and large-city contexts, consistent with research on innovation capacity and

socio-cultural interpretations of climate-related agendas (Zarębski *et al.*, 2022; Żuk & Żuk, 2021). However, these themes were less salient among small-town service entrepreneurs, for whom immediate liquidity and community trust dominated. This boundary condition cautions against universalising 'innovation-driven' narratives and highlights the need for place-sensitive entrepreneurship support.

At this point, it is appropriate to introduce a methodological reflection on the relevance of applying the appreciative inquiry approach in the present study. The literature notes that a strong focus on positive aspects of organisational functioning may risk underrepresenting structural constraints or negative experiences of social actors (Grant & Humphries, 2006). However, we did not employ appreciative inquiry to deny or obscure difficulties, but rather as a way of entering participants' narratives. Challenges such as bureaucracy, market crises, or institutional uncertainty emerged spontaneously in respondents' accounts, and the analysis focused on how entrepreneurs mobilised available resources to cope with these challenges and sustain leadership capacity. This perspective complements deficit-oriented entrepreneurship research, which tends to concentrate primarily on barriers and failures (Woodfield *et al*., 2017). By adopting an appreciative lens, we made visible generative leadership practices, such as reframing setbacks, building relationships, and engaging in institutional co-creation- that are often less apparent in problem-centred approaches, yet can be strengthened through education, support programmes, and public policy.

Commonly, scholars define entrepreneurial leadership as the capacity to influence others to manage resources strategically and to pursue opportunities under uncertainty (Renko *et al.*, 2015). Our findings suggest that, in Poland, this influence is enacted through a configuration of (a) personal psychological resources, (b) relational leadership and community embeddedness, and (c) engagement with local institutions. This micro-meso-macro configuration helps explain why 'the same' entrepreneurial leadership behaviours can have different effects depending on local legitimacy and institutional support.

The study's contribution is consolidated in three areas. Theoretical: we articulated entrepreneurial leadership in a post-transition economy as an interplay of resilience-as-learning, legitimacy, network bricolage, and institutional co-creation. Methodological: we demonstrated how appreciative-inquiry-informed interviewing elicits generative evidence that complements barrier-focused diagnostics. Practical and policy-related: we identified actionable levers for entrepreneurship education and for local ecosystem design, particularly the cultivation of peer networks, recognition practices, and accessible collaboration platforms.

Managerial and educational implications include: (1) treating failure narratives as structured learning resources in entrepreneurial training; (2) intentionally cultivating 'high-quality connections' in teams and inter-firm collaborations; and (3) using appreciative debriefs and future-oriented reflection to sustain opportunity recognition. Policy implications include: (1) supporting local peer-network infrastructure (mentoring circles, sectoral meet-ups, inter-municipal clusters); (2) designing transparent, low-bureaucracy entry points to local support programmes; and (3) recognising entrepreneurs as partners in place-based development rather than only as recipients of regulation.

CONCLUSIONS

By using an appreciative inquiry lens to examine entrepreneurial leadership in Polish businesses, this study has demonstrated the value of a strength-based approach to understanding and promoting entrepreneurship. Our research offers an alternative narrative to the prevalent discussion of barriers and gaps by emphasising the positive dimensions of entrepreneurial experience.

The appreciative lens does not disregard the difficulties of Polish entrepreneurship. Rather, it reinterprets them to show how challenges can spur development when addressed creatively and with appropriate support. This study advances a more nuanced theoretical understanding of entrepreneurship in post-transition economies for the scholarly community.

Using an appreciative inquiry lens, we identified five interconnected mechanisms of entrepreneurial leadership in Polish enterprises: resilience-as-learning, legitimacy shift and community embeddedness, network bricolage, institutional co-creation, and future orientation towards innovation and sustainability. Together, these mechanisms portray entrepreneurial leadership in Poland as a micro-

meso-macro configuration in which personal psychological resources enable relational leadership, and relational resources enable engagement with local institutions.

For entrepreneurship education and development programmes, the findings suggest designing curricula and mentoring formats that treat failure narratives as learning assets, cultivate reflective opportunity recognition, and intentionally strengthen entrepreneurs' relational capabilities. For policymakers, the study highlights the value of place-sensitive support: investing in peer-network infrastructure, lowering barriers to local support programmes, and treating entrepreneurs as co-creators of local development initiatives.

The study was qualitative and based on a purposeful, non-representative sample of eighteen interviews. Thus, we should interpret the results as analytically generalisable mechanisms rather than population estimates. As we conducted the interviews through a strengths-based protocol and translated them into English, some 'negativity' or linguistic nuance may be under-represented despite our attention to counterexamples and semantic equivalence. Rather than offering frequency claims, the study contributes analytically by clarifying leadership mechanisms and their boundary conditions, which are appropriate outputs of exploratory qualitative research.

Three directions appear particularly promising: (1) comparative studies across post-transition economies to assess which mechanisms are context-specific versus transferable; (2) longitudinal research that follows entrepreneurs across crises to observe how resilience and legitimacy evolve; and (3) mixed-method designs that combine qualitative mechanisms with quantitative measurement (*e.g.*, survey operationalisations of resilience, social capital, and institutional support), enabling hypothesis testing and policy evaluation.

In sum, we may understand Polish entrepreneurial leadership not only through the challenges entrepreneurs face but also through the strengths and relational practices that sustain opportunity-oriented action. Appreciative Inquiry offers a rigorous way to access these generative dimensions and to inform interventions aimed at entrepreneurial learning, cooperation, and ecosystem development.

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Acknowledgements and Financial Disclosure

The research underlying this article was not funded by any external sources.

Use of Artificial Intelligence

The text is free from the use of AI/GAI.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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International Entrepreneurship Review

2026, Vol. 12, No. 2

10.15678/IER.2026.1202.07

From transformational leadership to hybrid entrepreneurial intention: The serial mediating mechanism of work-life balance and self-efficacy

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ABSTRACT

Objective: This article aims to explore the interactive mechanism between workplace contextual resources and internal resources that leads to employees' hybrid entrepreneurial intention.

Research Design & Methods: By integrating conservation of resources theory and Social cognitive career theory, the study proposed a model in which transformational leadership influences hybrid entrepreneurial intention through two mediating variables, work-life balance and self-efficacy for work-venture conflict management. Primary data comprising 479 observations from employees in Viet Nam were analysed using partial least squares structural equation modelling.

Findings: The results revealed both direct and indirect effects of transformational leadership on hybrid entrepreneurial intention through the two serial mediators.

Implications & Recommendations: Practically, the results offered implications for managers in fostering innovation and supporting employees' career development.

Contribution & Value Added: Theoretically, the results provided evidence of a resource gain spiral within organisations.

Article type: research article

Keywords: hybrid entrepreneurial intention; transformational leadership; work-life balance; self-efficacy; conservation of resources theory; social cognitive career theory

JEL codes: M10, M13, M54

Received: 14 February 2026 Revised: 17 May 2026 Accepted: 22 May 2026

Suggested citation:

Nguyen, T.T., Duong, C.D., & Nguyen, N.H. (2026). From transformational leadership to hybrid entrepreneurial intention: The serial mediating mechanism of work-life balance and self-efficacy. *International Entrepreneurship Review,* 12(2), 115-125. https://doi.org/10.15678/IER.2026.1202.07

INTRODUCTION

Profound transformations in the global economy, influenced by digitalisation and the aftermath of the pandemic, drives individuals towards more flexible and diversified career paths (Shevchuk *et al.*, 2024). In this context, hybrid entrepreneurship has emerged as a notable trend, whereby individuals maintain paid employment whilst simultaneously developing their own business ventures. However, most studies still adopt a traditional binary perspective (employment versus self-employment) (Kurczewska *et al.*, 2020), failing to capture the adaptive and process-oriented nature of hybrid entrepreneurship (Demir *et al.*, 2020). This leaves a knowledge gap in hybrid entrepreneurial intention, where individuals deliberately treat it as a strategic stepping stone rather than a temporary expedient (Brändle & Kuckertz, 2022). At the same time, prior research tended to focus on end outcomes whilst overlooking the formation and development process of this choice. Conservation of resources theory conceptualises hybrid entrepreneurship as a safety net strategy aimed at protecting resources; however, the mechanisms of resource accumulation and the role of contextual factors remain unclear (Thorgren *et al.*, 2014). In addition, conflict between primary employment and business ventures defines a key feature of hybrid entrepreneur-

ship but remains insufficiently examined, despite its potential influence on individuals' beliefs in their capability to manage dual roles and on their outcome expectations (Carr *et al.*, 2023).

To address these gaps, we must identify a specific contextual resource that can facilitate resource accumulation and investment towards hybrid entrepreneurship. Transformational leadership offers this key contextual resource, helping employees achieve work-life balance whilst enhancing their self-efficacy. Accordingly, this study integrated conservation of resources theory and social cognitive career theory to propose a model examining leadership as a contextual resource creating a resource caravan passageway, enabling individuals to accumulate and transform resources into self-efficacy, thereby shaping hybrid entrepreneurial intention. In sum, this study addressed two research questions: (1) Does transformational leadership directly influence employees' hybrid entrepreneurial intention? (2) Do work-life balance and self-efficacy for work-venture conflict management serially mediate the effect of transformational leadership on hybrid entrepreneurial intention? Data were collected through an online survey conducted in Vietnam. The findings empirically establish a serial mediating mechanism linking transformational leadership to hybrid entrepreneurial intention through work-life balance and self-efficacy for work-venture conflict management.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Hybrid Entrepreneurial Intention: Conservation of Resources and Social Cognitive Career Perspective

Hybrid entrepreneurship occurs when an individual simultaneously maintains paid employment within an organisation whilst operating their own business venture (Folta *et al.*, 2010). From the perspective of conservation of resources theory (COR) (Hobfoll, 1989), the intention to pursue this path represents a strategy to accumulate, maintain, and protect valuable resources such as financial capital, energy, and self-esteem, thereby reducing stress (Thorgren *et al.*, 2014). In this context, salaried employment functions as a safety reserve, providing stable income and enabling individuals to engage in entrepreneurial activities without sacrificing financial security (Hobfoll, 2014). However, dual roles also increase resource depletion due to compounded pressures, requiring individuals to balance benefits of gaining experience against the risk of energy exhaustion. Conservation of resources theory is particularly relevant to hybrid entrepreneurial intention because salaried employment lets individuals to preserve and accumulate resource caravans, including financial stability, professional networks, and career-related benefits, whilst reducing the risks of venture creation (Maleki *et al.*, 2025). Yet managing dual roles may intensify resource depletion and lead to work-to-venture conflict (Carr *et al.*, 2023). Conservation of resources theory also explains individual differences among hybrid entrepreneurs, as older individuals possess greater knowledge and social capital, enhancing their resilience and capacity to sustain entrepreneurial passion.

From the perspective of social cognitive career theory (SCCT) (Lent *et al.*, 1994), the theory frames hybrid entrepreneurship as adaptive career behaviour, reflecting individuals' capacity for self-regulation in dynamic environments (Brändle & Kuckertz, 2022). This intention is shaped by key cognitive factors, particularly self-efficacy and outcome expectations (Brown & Lent, 2019). Accordingly, individuals do not view hybrid entrepreneurship as a binary choice but as a staged process in which they evaluate contextual supports and barriers, using it as a stepping stone before transitioning to full-time entrepreneurship. The integration of these two perspectives may provide a more comprehensive understanding of hybrid entrepreneurial intention, wherein contextual workplace factors such as leadership, function as resource caravan passageways, thereby enabling the accumulation and transformation of personal resources (e.g., work-life balance and self-efficacy). In this context, individuals more readily invest their resources either to protect against potential losses or to pursue long-term benefits through hybrid entrepreneurship. Social cognitive career theory is suitable for this study because it conceptualises individuals as proactive career agents who continuously evaluate opportunities, barriers, and long-term career goals (Brändle & Kuckertz, 2022). Beyond entrepreneurial intention, the theory highlights the importance of process self-efficacy in managing role conflict during the hybrid phase (Lent & Brown, 2013). It also positions hybrid entrepreneurship as a context for developing mastery

experiences, through which individuals strengthen confidence and capabilities before potentially transitioning to full-time entrepreneurship (Ferreira, 2020).

Transformational Leadership as a Contextual Resource

From the perspective of COR, transformational leadership functions as a contextual resource, creating a resource-facilitating context employees can accumulate additional resources (Yong & Zhang, 2025). Leaders' individualised consideration helps to identify employees' specific needs, including pressures from both work and personal life (Podsakoff *et al.*, 1990). By showing understanding and support, leaders provide conditional resources that reduce psychological energy depletion amid overlapping demands (Ratinet *et al.*, 2025). Consequently, employees feel more secure in their resource base, recover more effectively after work, and achieve a stronger sense of balance (Shahriar *et al.*, 2026). The following hypothesis is formulated:

H1: Transformational leadership has a positive effect on employees' perceived work-life balance.

Beyond stabilising present conditions, transformational leadership fosters a future-oriented outlook. Through intellectual stimulation and empowerment, this leadership style correlates with employees' entrepreneurial behaviours (Afsar *et al.*, 2016). This encourages investment in knowledge and skills, helping employees develop an entrepreneurial mindset. Moreover, psychological empowerment enhances perceptions of work meaningfulness and personal competence, thereby strengthening confidence in business ventures alongside primary employment (Crider *et al.*, 2024). The subsequent hypothesis is proposed:

H2: Transformational leadership has a positive effect on employees' hybrid entrepreneurial intention.

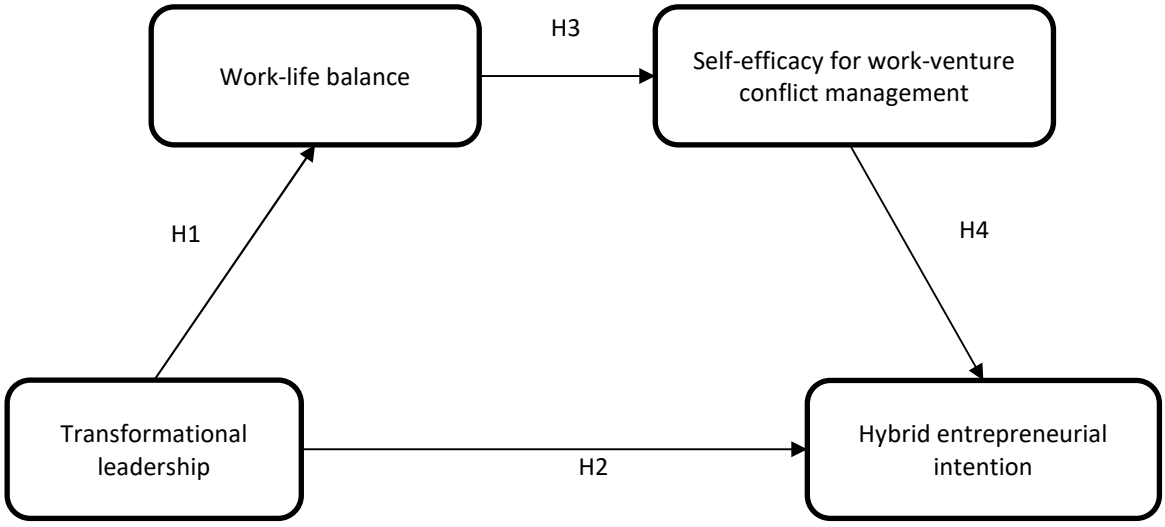

Figure 1. Conceptual model
Source: own elaboration.

Work-life Balance and Self-efficacy for Work-venture Conflict Management

Multiple sources develop self-efficacy, among which mastery experiences play a central role (Lent *et al.*, 1994). In multi-role contexts, achieving work-life balance is a genuine challenge (Ardianti *et al.*, 2022; Domagalska-Grędys *et al.*, 2025), requiring individuals to coordinate time effectively, energy, and psychological resources across roles (Drnovšek *et al.*, 2023). Once individuals experience work-life balance, they develop confidence in managing conflicts between their main job and entrepreneurial venture (Kuske *et al.*, 2025). They believe they possess sufficient abilities and psychological resources to handle conflicting demands (Albrecht *et al.*, 2026). This may yield a specific form of self-efficacy, namely self-efficacy for work-venture conflict management, enabling individuals to perceive dual-role engagement as feasible and controllable. The subsequent hypothesis is proposed:

H3: Employees' perceived work-life balance has a positive effect on their self-efficacy for work-venture conflict management.

In traditional entrepreneurship, entrepreneurial self-efficacy exhibits a clear positive effect (Newman *et al.*, 2019; Lam *et al.,* 2025). However, in the context of hybrid entrepreneurship, findings remain mixed; some studies suggest that less confident individuals more readily choose this form of engagement (Raffiee & Feng, 2014). From COR perspective, hybrid entrepreneurship is a resource-intensive process due to conflicts between employment and entrepreneurial activities (Carr *et al.*, 2023). As entrepreneurial effort increases, conflict rises, which may reduce job satisfaction and trigger intentions to leave the organisation (Albrecht *et al.*, 2026). In this context, self-efficacy for managing work-venture conflict serves as a key resource-preserving mechanism. When individuals are confident in their ability to manage conflict, they more readily believe they can simultaneously benefit from the stability of paid employment and the opportunities of entrepreneurial activity (Farrugia *et al.*, 2026). Consequently, the subsequent hypothesis is formulated:

H4: Self-efficacy for work-venture conflict management has a positive effect on employees' hybrid entrepreneurial intention.

RESEARCH METHODOLOGY

Participants and Procedure

Quantitative methodology was utilised, with primary data obtained via an online survey. We stratified the sample by gender, employment type, and educational level, and recruited it using convenience sampling. The respondents worked in the private sector in Vietnam, classified according to the international standard classification of occupations (ISCO-08) of the International Labour Organization, including four groups: managers, senior professionals, mid-level professionals, and office employees. This group likely develops hybrid entrepreneurial intentions (Petrova, 2012; Solesvik, 2017; Thorgren *et al.*, 2014). The survey ran from September 2025 to March 2026, yielding 479 valid responses. In terms of gender, the sample was relatively balanced, with 52.8% female and 47.2% male respondents. Regarding age, 41.1% fell in the 18–24 range, followed by 25.9% aged 25-34, 26.3% aged 35-44, and the remainder aged over 45. On educational attainment, 68.5% held an undergraduate degree, 20.0% held a postgraduate degree, and the remainder had completed upper secondary school or college. Regarding employment type, 70.6% were full-time employees, 16.1% were freelancers, and 13.4% worked part-time. These characteristics confirm the sample's appropriateness for studying employees in Vietnam, predominantly university-educated, mainly in full-time employment, and with a slightly higher proportion of female respondents.

Scales

For transformational leadership, we adopted a shortened seven-item scale measuring transformational leadership behaviours, assessed based on the frequency of leaders' actions (1 = Rarely or never, 5 = Very frequently) (Carless *et al.*, 2000). We adopted the work-life balance scale in its original 4-item form (Brough *et al.*, 2014). The hybrid entrepreneurial intention scale was adapted from the entrepreneurial intention scale (Liñán & Chen, 2009), with minor modifications reflecting the specific nature of hybrid entrepreneurship, emphasising entrepreneurship alongside ongoing employment and the prioritisation of salaried work as the main occupation (Demir *et al.*, 2020). We measured these two constructs using a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). The self-efficacy for work-venture conflict management scale was adapted from the work-family conflict self-efficacy scale (Cinamon, 2006), following established self-efficacy scale-development guidelines (Bandura, 2006), with an emphasis on 'I can' statements. The item content was also informed by prior research on conflict between employment and entrepreneurial activities (Carr *et al.*, 2023). We measured this construct using a 10-point scale (0 = Cannot do at all, 10 = Completely certain can do). Due to the use of different measurement scales, all data were standardised into z-scores prior to analysis. We used SmartPLS to evaluate both the measurement and structural models via partial least squares structural equation

modelling (PLS-SEM). We tested hypotheses using bootstrapping with 5 000 resamples at a 5% significance level ($p < 0.05$). Detailed results are presented in Table 1.

RESULTS AND DISCUSSION

Measurement Model

Table 1 presents the study variables, items, and the outer loadings. The outer loadings should exceed 0.7 to ensure adequate measurement quality (Hair *et al.*, 2019). In the initial estimation of the measurement model, one item (ZWLB2) was removed as it did not meet the required threshold. In the subsequent estimation, all outer loadings ranged from 0.767 (ZTL1) to 0.856 (ZSE4). Therefore, all measurement scales demonstrated satisfactory quality and were retained for further analysis.

Table 1. Outer loadings of the measurement scales

Variables/Shortened items	Code	Outer loadings
Hybrid entrepreneurial intention	HEI	
Ready to start a business while maintaining current job	ZHEI1	0.827
Goal is to start a business while continuing current career	ZHEI2	0.815
Will make every effort to start and run a business in parallel	ZHEI3	0.855
Determined to create a business in the future while keeping current job	ZHEI4	0.790
Seriously thought about starting a business alongside current job	ZHEI5	0.792
Have a firm intention to start a business while keeping primary job	ZHEI6	0.844
Self-efficacy for work-venture conflict management	SE	
Start business without affecting urgent work tasks	ZSE1	0.777
Fulfil work duties despite startup pressures	ZSE2	0.797
Perform entrepreneurial role effectively after stressful work	ZSE3	0.811
Invest in current job despite business project pressures	ZSE4	0.856
Succeed in entrepreneurial role despite work obstacles	ZSE5	0.804
Succeed in work role despite startup difficulties	ZSE6	0.832
Invest in startup despite heavy work responsibilities	ZSE7	0.829
Focus on work tasks despite startup disruptions	ZSE8	0.816
Transformational leadership	TL	
Communicating a positive future vision	ZTL1	0.767
Supporting individualised staff development	ZTL2	0.803
Providing staff recognition and praise	ZTL3	0.852
Fostering team trust and cooperation	ZTL4	0.828
Promoting innovative problem-solving	ZTL5	0.824
Practising core values consistently	ZTL6	0.808
Inspiring respect through professional competence	ZTL7	0.854
Work-life balance	WLB	
Have a good balance between the time at work and non-work activities	ZWLB1	0.863
The balance between my work demands and non-work activities is right	ZWLB3	0.840
Overall, I believe that my work and non-work life are balanced	ZWLB4	0.835

Note: n = 479.
Source: own study.

The reliability, convergent validity, and discriminant validity of the measurement scales are presented in Table 2. CR and Cronbach's alpha for all constructs exceed 0.7, indicating good internal consistency. AVE for all constructs exceeds the 0.50 threshold, confirming satisfactory convergent validity. We evaluated discriminant validity via HTMT, with all derived HTMT outcomes remaining under the 0.85 benchmark (Henseler *et al.*, 2015), thereby confirming discriminant validity. Furthermore, all variance inflation factor (VIF) values are below 1.092, indicating that multicollinearity is not a serious concern in this study (O'brien, 2007).

Table 2. Results of reliability and validity evaluation

Variable	α	CR	AVE	Heterotrait-monotrait ratio (HTMT)			
				HEI	SE	TL	WLB
HEI	0.903	0.925	0.674	–	–	–	–
SE	0.928	0.941	0.665	0.541	–	–	–
TL	0.919	0.935	0.672	0.428	0.307	–	–
WLB	0.802	0.883	0.716	0.400	0.406	0.374	–

Note. n = 479; AVE: Average variance extracted; α: Cronbach's alpha; CR: Composite reliability.
Source: own study.

Hypothesis Testing

Table 3 presents the results of the path analysis. All direct effects in the model are statistically significant. Specifically, transformational leadership has a positive effect on work-life balance (β = 0.329, p < 0.001) and on employees' hybrid entrepreneurial intention (β = 0.272, p < 0.001). Therefore, hypotheses H1 and H2 are supported. Next, work-life balance has a positive effect on self-efficacy for work-venture conflict management, thereby validating hypothesis H3 (β = 0.353, p < 0.001). Furthermore, this self-efficacy construct exerts a highly significant positive impact on hybrid entrepreneurial intention (β = 0.421, p < 0.001), which sustains hypothesis H4.

Table 3. Hypothesis testing results

Hypotheses	Effects	β	t-value	p-value	Conclusion
Direct effects					
H1	TL -> WLB	0.329	7.283	< 0.001	Supported
H2	TL -> HEI	0.272	5.958	< 0.001	Supported
H3	WLB -> SE	0.353	8.107	< 0.001	Supported
H4	SE -> HEI	0.421	10.371	< 0.001	Supported
Specific indirect effects					
–	TL -> WLB -> SE	0.116	4.754	< 0.001	–
–	TL -> WLB -> SE -> HEI	0.049	4.061	< 0.001	–
–	WLB -> SE -> HEI	0.149	5.664	< 0.001	–
Total indirect effects					
–	TL -> HEI	0.049	4.061	< 0.001	–
–	TL -> SE	0.116	4.754	< 0.001	–
–	WLB -> HEI	0.149	5.664	< 0.001	–

Note: n = 479.
Source: own study.

Beyond the direct relationships, the results indicate indirect effects among the variables in the model. Specifically, the indirect effect of transformational leadership on self-efficacy for work-venture conflict management through work-life balance proves significant (β = 0.116, p < 0.001). Notably, the study confirmed a sequential mediation pathway from transformational leadership, through work-life balance and self-efficacy for work-venture conflict management, to hybrid entrepreneurial intention, with a significant effect (β = 0.049, p < 0.001).

Discussion

The positive relationship between transformational leadership and work-life balance underscores the vital role of immediate managers in providing essential contextual resources. This finding aligns with the established view that transformational leadership fosters employee trust and satisfaction (Podsakoff *et al.*, 1990), and extends the literature by showing how transformational leaders enhance subordinates' work-life balance through collective regulations (Ratinet *et al.*, 2025).

The positive link between transformational leadership and hybrid entrepreneurial intention reveals that this leadership style's influence transcends organisational boundaries. It directly inspires

employees to develop external careers proactively. This direct linkage complements recent evidence on employees' entrepreneurial behaviour (Afsar *et al.*, 2016; Moriano *et al.*, 2011), yet offers a unique insight: a leadership style traditionally designed to enhance organisational commitment simultaneously equips individuals with the psychological resources to initiate external, hybrid ventures.

The positive nexus between work-life balance and self-efficacy can be explained through COR; individuals who conserve resources in one domain experience a positive spiral, building a rich reservoir of psychological capital (Hobfoll, 1989). This finding offers a more nuanced, context-specific understanding than prior, broader accounts of role balance and self-efficacy (Roche *et al.*, 2016). Viewed through the lens of SCCT, work-life balance may act as a mastery experience or a source of positive affect, which directly cultivates localised self-efficacy (Lent & Brown, 2013). The path from self-efficacy to hybrid entrepreneurial intention emerged as the strongest relationship in the model. This reinforces the premise that self-efficacy dominates the shaping of career intentions and behaviours (Lent *et al.*, 1994). Unlike previous studies focused narrowly on general entrepreneurial self-efficacy (Brändle & Kuckertz, 2022; Kurczewska *et al.*, 2020; Raffiee & Feng, 2014), which often yielded inconsistent results, the current study introduced a process-oriented form of self-efficacy that provides significant explanatory power within the hybrid entrepreneurship context.

Finally, empirically validating the sequential indirect effect maps a comprehensive resource transformation pipeline. Rather than treating environmental and personal factors as isolated predictors, this study integrated them into a cohesive chain, conceptualised in COR as a 'resource caravan' (Hobfoll, 2014). Whilst the role of transformational leadership as a resource corridor has previously been examined primarily through employee strain reduction (Yong & Zhang, 2025), the current study synthesised these fragmented pathways. Consequently, it advances both COR and career transition literature by showing how individuals internalise contextual support to help individuals safely and sustainably pursue dual-career paths.

CONCLUSIONS

From a theoretical perspective, this study identified the psychological mechanism through which supervisor support enables employees to accumulate the resources to pursue hybrid entrepreneurial intention, thereby clarifying why and how individuals combine employment with entrepreneurial activities (Solesvik, 2017). Rather than treating hybrid entrepreneurship as an escape from organisations, the study showed it to be the outcome of a capability-development process facilitated by modern leadership styles. The findings provide empirical evidence for hybrid entrepreneurship, supporting the resource gain spiral argument of COR, whereby resources not only help individuals maintain stability but also generate positive reinforcing cycles (Hobfoll, 2014). Accordingly, entrepreneurial intention does not arise solely from job dissatisfaction or resource depletion, but also from a positive work environment. This study clarified the sequential influence of leadership on hybrid entrepreneurial intention, emphasising that work-life balance alone proves insufficient to generate such intention; it must transform into a specific cognitive resource, namely self-efficacy for managing role conflict. This extends prior research, which typically focused on single mediators. Moreover, the study bridged organisational behaviour and hybrid entrepreneurship literature, showing that leadership not only enhances retention and performance but also supports employees' diverse career development in contemporary contexts.

Practically, the findings suggest that managers should develop transformational leadership and foster a work-life balance culture, rather than relying on traditional reward policies alone. When employees accumulate sufficient psychological resources and gain confidence in managing multiple roles, they are more likely to translate entrepreneurial ideas into actual intentions, thereby creating value for both individuals and organisations.

Several limitations persist in this research, particularly its cross-sectional nature, which constrains the establishment of causal inferences (Nguyen, 2021). The reliance on a convenience sampling technique introduces potential selection bias, which may limit the generalisability of the findings to the wider employee population. Moreover, it does not fully account for resource-loss factors in the work context. Future research should employ longitudinal designs and test the model using time-lagged

data, while also incorporating potential negative factors that may influence employees' hybrid entrepreneurial intentions. To strengthen external validity, it would be beneficial for subsequent studies to test this model across more diverse industry sectors and demographic strata. The scope of enquiry could be modestly expanded by examining multi-level factors, spanning macro-environmental conditions to individual personality traits. Given that self-efficacy for work-venture conflict management proves promising in this study, we encourage future researchers to validate this scale and explore its utility in alternative research contexts beyond hybrid entrepreneurship.

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The contribution share of authors is as follows: TTN contributed 50% of the work, including conceptualisation, data collection, analysis, and manuscript preparation. CDD contributed 30%, providing academic supervision, research-design guidance, and critical revisions of the manuscript. NHN contributed 20%, providing academic supervision, revising the manuscript after addressing reviewing comments and suggestions from the reviewers as well as responding the reviewers.

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Acknowledgements and Financial Disclosure

This research received no external funding.

Use of Artificial Intelligence

The authors declare that no AI or GAI tools were used in the preparation of this manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Published by Krakow University of Economics – Krakow, Poland

The publisher:

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ISSN 2658-1841