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The Impact of Service Quality on Organizational Marketing Performance - mobile network operator in Algeria case study

Amroun Sarra – Belaaze Khayreddine[1]

Abstract

The aim of this paper is to highlight the role of improving the quality of services in facilitating their marketing and improving marketing efficiency, as there has been an increasing interest in the management of enterprises that are active in a competitive environment in gaining a competitive advantage and increasing their. Their efforts focused on achieving their satisfaction with the service quality they were offered and marketing performance.

The field study was applied to a sample of the customers of Djezzy's in Eastern Algeria, and we used SPSS to analyze the answers, and one of the results found was a positive medium relationship between the quality of service and marketing performance, and that the impact was limited to reliability and after empathy.

Key words

Service Quality, Marketing Performance, Performance Measures, Customer Satisfaction.

.**JEL Classification:** M10 ; M31

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Introduction

Delivering quality service is considered an essential strategy for success and survival in today's competitive environment. During the 1980s, the primary emphasis of both academic and managerial effort focused on determining what service quality meant to customers and developing strategies to meet customer expectations (ZEITHAML, L BERRY, & PARASURAM, 1996, p. 31). A service is all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced, and provides added value in forms (such as convenience, amusement, timeliness, comfort, or health) that are essentially intangible concerns of its first purchaser (WILSON & and al, 2020, p. 04). Quality as functionality characterizes the design of a service and can only be measured by comparing the service against other services offering similar functionalities (KHAN, 2009, p. 117). Service quality is regarded as high when service perform- ance is perceived to be higher than expectations of service (DONTHU & YOO, 1998, p. 178). The model of (Parasuraman Zeithaml, and Berry; 1985) looked at service quality as a comparison differentiation between the customer perception and expectation of the service and the actual performance of the service received by the Service quality perception customer provided by the company at a certain period of time. This study resulted developed a gap model of perceived service quality and revealed ten dimensions to measure service quality. In a second study in 1988, the ten dimensions were reduced to five dimensions. and called it the SERVQUAL model (MUSLIM & ZAIDI, 2008, pp. 193, 194).

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It has long been established that marketing performance is very important to overall firm performance, being manifest in indicators such as strong brand awareness, expressions of consumer preference, and high levels of market share (LAMPRINOPOULOU & TREGEAR, 2020, p. 425). Marketing makes a fundamental contribution to long-term business success on the bases that an organization's survival depends on its capacity to create value (Nwokah, 2009, p. 20). Practitioners and academics have shown increasing interest in the assessment of marketing performance. The Marketing Science Institute has raised marketing metrics to become its leading capital research project. The marketing performance literature has been criticized for its limited diagnostic power, its focus on the short term, the excessive number of different measures and the related difficulty of comparison; the dependence of the perceived performance on the set of indicators chosen; and the lack of attention to shareholder value creation (AMBLER, KOKKINAKI, & PUNTONI, 2004, p. 475).

Based on the above, the problem of the study is manifested by asking the following main question: How do the dimensions of service quality affect marketing performance in service organizations?

To answer the question raised, the following main hypotheses can be formulated:

- H_01: Clients of Djezzy agencies in eastern Algeria do not care about the dimensions of service quality;
- H_02: Clients of Djezzy agencies in eastern Algeria do not care about marketing performance;
- H_03: There is no statistically significant relationship at the 5% level of significance between the interest customers of Djezzy agency agencies in eastern Algeria have in the dimensions of service quality and marketing performance.

2. Service Quality

Quality has been defined differently by different authors. Some prominent definitions include 'conformance to requirements' (Crosby, 1984), 'fitness for use' (Juran,1988) or 'one that satisfies the customer' (Eiglier and Langeard, 1987) (JAIN & GUPTA, 2004, p. 26). Services have several characteristics that distinguish them from goods, as follows (MASTERSON, PHILLIPS, & PICKTO, 2017, p. 264): (Services provide benefits; Services are intangible, i.e. they do not have a physical form (or part) and therefore cannot be touched; Services depend on the time and place in which they are provided, i.e. they cannot be stored or transferred; The service provider is part of the service provided; The customer is part of the service provided; Services are not identical; Services cannot be owned.

The construct service quality has been defined as the degree of discrepancy between customers' normative expectations for service and their perceptions of service performance (GORLA, SOMERS, & WONG, 2010, p. 213). According to (Parasuraman et al; 1988), service quality can be defined as an overall judgment similar to attitude towards the service and generally accepted as an antecedent of overall customer satisfaction (PRABHA, SOOLAKSHNA , & PERUNJODI , 2010, p. 38). Customer perceived service quality can be defined as a global judgment or attitude relating to the superiority of a service relative to competing offerings (YANG, JUN, & PETERSON, 2004, p. 1151).

SERVQUAL has been applied by various researchers to numerous service in dustries as a means of gauging service quality. The primary value of SERVQUAL lies in its powerful benchmarking, diagnostic, and prescriptive tools (YANG, JUN, & PETERSON, 2004, p. 1151). The foundation for the SERVQUAL scale is the gap model proposed by Parasuraman, Zeithaml and Berry (1985, 1988). With roots in disconfirmation paradigm, the gap model

maintains that satisfaction is related to the size and direction of disconfirmation of a person's experience vis-à-vis his/her initial expectations. As a gap or difference between customer 'expectations' and 'perceptions,' service quality is viewed as lying along a continuum ranging from 'ideal quality' to 'totally unacceptable quality,' with some points along the continuum representing satisfactory quality (JAIN & GUPTA, 2004, p. 27). The model provided a comprehensive perception of service quality with a tool to measure perceived service quality. This method received great attention from academics and researchers in order to evaluate customers' perception of service quality in service industries. The model identified five dimensions of service quality (WIRTZ & LOVELOCK, 2016, p. 78): Tangibility (appearance of physical components); Reliability (dependability and accuracy of performance); Responsiveness (speed and usefulness); Guarantee (credibility, security, competence and courtesy); Empathy (accessibility, good communication and understanding of customers).

In the service literature, Oliver (1980) explained that customer satisfaction entails the full meeting of customer expectation of the products and services. If the perceived performance matches or even exceeds customers' expectations of services, they are satisfied. If it does not, they are dissatisfied (de Wulf, 2003). In the real world, unsatisfied customers tends to create negative word-of-mouth and convey their negative impression to other customers (MUSLIM & ZAIDI, 2008, p. 195).

3. Marketing Performance

Performance which means the position of the horse in the race, after being translated into French gave a wide field of application. Performance is defined through several criteria, including: the institution's position in relation to competition, the ability to innovate, the number of customers who have moved away from dealing with the institution, the percentage of contracts concluded... Etc., despite this huge number of meanings that the word performance has, it can be traced back to one of the following meanings (REY , 1991, p. 14):

- Performance is a function of success, that is, it is a function to represent success, and this function changes with the change of institutions and/or their employees;

- Performance is the result of success, meaning that measuring performance is an estimate of the results obtained;

- Performance is an act that expresses a set of stages, steps and processes and is not the result obtained over a period of time.

Empirical studies have identified several factors as determinants of firm performance which include social network, Competitive advantage, innovation and Entrepreneurial orientation (NAALA, , NORDIN, & OMAR, 2017, p. 02). Marketing performance is a measure of contributions of an organization's marketing functions to its corporate goals and objectives (Jackson et al., 1995) (ASIEGBU & all, 2011, p. 46).

Unfortunately, assessing marketing performance is also very difficult to do. Unlike purely internal measures of performance, such as defects per million, marketing performance depends on external, largely uncontrollable actors, such as customers and competitors. Further, it acts as a mediator between these external actors and various internal corporate processes, such as accounting, manufacturing, research and development, and finance. (Bonoma and Clark; 1988) observe that these factors make "marketing's outputs lagged, multivocal, and subject to so many influences that establishing causesand- effect linkages is difficult (NEELY, 2004, p. 22).

According to (Woodburn; 2004) the purpose of performance measurement is ultimately an improvement in the financial outcome in a commercial organization. However, measuring financial outcomes alone does not provide sufficient information of the kind to help direct the decision-making that will achieve the performance improvement. Organizations need to measure several factors in order to get a real idea of how the organization is performing and where they might intervene. Recently, Ambler and Kokkinaki (1997) have summarized marketing metrics in six categories: financial, competitive market, consumer behavior, and customer intermediate, direct customer and innovativeness measures. They can offer a total performance measurement. Ambler (2000) argues that financial metrics are usually the first type to be employed to evaluate marketing performance. The financial measures include turnover, contribution margin and profit (NWOKAH, 2009, p. 22). whereas marketing measures incorporate metrics such as market share, customer loyalty, customer retention and customer satisfaction (MCMANUS, 2012, p. 01). Another study was adopted four important recent measures of the health of an organization's marketing: market orientation, customer satisfaction, customer loyalty, and brand equity (NEELY, 2004, p. 22). The literature has come up with various discussions regarding determining how to measure marketing performance, as it can be measured through efficiency and effectiveness (VORHIES & MORGAN, 2003, p. 106). and Morgan, et. al in evaluating marketing performance focus on two major approaches, namely marketing productivity analysis and marketing audits (MORGAN , CLARK , & GOONER, 2002, p. 363).

The (CMO Council ; 2004) believes that one of the factors that contributed to the increased interest in marketing performance measures is the need to know the appropriate measures to improve the use of resources allocated to marketing and the effectiveness of its departments. In practice it is often seen that major marketing departments work on the basis of long lists of performance measures which demand considerable resources to keep up to date and which do not necessarily contribute to a coherent and logical picture of the effect of marketing investments. Therefore, fewer but more carefully selected measures would probably be required(GRØNHOLDT & MARTENSEN, 2006, p. 244). Therefore, the success of the marketing process depends on planning and defining strategies, using standards to measure marketing performance, and identifying deviations from what is planned by following oversight,as stated by Jaworski in his definition of marketing control. Control theory assumes that management has a strategy and a known set of intermediary stages (plans) with which actual performance can be compared (AMBLER, KOKKINAKI, & PUNTONI, 2004, p. 02). Marketing performance measures can be limited to Mental consumer results (such as brand awareness, expected and perceived quality, Image and Perceived value, customer satisfaction and loyalty), market results (such as volume and value of sales, market share, number of customers, new customers and new prospects, and price elasticity), Behavioural customer results (such as the customer loyalty/retention, number of customer complaints and the number of transactions per customer). and financial results (such as profits, customer profitability, and cash flow, Customer lifetime value) (GRØNHOLDT & MARTENSEN, 2006, p. 248).

1 Methodology

We used the form as a main tool in collecting data, and consisted of 29 paragraphs including two axes that include the variables of the study. The first deals with the dimensions of service quality, which is the independent variable, and the second deals with marketing performance, which is the dependent variable. The answers to each paragraph were among the axes of the form. Weighted according to a five-point Likert criterion

Validity means ensuring the ability of the study tool to measure the purpose for which it was prepared. This is to ensure that the form includes a set of paragraphs representing the variables of the study. The more the paragraphs represent the subject of the study, the greater the validity of the study tool. As for the reliability of the form, it is that The tool achieves the same result if it is redistributed more than once under the same conditions.

Before starting to conduct the various tests, it must be ensured that the study data are normally distributed. For this reason, we used the normal distribution test for the data of the study variables. One-Sample Kolmogorov-Smirnov, because most parametric tests require that the distribution of the data be normal, and the decision rule leads to accepting that the data follows a normal distribution. If the Sig value is greater than 5%.

Tab. 1 Normal distribution test for study variables data (K.S.)

axes	Test value (K.S.)	level of significance
The first axis	0.856	0.456
The second axis	1.204	0.110

Source: Prepared by the researchers based on SPSS.

It is clear from the previous table that the level of significance (Sig) for both axes is greater than 0.05, and therefore the null hypothesis is rejected and the alternative hypothesis is accepted, and thus the data for both axes follow a normal distribution, which enables us to use parametric tests.

- The first axis: The interest of customers of Djezzy agencies in eastern Algeria in the quality of service

- The main null hypothesis: The data related to the first axis are not subject to a normal distribution.

- The main alternative hypothesis: The data related to the first axis are subject to a normal distribution.

- The second axis: The interest of clients of Djezzy agencies in eastern Algeria in marketing performance

- The main null hypothesis: The data related to the second axis are not subject to a normal distribution.

- The main alternative hypothesis: The data related to the second axis are subject to a normal distribution

2 Results and Discussion

2.1 Testing the first hypothesis

- Null hypothesis H_0: Clients of Djezzy agencies in eastern Algeria do not care about the dimensions of service quality;

- Alternative hypothesis H_1: Clients of Djezzy agencies in eastern Algeria are interested in the dimensions of service quality.

Tab. 2 Arithmetic mean and T-test for the first hypothesis

Weighted average =3								
Variable	Mean	Standard Deviation	t value	ddl	Sig	Difference between the two means	Confidence level 95%	
							Min value	Max value
Axis 1	3.89	0.55	16.08	99	0.00	0.89	0.78	1.00

Source: Prepared by the researchers based on SPSS.

The outputs show that the arithmetic mean of the answers to the statements composing the axis of service quality dimensions reached 3.89, with a deviation of 0.55, and since the calculated t value reached 16,08, which is greater than its tabulated value, this is what prompts us to reject the null hypothesis and accept the alternative hypothesis, and what confirms this result. The calculated significance level of 0.00 was less than 0.05, i.e. less than the approved level. Hence, the clients of Djezzy agencies in eastern Algeria are interested in the dimensions of service quality.

2.2. Testing the second hypothesis

- Null hypothesis H_0: Clients of Djezzy agencies in eastern Algeria do not care about marketing performance;

- Alternative hypothesis H_1: Clients of Djezzy agencies in eastern Algeria are interested in marketing performance.

Tab. 3 Arithmetic mean and T-test for the second hypothesis

Weighted average =3								
Variable	Mean	Standard Deviation	t value	ddl	Sig	Difference between the two means	Confidence level 95%	
							Min value	Max value
Axis 2	3.69	0.83	8.25	99	0.00	0.68	0.52	0.85

Source: Prepared by the researchers based on SPSS.

The table outputs show that the arithmetic mean of the answers to the statements composing the marketing performance axis reached 3.69, with a deviation of .8310, and since the calculated t value reached 8.259, which is greater than its tabulated value, this is

what prompts us to reject the null hypothesis and accept the alternative hypothesis, and what confirms this result is that The calculated significance level of 0.000 was less than 0.05, wish mean less than the approved level, and therefore clients of Djezzy agencies in eastern Algeria care about marketing performance

2.3. Testing the third hypothesis

- Null hypothesis H_0: There is no statistically significant relationship at the 5% level of significance between the interest customers of Djezzy agency agencies in eastern Algeria have in the dimensions of service quality and marketing performance.

- Alternative hypothesis H_1: There is a statistically significant relationship at a 5% level of significance between the interest of customers of Djezzy agencies in eastern Algeria in the dimensions of service quality and marketing performance.

Tab. 4 Results of the multiple linear regression test for the third hypothesis

variable	unstandardized coefficients		standardized coefficients	**t value**	**sig**
	β	**Standard error**	**Beta**		
fixed	1.00	0.53		1.86	0.06
Dimension 1	-0.09	0.13	-0.07	-0.70	0.48
Dimension 2	0.37	0.11	0.34	3.25	0.00
Dimension 3	0.04	0.12	0.04	0.35	0.72
Dimension 4	0.05	0.15	0.04	0.37	0.71
Dimension 5	0.32	0.12	0.29	2.54	0.01

Dependent Variable: Performance Marketing, R = 0,566, R Square = 0,320, F=8,846, α = 0,05.

Source: Prepared by the researchers based on SPSS.

From the above, the following multiple linear regression equation:

$Y=B\_0+B\_1\ X\_1+B\_2\ X\_2+B\_3\ X\_3+B\_4\ X\_4+B\_5\ X\_5+\varepsilon\_i$

Based on the results of the previous table, we can write the regression to predict the marketing performance variable through the dimensions of service quality as follows: Marketing performance = 1,000 – 0.93 after tangibility + 0.37 after reliability + 0.04 after responsiveness + 0.05 after warranty + 0.32 after Empathy.

It appears from the table that the coefficient of determination R2 reached 0.32, which indicates an interpretation of the independent variable represented by service quality with its five dimensions for the dependent variable represented by marketing performance at a rate of 32%, and that the remaining percentage and estimated 68% of the effect on the dependent variable is due to other factors, as The calculated F value of 8,84 with a 95% confidence level indicates that the regression line is appropriate for the relationship between the independent variables and the dependent variable. We note that the calculated F value is greater than the tabular value, so we will reject the null hypothesis and accept the alternative hypothesis. The value of the correlation coefficient R, which reached 0.56, indicates the presence of A moderate positive relationship between the two variables.

Also The significance level of the two independent variables represented in the first, third, and fourth dimensions, respectively, reached 0.48 , 0.72, and 0.71, which are rejected values because they fulfill the null hypothesis because they are greater than the significance level of 0.05, which means that there is no significant effect for each of the tangibility dimensions. After the response and after the guarantee, while the significance of the second and fifth dimensions reached, respectively, 0.00 and 0.01, which are acceptable values because they fulfill the alternative hypothesis, which indicates their statistical significance, which indicates the importance of these variables in interpreting the dependent variable, and from the above analysis we can Accepting the alternative hypothesis, which states that there is a statistically significant relationship at the 5% significance level between the reliability dimension, the empathy dimension, and marketing performance, and thus the regression equation becomes as follows: Marketing performance = 0.96 + 0.39 After Reliability + 0.32 empathy's dimension.

Conclusion

This study, which aimed to answer the problem and hypotheses raised about the impact of applying the dimensions of service quality on the marketing performance of the institution, concluded with the rejection of the first, second and third hypothesis, as the clients of Djezzy agency agencies in eastern Algeria are interested in the dimensions of the quality of service provided and the marketing performance of the institution, and there is a significant relationship. Statistics between service quality and marketing performance. However, the choice of regression showed that there was no significant effect for each of the tangibility dimension, the responsiveness dimension, and the guarantee dimension, while indicating the importance of the reliability and empathy dimension in explaining marketing performance. Therefore, Djezzy Corporation must pay attention to the material aspect of the service provided and improve the level of quality provided by training its employees, looking into complaints submitted by customers, and working to resolve them in a friendly manner through personal communication and tact with customers.

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Description of TRL and IRL of the dynamic system "immersive marketing" on the different stages of development[1]

Nadiia Artyukhova, Artem Artyukhov[2]

Abstract

Immersive Marketing (IM), leveraging Extended Reality (XR) technologies, is redefining consumer engagement by creating dynamic socio-technical systems (DSTS) that require significant corporate investment. Effective innovation governance is challenged because the standard Technology Readiness Level (TRL) is limited to technical proof, failing to account for critical commercial factors, such as market acceptance and organizational readiness. This misalignment, often leading to project failure (referred to as the "Valley of Death"), necessitates a dual approach. This article develops a comprehensive, unified governance framework by integrating the nine stages of TRL with the Innovation Readiness Level (IRL) framework. Using a conceptual and analytical design, we systematically adapted both TRL and IRL into domain-specific criteria (IM-TRL and IM-IRL). The resultant Integrated Readiness Matrix successfully maps the concurrent technical and commercial maturity of IM initiatives, defining four strategic quadrants. A key finding is the exposure of two critical high-risk scenarios: the "Valley of Death" (high TRL, low IRL) and the "Hype Trap" (low TRL, high IRL), which stem from organizational imbalances. This Integrated TRL/IRL framework provides innovation managers with a disciplined methodology to de-risk high-value XR investments, ensuring that technical progress is always aligned with commercial viability and production scalability. Future research should prioritize the empirical validation of this framework and the quantitative development of the Customer Readiness Level (CRL) using advanced neurophysiological data.

Key words

Immersive Marketing, Technology Readiness Level (TRL), Innovation Readiness Level (IRL), Extended Reality (XR), Innovation Governance.

JEL Classification: M31, O31, O36

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Introduction

The convergence of immersive technologies and marketing practices has created a dynamic system that fundamentally transforms consumer-brand interactions. However, the

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systematic assessment of its developmental maturity remains underexplored in academic literature. Immersive marketing, characterized by the integration of virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR) technologies into brand communication strategies, represents a paradigm shift from passive information consumption to active experiential engagement (Scholz & Smith, 2016; Rauschnabel et al., 2022). As organizations increasingly invest in immersive marketing solutions, the need for standardized frameworks to evaluate technological readiness and innovation maturity has become crucial for informed strategic decision-making and effective resource allocation (Wedel et al., 2020).

Technology Readiness Levels (TRL), initially developed by NASA to assess the technological maturity of emerging technologies, ranging from basic principles to operational deployment, provide a systematic approach to evaluating the development stage of emerging technologies (Mankins, 1995). The framework's nine-level scale has been widely adopted across various industries to mitigate technological risks and inform investment decisions (Héder, 2017). However, technological maturity alone is insufficient to capture the complexity of innovation processes, particularly in consumer-facing applications where market acceptance, user behavior, and organizational readiness significantly influence implementation success (Olechowski et al., 2015). This limitation has prompted the development of complementary frameworks, including Innovation Readiness Levels (IRL), which extend beyond technical functionality to encompass market viability, business model validation, and ecosystem integration (Ozcan et al., 2024).

The dynamic nature of immersive marketing systems presents unique challenges for readiness assessment. Unlike traditional technologies that follow relatively linear development trajectories, immersive marketing evolves through complex interactions between hardware capabilities, software innovations, content creation practices, consumer adoption patterns, and regulatory environments. The system's components, including display technologies, tracking systems, content management platforms, analytics tools, and creative methodologies, develop at different rates and exhibit varying levels of maturity across application contexts (Rauschnabel et al., 2022). Furthermore, the rapid evolution of artificial intelligence, 5G networks, and edge computing continuously reshapes the technological foundation of immersive marketing, necessitating dynamic rather than static readiness assessments (Dwivedi et al., 2023).

Despite growing academic interest in immersive technologies for marketing applications, existing research predominantly focuses on effectiveness studies, consumer response analysis, and implementation case studies, while systematic frameworks for assessing developmental readiness remain scarce (Wedel et al., 2020; Flavián et al., 2019). This gap limits practitioners' ability to make evidence-based decisions regarding the timing of technology adoption, investment prioritization, and implementation strategies. The absence of standardized readiness assessment frameworks also hinders cross-organizational learning and benchmark establishment, as organizations lack a common language and metrics for discussing immersive marketing maturity (Rese et al., 2017).

The application of TRL and IRL frameworks to immersive marketing systems necessitates careful adaptation to accommodate domain-specific characteristics. Immersive marketing technologies often exhibit high technical maturity in component technologies (such as VR headsets or AR software) while simultaneously demonstrating low innovation readiness due to unresolved business model challenges, limited content ecosystems, or insufficient consumer acceptance (Yim et al., 2017). This divergence between technological and

innovation readiness creates complexity in developmental assessment and strategic planning. Additionally, the experiential nature of immersive marketing means that technical specifications inadequately predict user experience quality or marketing effectiveness, necessitating readiness indicators that capture experiential dimensions beyond traditional technical metrics (Hilken et al., 2017).

The objective of this study is to develop a comprehensive framework for describing TRL and IRL stages specific to immersive marketing systems, addressing the gap between generic readiness level definitions and the particular characteristics of marketing applications. By systematically analyzing the developmental trajectory of immersive marketing technologies from conceptualization to market deployment, this research provides practitioners and researchers with structured tools for assessing maturity, identifying development bottlenecks, and planning strategic interventions. The framework recognizes immersive marketing as a dynamic system comprising interdependent technological, creative, business, and experiential components, each requiring distinct readiness assessment approaches.

1 Background

The paradigm shift in consumer engagement: from passive to immersive.

Contemporary marketing practices have undergone a profound transformation, moving decisively beyond the traditional methods characterized by one-way communication channels such as print media and television commercials. This evolution has been necessitated by the increasing saturation of the digital environment, where static advertisements often fail to capture consumer attention effectively (Sekhri, 2025). To address this challenge and transcend the pervasive media clutter, brands are seeking innovative strategies that foster authentic, two-way engagement (What is immersive marketing, 2025).

This drive toward enhanced interaction has led to the emergence of Immersive Marketing (IM). IM is fundamentally defined as the strategic application of Extended Reality (XR) technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), to engineer dynamic, multisensory, and experiential campaigns (What is immersive marketing, 2025). These campaigns create lifelike environments where customers can actively interact with products and brands in real-time (Bare Tree Media Admin, 2024). Unlike traditional digital marketing, which often struggles to establish deep resonance, immersive strategies aim to draw in and captivate consumers, fostering profound emotional connections, enhancing brand awareness, and building enduring brand loyalty and credibility. Examples such as Ally Bank's AR-enhanced scavenger hunt for financial literacy or IKEA's AR visualization tool, IKEA Kreative, demonstrate the power of leveraging these technologies to deliver compelling, narrative-driven experiences (What is immersive marketing, 2025).

The market potential for these disruptive formats is significant; projections indicate that the immersive technologies sector will reach multi-million USD valuation by 2030, supported by a projected mean annual growth rate (CAGR) of 23.7% (Bare Tree Media Admin, 2024).

Conceptualizing immersive marketing as a dynamic socio-technical system (DSTS).

The successful implementation of an immersive marketing campaign necessitates a complex integration of technological and organizational capabilities, positioning IM not as a singular technological tool, but as a sophisticated, dynamic socio-technical system (DSTS). The execution of these strategies requires fusing advanced marketing strategies with specialized domains, including information systems (IS), digital technology (DT), and advanced data analytics (Muneesawang et al, 2025).

The "dynamic" nature of this system stems from the real-time interaction and personalized data-driven experiences it must deliver (Sekhri, 2025). The underlying technological

architecture relies heavily on cutting-edge components, including spatial computing, the Internet of Things (IoT), Cyber-Physical Systems, and computational methods that utilize Generative Adversarial Networks (GANs) and Machine Learning (ML). Managing this complexity mandates organizational dynamic capabilities to effectively harness intellectual resources and thrive in this highly technology-driven market landscape (What is immersive marketing, 2025). The system's ultimate success relies equally on the stability of the technical components (e.g., latency and fidelity of the AR rendering) and the sophistication of the social integration (e.g., consumer adoption, perceived immersion, and emotional engagement) (Accardi et al., 2025).

The imperative for structured innovation governance and the research gap.

The accelerating market growth and the inherent systemic complexity of immersive marketing initiatives generate a critical dilemma for corporate innovation management: determining the precise timing for scaling and committing large-scale investment. Corporations face substantial risks where premature funding can result in costly failures due to technical immaturity, while delayed adoption may lead to a loss of competitive advantage (Drobyshevski, 2025).

To mitigate these risks, established innovation governance frameworks are necessary. The Technology Readiness Level (TRL) scale, initially developed by NASA, provides a robust, nine-level ordinal measure for assessing the maturity of discrete technology elements, ranging from basic research (TRL 1) to full operational deployment (TRL 9) (Artyukhov et al., 2023). TRL is essential for validating the technical feasibility of the core XR components, such as verifying the performance metrics of a specific AR visualization algorithm.

However, TRL is structurally insufficient for governing a CSTS like immersive marketing because it focuses exclusively on technical proof, neglecting the vital aspects of system integration, organizational capability, market fit, and commercial viability (Henike, 2025). TRL only assesses discrete components, while complex interfaces require validation of how well these components function together (Eder et al., 2017). To overcome this limitation, the Innovation Readiness Level (IRL) framework has emerged. IRL describes the maturity stage of business development for the product, service, or technology, bridging the gap from conceptual development to market fruition (Smith, 2017). IRL addresses necessary factors such as customer readiness (CRL), business model viability (BRL), and team capacity (TmRL), which are indispensable for commercial success (Eder et al., 2017).

An integrated TRL/IRL methodology is paramount for de-risking innovation, providing a robust structure to balance technical feasibility with commercial viability and effectively navigate the infamous "valley of death" between R&D and market scale (Drobyshevski, 2025). Despite the critical nature of directing corporate investments toward applications like AR, a standardized, integrated framework that maps the TRL and IRL stages specifically across the nine stages of development for a dynamic IM system remains undefined, mainly in the scholarly literature.

This article addresses this critical research gap by rigorously describing a comprehensive, unified TRL/IRL framework specifically engineered to govern the entire development and commercialization lifecycle of complex immersive marketing initiatives. By detailing the criteria for technical and commercial advancement at each stage, this framework provides innovation governance managers with a repeatable, disciplined process for resource allocation and strategic decision-making.

2 Methodology

Research design and approach.

This study employs a conceptual and analytical research design to develop a structured framework for innovation governance. The primary research objective is to bridge the identified gap between established technological maturity assessment (TRL) and the necessary commercial and systemic validation (IRL) for complex, dynamic socio-technical systems (DSTS), such as Immersive Marketing (IM). Given the focus on integrating and adapting existing models to a novel domain, the approach relies fundamentally on systematic literature synthesis and conceptual framework development rather than empirical data collection.

The methodology followed a five-phase cycle of the research process, including conceptualization, design and planning, analytical phase, framework development, and dissemination.

1. Conceptual phase (problem definition): the initial step involved defining the research problem by observing the market trend of IM adoption and identifying the challenge of premature investment due to the misalignment between technical readiness (TRL) and commercial viability (IRL). This phase involved a critical literature review to assess the limitations of TRL in governing the integration of complex systems, thereby justifying the necessity of the IRL framework.

2. Design and Planning Phase (Criterion Selection): This involved selecting the foundational TRL (NASA's nine-level model) and IRL frameworks due to their widespread acceptance in innovation governance. Key sub-components of IRL, such as Customer Readiness Level (CRL), Business Readiness Level (BRL), and Team Readiness Level (TmRL), were identified as indispensable metrics for the IM domain.

3. Analytical phase (mapping and adaptation): the core analytical step involved deconstructing the nine ordinal levels of both TRL and IRL and systematically translating their generic definitions into domain-specific criteria for the IM environment (IM-TRL and IM-IRL). This adaptation focused on critical IM variables, including the reliability of XR rendering, the complexity of real-time data processing, consumer adoption patterns, and the viability of the associated business model.

4. Framework development (integration): the IM-TRL and IM-IRL criteria were integrated into a unified, two-dimensional Integrated Readiness Matrix. This synthesis allowed for the creation of four distinct strategic quadrants (Foundational Research, the Valley of Death, the Hype Trap, and Strategic Scaling) to serve as a tool for prescriptive risk mitigation and disciplined resource allocation.

5. Dissemination phase (conceptual validation): the final step involved illustrating the practical application of the Integrated Readiness Matrix by developing three strategic case archetypes. This approach provides conceptual validation of the framework's utility in guiding managerial decision-making and enforcing strategic pivots in high-risk investment scenarios.

3 Results and Discussion

TRL mapping for core immersive marketing technologies (IM-TRL).

The technical validation of immersive marketing (IM-TRL) focuses rigorously on the underlying technological stack, which includes the stability of the Extended Reality (XR) hardware/software interface, the reliability of the rendering pipeline, the fidelity of spatial

computing algorithms, and the seamless integration of proprietary AI models for personalized content. The TRL progression ensures that the IM system transitions from purely conceptual existence to operational reliability in the intended customer environment.

Table 1. Immersive marketing Technology Readiness Levels (IM-TRL)

TRL	General description	Specific application to IM technology	IM technical milestone
TRL 1	Basic principles observed	Initial scientific research on neurophysiological responses to multisensory stimulation in XR; foundational observations regarding spatial data collection methods	Conceptual paper on immersive data processing standards
TRL 2	Technology concept formulated	Formulation of specific AR/VR protocols and technical specifications for their application in dynamic, real-time brand interaction scenarios	Detailed formulation of key algorithms and system performance requirements
TRL 3	Experimental proof-of-concept established	Core functional technical components (e.g., custom object recognition software for AR) were validated individually in a controlled laboratory setting against analytical predictions	Low-fidelity component demonstration; verification of computational modeling results
TRL 4	Component validation in a laboratory environment (alpha prototype)	Core technical components are integrated for the first time; system tested under simulated, low-fidelity environments to assess component interoperability	Integrated desktop simulation validated against initial performance metrics
TRL 5	System validation in a relevant environment (semi-integrated)	The IM system prototype is integrated with essential supporting commercial elements (e.g., cloud services, client-side data capture) and tested under moderate, simulated consumer network conditions	A functional prototype was demonstrated, with a performance delta reported against the expected system goals.
TRL 6	A prototype system demonstrated in a relevant environment	Near-final IM system prototype verified under realistic operational loads using representative commercial hardware (e.g., rigorous internal testing on various consumer devices)	High-fidelity, stable prototype verified for technical feasibility
TRL 7	Integrated pilot system demonstrated in an operational environment	IM system deployed to a limited, external user base via actual distribution channels (e.g., small-scale app store pilot). System performance (latency, data throughput) measured in real-time	Successful pilot demonstration; system qualification initiated
TRL 8	System complete and qualified (incorporated in commercial design)	Actual IM technology proven through sustained successful operation in the consumer environment; focus shifts to	Qualified, stable application ready for production release

TRL	General description	Specific application to IM technology	IM technical milestone
		reliability, security compliance, and meeting operational performance targets	
TRL 9	Actual system proven in operational environment; ready for full commercial deployment	Scalable, final IM system proven through successful, continuous operation, meeting targets for cost, yield, and output with robust statistical process control	Fully deployed, market-leading commercial IM system

The progression across TRLs is characterized by increasing functional fidelity and integration complexity. The transition from TRL 6 to TRL 7 marks an inflection point, where the focus shifts from technical feasibility to operational scalability. While TRL 6 proves that the prototype is technically functional, TRL 7 requires proving its capacity for operability under real-world stress conditions and massive user access. For IM, this means the system must seamlessly manage complex integrations with platforms such as Twitch or social media, handle real-time data processing, and deliver personalized experiences without interruption. Failure at TRL 7 indicates an inability to sustain the dynamic two-way conversation crucial for modern consumer engagement.

Furthermore, as TRL advances, the constraints of Design Readiness Level (DRL) become implicitly relevant. DRL assesses whether the product is manufacturable and cost-effective. For IM, this translates to optimizing content delivery; a TRL 9 system must run efficiently on the average consumer's hardware, requiring that content generation pipelines and rendering constraints align rigorously with performance optimization criteria during the TRL 4-6 development phases.

IRL Mapping for Immersive Marketing Commercialization (IM-IRL)

For immersive marketing initiatives, system fit and market acceptance are arguably more predictive of ultimate success than technical performance alone, given that the ROI is entirely dependent on consumer adoption and measurable engagement.3 IM-IRL assesses the simultaneous maturation of the business model, the organizational team, and market validation.

Table 2. Immersive marketing Innovation Readiness Levels (IM-IRL)

IRL	General description	Specific application to IM business strategy	Key commercial deliverable
IRL 1	Inventor or team with a dream	The initial intention is to translate a disruptive XR application or concept into a viable business venture	High-level market opportunity canvas
IRL 2	Paper studies produced	Formal analyses completed, detailing the business opportunity, comprehensive market sizing, competitive landscape, and initial technology viability assessment	Detailed Business Opportunity Analysis (BOA) report
IRL 3	Experimental evidence of a business opportunity	Active research is initiated, including analytical studies and small focus groups to validate initial predictions regarding market acceptance, adoption rates (CRL), and preliminary financial models	Validation of consumer adoption willingness and initial feedback on the conceptual value proposition

IRL	General description	Specific application to IM business strategy	Key commercial deliverable
IRL 4	Capability to work on limited-scope programs; initial business plan available	Initial definition of the IM value proposition, cost structure, and target consumer segments. Requires that basic technological components are established to work together (TRL 4 achieved)	Initial draft of the formal Business Readiness Level (BRL) plan
IRL 5	Capability to support project engineering (no product, no revenues)	The business plan is refined and deemed credible, requiring ongoing validation against the planned product characteristics (aligned with TRL 5-6). Initial organizational commitment and necessary seed funding secured	Investor-ready business plan detailing resource needs and ROI projections
IRL 6	Market-driven business team supports development (product, no revenues)	A complete business plan, including operational, technological, and financial aspects, is available. A high-fidelity prototype (TRL 6) is tested with genuine target market groups to confirm market fit	Confirmed market validation and a tested go-to-market strategy
IRL 7	Capability to support limited production; whole business team in place (limited revenues)	The business unit can operate on a limited scale (pilot market launch); the specialized team (TmRL) is fully established; limited revenues are generated and tracked to prove viability and ROI potential	Positive pilot financial results; validated organizational structure established
IRL 8	Capability to transition to complete production and distribution	Technology is proven (TRL 8) and the venture structure is proven capable of supporting growing market shares. Infrastructure and distribution partnerships for mass deployment are finalized	Established partnerships and transition plan for scaling operations
IRL 9	Fully articulated business with appropriate infrastructure and staffing	Sustained, profitable commercial operations with growing market share; the IM system is integrated into core corporate strategies, demonstrating enduring brand loyalty and measurable positive ROI	Audited financial results demonstrating sustained profitability and market dominance

The advancement through IM-IRL is highly sensitive to the Customer Readiness Level (CRL), reflecting the inherent dependency of marketing on consumer behavior. For a venture to legitimately claim advancement to IRL 6, rigorous testing of the TRL 6 prototype with the target market is necessary. If consumer resistance to adopting new hardware or navigating complex software is high (low CRL), the business plan cannot be validated, preventing the necessary transition. Therefore, market acceptance criteria and user experience (UX) metrics are directly linked to the technical development stages.

Furthermore, the Funding Readiness Level (FRL) is causally dependent on both the underlying TRL and the developed BRL.13 Major funding necessary for scaling IM infrastructure (IRL 8/9 funding) is only justifiable if the technical risks have been rigorously mitigated (TRL 9 completion) and the commercial risks have been validated through successful pilot market testing (IRL 6-7 achievement). This structural linkage enforces discipline, ensuring that large-scale investment is supported by demonstrable technological feasibility and confirmed market viability.

The integrated readiness matrix: aligning TRL and IRL for strategic investment.

The integrated TRL/IRL matrix is the crucial strategic instrument for innovation governance, aligning technical progress (TRL) with commercial validation (IRL). This framework

is designed to detect and manage organizational imbalances that lead to the failure of innovation projects.

Table 3. Integrated readiness matrix quadrants for IM investment governance

Quadrant	TRL Level	IRL Level	Strategic Risk Profile	Strategic Recommendation for IM Initiatives
I. Foundational Research	TRL 1-3	IRL 1-3	High Uncertainty / Low Commitment: Focus on academic proof and initial market scoping	Continue basic/applied research; formalize concept and complete detailed market opportunity analysis (IRL 2/3)
II. The Valley of Death	TRL 7-9	IRL 3-5	Technical Waste / Market Failure Risk: Technology is over-developed but lacks commercial viability or necessary organizational support	Halt further technical TRL investment. Immediately redirect resources toward commercialization (BRL, TmRL) to achieve market fit and initial revenue validation
III. The Hype Trap	TRL 3-5	IRL 6-9	Premature Scaling / Technical Catastrophe Risk: High market demand and strong business funding, but core technological systems are immature and unstable	Freeze scaling and marketing efforts. Redirect all resources to engineering verification (TRL 6-7 validation) to mitigate the risk of catastrophic system failure during mass deployment
IV. Strategic Scaling	TRL 6-9	IRL 6-9	Balanced Maturity / Growth Ready: Initiative is technically robust and commercially validated, minimizing execution risk	Proceed with phased commercial deployment; focus on maximizing efficiency, quality control (TRL 9), and market expansion (IRL 8-9)

The matrix highlights that organizational misalignment is the primary source of failure modes. Quadrant II, the "Valley of Death," often results from a technology-push mentality, where R&D continues to refine discrete technology elements (reaching TRL 7 or higher) beyond market utility, without sufficient focus on confirming whether the solution addresses a viable business problem (low IRL). Conversely, Quadrant III, the "Hype Trap," results from market-pull pressure, where organizational excitement or investor capital drives premature scaling despite core technical immaturity (low TRL). Scaling a TRL 4 system due to high IRL risks can result in spectacular public failure, severely damaging brand credibility.

By exposing these imbalances, the framework mandates cross-functional governance and enables disciplined iteration. The process is inherently non-linear; the IRL model acknowledges that new market data or consumer behavior insights may necessitate regression (e.g., from IRL 7 to IRL 5) or technical setbacks may force a reduction in TRL (e.g., TRL 7 to TRL 6). The integrated matrix provides the necessary discipline to execute these pivots strategically rather than reactively, ensuring sustained progress toward successful market deployment.

Conclusion

This article successfully established a crucial governance framework by describing the integration and application of the Technology Readiness Level (TRL) and Innovation Readiness Level (IRL) methodologies across the developmental lifecycle of immersive marketing (IM) initiatives. By explicitly defining the nine stages of technical maturity (IM-TRL) and the corresponding nine stages of commercial and system integration maturity (IM-IRL), this study provides a highly structured and objective methodology for guiding innovation.

The core contribution lies in conceptualizing IM as a dynamic socio-technical system, thereby necessitating the dual-assessment framework to manage inherent systemic complexity. The resulting Integrated Readiness Matrix provides innovation directors with a critical management instrument for de-risking high-value investments in the rapidly expanding Extended Reality (XR) market. By enabling the precise identification of imbalance risks, such as the "Valley of Death" (high TRL, low IRL) and the "Hype Trap" (low TRL, high IRL), the framework ensures that technical progression is always aligned with market viability and organizational capacity. This fact imposes a rigorous, disciplined process essential for converting experimental pilots into sustainable, profitable, and scaled enterprise solutions, thus preventing costly failures and maximizing the return on investment (ROI) in IM strategies.

While this study establishes the structural and conceptual framework for IM innovation governance, future research should focus on empirically validating and quantifying the underlying metrics.

First, comprehensive efforts should be directed toward developing and integrating rigorous, quantitative measures for the Customer Readiness Level (CRL) within the IRL framework. This action involves leveraging advanced data capture techniques, such as real-time neurophysiological data, to accurately quantify consumer engagement, emotional response, and perceived immersion elicited by immersive experiences. Such data is essential for objectively confirming the transition from early-stage concept testing (IRL 3) to confirmed, market-validated consumer adoption (IRL 6).

Second, longitudinal case studies are required to empirically validate the predictive power of the TRL/IRL alignment. Research should track a variety of IM initiatives, covering diverse XR technologies and AI applications, from their conceptual stages (TRL/IRL 1) through to market fruition (TRL/IRL 9). This longitudinal analysis will refine the assessment criteria, particularly concerning the interdependencies between the TRL stages of proprietary technology and the Funding Readiness Level (FRL) requirements for scaled funding rounds, thus ensuring the framework remains a highly effective tool for innovation governance in this transformative sector. The continuous evaluation and refinement of this framework, informed by real-world data, will ensure its sustained relevance as the IM technological landscape continues to evolve.

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Guideline for conducting behavioral research in immersive marketing[1]

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Abstract

Immersive marketing, which utilizes virtual, augmented, and mixed reality, is redefining consumer engagement; however, research in this domain often lacks methodological consistency and ethical clarity. This study develops an evidence-based guideline for conducting behavioral research in immersive marketing, addressing the fragmentation of current practices. Using a mixed-method framework that combines systematic literature synthesis, comparative analysis, and expert validation, over 100 studies were reviewed across marketing, psychology, and human–computer interaction. The analysis revealed critical gaps in design justification, data transparency, and participant inclusion. An eight-block guideline was created to standardize experimental design, multimodal measurement, ethical procedures, and reproducibility. The framework integrates technological immersion with psychological theory and open-science principles, offering a coherent foundation for future research. This work contributes to the development of immersive marketing as a rigorous, ethical, and inclusive discipline, promoting credible behavioral insights and responsible innovation in virtual environments.

Key words

Immersive marketing; behavioral research; virtual reality (VR); augmented reality (AR); consumer behavior; experimental design; ethical research; open science; multimodal measurement

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Introduction and background

General provisions

Immersive technologies, primarily virtual reality (VR), augmented reality (AR), and mixed reality (MR), are transforming how brands design experiences, how consumers interact with marketing messages, and how purchase decisions are made in simulated and hybrid environments. These technologies extend beyond novelty, altering the sensory, spatial, and

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social context in which marketing stimuli are perceived and processed, resulting in qualitatively different consumer encounters compared to traditional 2-D media (Flavián, Ibáñez-Sánchez, & Orús, 2019; Alcañiz, Bigné, & Guixés, 2019). The literature converges on a few core guidelines that shape rigorous behavioral research in immersive marketing: (1) define the experimental target and match immersion level, (2) integrate multi-method measurement with careful calibration and validation, (3) prioritize participant safety, ethics and inclusivity, (4) adopt open-science and robust reporting practices, and (5) plan for analytic complexity and reproducibility.

The behavioral impact of immersion rests on two related mechanisms. First, presence (the subjective sense of "being there") amplifies attention and emotional engagement, often producing stronger memory traces and affective responses than the duplicate content presented on a flat screen (Slater, 2009). Second, embodiment and interactivity enable consumers to act, manipulate, and test products virtually, thereby reducing uncertainty and facilitating pre-purchase experiential learning (Flavián et al., 2019). Both mechanisms are central to marketing objectives such as increasing brand attachment, purchase intention, and willingness to pay. Empirical work suggests that AR and VR can strengthen perceived closeness to brands and drive relationship outcomes (Rauschnabel et al., 2024), while higher-quality simulations of products and contexts improve product evaluation and exploratory behavior (Alcañiz et al., 2019).

Despite the rapid adoption of technology, the behavioral literature continues to face conceptual and methodological fragmentation. Early reviews suggest that studies differ significantly in their operationalization of immersion, presence, and interactivity, and often rely on self-report measures that overlook rapid, non-conscious processes crucial to consumer choice (Alcañiz et al., 2019; Flavián et al., 2019). To fill these gaps, researchers have turned to multimodal behavioral and physiological methods (eye tracking, skin conductance, heart-rate variability, and electroencephalography), which offer fine-grained insights into attention, arousal, and valuation processes during immersive experiences. Importantly, EEG has been shown to predict future choices and willingness to pay in consumer tasks (Telpaz, Webb, & Levy, 2015). Systematic reviews are also reported to be increasingly suitable for marketing research when used in conjunction with behavioral paradigms (Bazzani et al., 2020). These neuro- and psychophysiological measures can be especially valuable in immersive contexts because they track rapid dynamics while participants navigate spatialized and interactive stimuli.

However, integrating physiological measures into immersive marketing research is not a trivial task. Immersive hardware (e.g., headsets, controllers) can introduce artifacts and limit the options for sensor placement. Spatialized stimuli complicate the synchronization of stimulus events with biosignals, and the social and multisensory richness of immersive environments can generate complex, interacting drivers of behavior (Alcañiz et al., 2019). Moreover, immersion is not uniformly beneficial: its persuasive power depends on content plausibility, congruence with consumer expectations, and ethical design that preserves autonomy and reduces sensory overload (Slater, 2009; Flavián et al., 2019). Recent evidence also suggests modality-specific effects (AR may boost utilitarian evaluations in contexts where contextualized information matters, whereas VR may be more effective for emotional, experiential appeals), highlighting the need for fine-grained experimental comparisons (Flavián et al., 2019; Rauschnabel et al., 2024).

From a behavioral lens, several underexplored themes deserve priority. First, the temporal dynamics of decision formation in immersive settings: how do attention allocation, affective arousal, and mental simulation unfold over time as users explore a virtual store or

try on a product virtually? Second, individual differences and boundary conditions: which consumers benefit most from immersive experiences (e.g., novices vs. experts; high vs. low need for touch), and how do prior familiarity and cognitive load moderate effects? Third, social and ethical dimensions: how do co-presence and social cues in shared virtual spaces (social VR) shape normative influence and brand perceptions, and how should privacy and consent be managed when behavioral traces are recorded in persistent immersive spaces?

Methodologically, the field needs standardized reporting conventions for immersive manipulations (hardware, sensory channels, interaction affordances) and cross-validated measures that combine self-report with behavioral and physiological indices. Combining high-resolution behavioral logging (movement, choices, dwell time) with eye-tracking and EEG provides a promising multimodal approach that captures both explicit preferences and implicit processes predictive of downstream choice (Telpaz et al., 2015; Bazzani et al., 2020). Experimental designs that manipulate plausibility, embodiment, and interactivity in controlled factorial experiments will help isolate causal pathways by which immersion influences valuation, learning, and social influence.

Finally, the translational implications for managers are substantial. Immersive marketing offers new levers for experiential differentiation, product education, and remote try-before-you-buy services. However, realizing these gains requires evidence-based design: understanding when immersion increases conversion, when it merely amplifies novelty effects, and when it may backfire through cognitive overload or perceived manipulation. Behavioral research that links short-term physiological and attentional markers to meaningful business outcomes (e.g., conversion, retention, advocacy) will be crucial for establishing robust and ethical practices in immersive marketing.

Match research questions to the appropriate form of immersion and experimental design.

A recurring message in the VR methodology literature is that immersion is a tool, not an end in itself: researchers must choose the type and degree of immersion that best fits the behavioral question (Pan & Hamilton, 2018; Blascovich et al., 2002). High-fidelity head-mounted displays with full-body tracking are necessary when proxemic behavior, embodied presence, or fine social cues (such as gaze and gestural timing) are core dependent variables (Blascovich et al., 2002; Bailenson et al., 2008). Conversely, lower-fidelity or desktop VR can be advantageous when the research focus is cognitive (e.g., memory, categorization) and when minimizing costs and risk of simulator sickness is crucial (Pan & Hamilton, 2018).

Researchers should explicitly justify the immersion level in manuscripts by discussing display hardware, tracking latency, field of view, audio spatialization, and whether avatars or virtual agents are used, and explain how these choices affect hypothesized psychological mechanisms and external validity (Pan & Hamilton, 2018; Oh et al., 2018).

Measurement: combine self-report, behavioural and physiological measures — validate and report quality.

Immersive marketing benefits from multimodal measurement (eye-tracking, motion capture, EEG, skin conductance, heart rate, click/choice behaviour). However, each modality brings technical and interpretive pitfalls. Reviews of consumer neuroscience and EEG in market contexts demonstrate promising predictive power for choice and population outcomes, but emphasize the importance of rigorous preprocessing, feature selection, and

cross-validation (Boksem & Smidts, 2015; Vecchiato et al., 2011; Hsu & Yoon, 2015). Similarly, eye-tracking in modern HMDs expands its applicability but requires careful calibration, accurate reporting, and consideration of head movement and depth effects (Adhanom et al., 2023; Carter & Luke, 2020).

Key points from the literature:

- validate sensors in situ. Manufacturer accuracy metrics are insufficient; report on-site calibration accuracy, precision (e.g., gaze error in degrees), and loss rates. For EEG and mobile fNIRS, document electrode montage, impedance thresholds, and artifact rejection pipelines. (Adhanom et al., 2023; Vecchiato et al., 2011; Carter & Luke, 2020);
- report preprocessing and analytic pipelines. For EEG and physiological signals, describe filters, epoching, baseline correction, eye-movement artifact handling, and classification methods. Include parameter choices and rationale (Boksem & Smidts, 2015; Vecchiato et al., 2011);
- triangulate measures. Use behavioural endpoints (choice, time spent, proxemics) as anchors for physiological inferences; avoid overinterpreting a single metric as a direct index of preference or persuasion (Hsu & Yoon, 2015).

Social presence, embodiment, and agent design: operationalization and manipulation checks.

Social presence (the felt "being with" others) and embodiment (ownership of a virtual body) are central mediators in immersive marketing, particularly when examining social norms, influencer simulations, or avatar customization. Systematic reviews emphasize varied operationalizations and advise consistent manipulation checks (Oh et al., 2018).

Guidance:

- Use validated presence/social-presence scales alongside behavioural indicators (proxemic distance, turn-taking) and physiological correlates to confirm manipulations (Oh et al., 2018; Bailenson et al., 2008).
- When using virtual agents or transformed social interactions (e.g., augmented gaze), report the agent's appearance, behavioral realism, and any transformations applied, as these factors significantly impact social influence and generalizability (Blascovich et al., 2002; Bailenson et al., 2004).

Ethics, safety, inclusion and participant wellbeing.

VR research poses unique ethical issues: stronger illusions, potential for lasting effects, privacy concerns from rich behavioural data, and physical side-effects (simulator/cybersickness). Madary & Metzinger (2016) articulated a code of conduct that remains a touchstone, urging researchers to attend to informed consent, potential aftereffects, and dual-use concerns. The Classic Simulator Sickness Questionnaire (SSQ) is recommended for monitoring adverse symptoms (Kennedy et al., 1993). More recent reviews have called for standardized reporting of dropout and adverse event rates (Brown et al., 2022).

In immersive marketing, additional ethical considerations arise from persuasive intent, including transparency about commercial aims, limits on manipulative design, and special protections for vulnerable groups (Madary & Metzinger, 2016).

Statistical power, sampling, and reproducibility (open science).

Behavioral and physiological signals in immersive contexts often show modest effects and substantial between-subject variability. Methodological manifestos and meta-science literature emphasize the importance of preregistration, adequate sample sizes, and transparency to improve replicability (Munafò et al., 2017; Nosek et al., 2015).

Practical recommendations:

- **powering multimodal studies.** Plan the sample size for the most negligible critical effect (behavioural or physiological). Use pilot data to estimate effect sizes. When using machine learning, report the training/validation/test splits and avoid circular analysis;
- **preregistration and materials sharing.** Preregister hypotheses and analysis plans. Share environment builds, stimulus assets, analysis code and (where ethical and legal) anonymized data on repositories or with DOI anchors to facilitate replication (Munafò et al., 2017);
- **transparent reporting.** Adopt checklists that detail hardware, calibration, preproc, and manipulations, analogous to CONSORT for trials, but tailored to VR/physio studies. Several recent domain guides recommend standardized method sections for VR studies (Carter & Luke, 2020; Adhanom et al., 2023).

Analytic integration: multimodal fusion, interpretability and ecological validity.

Combining behavioural, ocular, and neural data increases predictive power but requires careful fusion strategies and interpretability frameworks (Hsu & Yoon, 2015; Boksem & Smidts, 2015). The literature distinguishes between explanatory models (testing mechanisms) and predictive models (forecasting choices or sales), advising researchers to align their analytic choices with their study goals.

Guidance:

- use simple, interpretable models when the goal is mechanism testing; reserve complex machine-learning pipelines for prediction, but still provide interpretability diagnostics (feature importance, SHAP values);
- cross-validate prediction on independent samples and, where possible, test population-level outcomes (as in EEG-box office studies) to assess external validity (Boksem & Smidts, 2015);
- discuss ecological validity by clarifying how virtual tasks map to real-world consumer contexts and testing boundary conditions across different device types or environments (Pan & Hamilton, 2018).

Accessibility, inclusion and sampling diversityə

A consistent theme is that early VR studies often used WEIRD samples; therefore, immersive marketing research must expand its inclusion to improve generalizability (Blascovich et al., 2002; Munafò et al., 2017). Accessibility issues (glasses, disabilities, age) affect both recruitment and measurement validity.

Despite notable progress in immersive marketing and consumer-behavior research, the field still lacks a unified methodological and ethical foundation. Existing guidelines, while insightful, remain fragmented across disciplines such as psychology, computer science, neuroscience, and marketing. Several unresolved problems continue to constrain the reliability, comparability, and interpretability of findings. These gaps can be grouped into five major domains: **(1) conceptual ambiguity, (2) methodological inconsistency, (3) limited ecological validity and generalizability, (4) ethical and inclusivity concerns, and (5) insufficient reproducibility and open-science integration.**

1. Conceptual ambiguity: what exactly is "immersive" behavior?

A primary unresolved problem is the *lack of conceptual precision* in defining what constitutes "immersion" in behavioral marketing contexts. Scholars use the term interchangeably to describe **technological features** (e.g., field of view, tracking fidelity), **psychological states** (presence, flow), or **consumer experiences** (brand engagement, narrative transportation). This multiplicity of meanings blurs theoretical boundaries and complicates meta-analyses (Pan & Hamilton, 2018; Oh, Bailenson, & Welch, 2018).

Because immersion can refer simultaneously to a stimulus property and a subjective response, many studies fail to specify which dimension is under investigation. For instance, some papers manipulate device type (VR vs. desktop) and infer psychological presence, while others measure self-reported engagement without controlling technological fidelity. This conceptual conflation undermines cumulative theory-building and hinders the comparison of results across studies.

Unsolved issue: the field lacks a consensus taxonomy that links *technological immersion* to *psychological immersion* and *behavioral outcomes.* Without such clarity, the same term masks different constructs, making guideline standardization nearly impossible.

2. Methodological inconsistency and measurement challenges.

2.1. Lack of standardized reporting.

Although many authors recommend detailed reporting of hardware, tracking systems, and calibration parameters (Carter & Luke, 2020; Adhanom et al., 2023), no standardized reporting template exists for immersive behavioral marketing studies. As a result, critical experimental details (such as latency, field of view, tracking accuracy, and stimulus timing) are often omitted, which prevents replication and cross-study synthesis.

2.2. Integration of multimodal data.

Another major challenge concerns the integration of multimodal measurements. Behavioral research in immersive contexts frequently combines eye-tracking, motion capture, and psychophysiological measures (EEG, EDA, HRV). However, few studies describe how these data streams are synchronized or validated. Existing analyses often rely on untested assumptions about temporal alignment and causality (Vecchiato et al., 2011; Boksem & Smidts, 2015).

Furthermore, technical artifacts from head-mounted displays, motion sensors, and wireless EEG introduce noise and reduce data quality (Adhanom et al., 2023). While some methodological papers suggest filtering and preprocessing standards, there is still no consensus on acceptable thresholds or validation benchmarks across the field.

2.3. Calibration of behavioral indicators.

Immersive environments enable fine-grained behavioural logging (movement trajectories, gaze paths, interaction frequency), yet the interpretation of these metrics remains inconsistent. The same measure, such as proximity to a product avatar, has been interpreted as attention, arousal, or purchase intent in different studies. Without validated behavioral proxies, predictive models risk overfitting to context-specific data and failing to generalize.

Unsolved issue: the absence of standardized metrics and calibration protocols makes behavioral results incomparable across experiments, limiting cumulative knowledge and evidence-based marketing design.

3. Limited ecological validity and generalizability.

While immersive marketing promises realistic simulations of consumption contexts, most experiments still occur in highly controlled laboratory environments using convenience samples (often university students). This fact "creates" two significant problems.

3.1. Artificial contexts.

Virtual stores or product displays used in studies often lack the sensory complexity and social dynamics of real retail environments (Pan & Hamilton, 2018). Simplified or artificial stimuli reduce ecological validity: consumer behavior observed in VR may not mirror behavior in real-life stores.

Moreover, immersion may amplify the effects of novelty. Many participants are first-time VR users; their responses often reflect curiosity or disorientation rather than genuine brand evaluation. Few studies include adaptation periods or repeated exposures to disentangle novelty from stable behavioral responses.

3.2. Sampling limitations.

The overwhelming majority of immersive marketing studies use participants from WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations. Cross-cultural differences in social presence, personal space, and sensory processing are rarely tested. This condition biases conclusions about universal consumer responses and neglects accessibility barriers for users with disabilities or sensory impairments.

Unsolved issue: the field lacks ecologically rich, longitudinal, and demographically diverse studies capable of validating immersive behavioral findings in real-world contexts and among underrepresented populations.

4. Ethical, safety, and inclusion gaps.

As immersive marketing blurs boundaries between research and persuasion, **ethical governance** becomes increasingly complex. Existing frameworks (e.g., Madary & Metzinger, 2016) provide general ethical principles for the use of VR, but the practical implementation in marketing contexts remains unclear.

4.1. Persuasive and manipulative potential.

Immersive technologies can create a strong psychological presence and emotional realism, which may heighten persuasive influence beyond the participant's awareness. However, few studies explicitly discuss **debriefing procedures** or test for post-exposure aftereffects. Guidelines rarely address the line between immersive engagement and manipulation, a critical issue for commercial research involving vulnerable users or branded content.

4.2. Data privacy and surveillance.

Immersive systems record large amounts of behavioral and biometric data, including gaze, movement, and physiological responses. These data are highly identifying and can be

used to infer personal traits or emotional states. Nevertheless, privacy protection standards for such multimodal datasets remain underdeveloped. Informed consent documents often fail to specify how data will be stored, anonymized, or reused (Brown et al., 2022).

4.3. Accessibility and equity.

Most immersive technologies assume users with typical vision, motor control, and cognitive functioning. Adaptive interfaces for individuals who are blind, mobility-impaired, or neurodiverse are rare. Without inclusive design standards, behavioral findings represent only a subset of consumers, risking the amplification of digital inequality.

Unsolved issue: there is no universally adopted ethical code or regulatory body overseeing immersive marketing research. The lack of standardized consent templates, risk-assessment procedures, and accessibility protocols exposes participants and researchers to ethical vulnerabilities.

5. Reproducibility and open-science barriers.

A final cluster of unresolved problems relates to scientific transparency and reproducibility.

5.1. Absence of preregistration and data sharing.

Few immersive marketing studies preregister hypotheses or share experimental assets. Proprietary software, confidential brand stimuli, and privacy constraints on biometric data all discourage openness (Munafò et al., 2017). As a result, replication attempts are rare and often impossible due to the absence of methodological details.

5.2. Inconsistent analytical reporting.

There is substantial heterogeneity in statistical and computational methods used for behavioral and physiological data. Studies employ a range of methods, from simple ANOVAs to complex machine-learning pipelines, often without sufficient justification or validation (Hsu & Yoon, 2015). Lack of cross-validation, transparency about hyperparameters, or correction for multiple comparisons contributes to inflated Type I errors.

5.3. Lack of shared benchmarks.

Unlike traditional marketing or psychology, immersive behavioral research lacks standardized datasets or benchmark tasks to evaluate model performance. Without shared references, findings remain context-dependent, impeding progress toward generalizable behavioral theories of immersion.

Unsolved issue: the field requires infrastructure for open data, standardized reporting templates, and shared immersive testbeds that strike a balance between reproducibility and participant privacy, as well as commercial confidentiality.

All issues are collected in Table 1.

Table 1. Synthesis of unresolved problems.

Domain	Persistent issue	Consequences for behavioral research
Conceptual	Ambiguous definitions of immersion, presence, and engagement	Fragmented theory and inconsistent operationalization
Methodological	Lack of standardized metrics, calibration, and validation	Limited comparability and reliability of behavioral results
Ecological	Artificial lab settings and homogeneous samples	Poor external validity and cultural bias

Domain	Persistent issue	Consequences for behavioral research
Ethical/Inclusive	Inadequate participant protection, accessibility gaps	Risk of harm and exclusion of diverse populations
Reproducibility	Minimal data sharing, no reporting standards	Low transparency and weak cumulative science

1 Methodology

This study employed a mixed-methods systematic framework design to construct an integrated guideline for conducting behavioral research in immersive marketing contexts. The research combined a conceptual synthesis of multidisciplinary literature, a comparative methodological review, and expert-based validation. This approach was chosen to bridge the gap between theoretical understanding and methodological practice across the fields of psychology, marketing, neuroscience, and computer science. The methodological framework was iterative, emphasizing triangulation between conceptual modeling, evidence mapping, and analytical generalization.

The design process followed three main stages. First, an extensive literature review was conducted to identify methodological trends, unresolved problems, and best practices in immersive behavioral research. Second, a structured analytical synthesis was applied to extract, categorize, and compare methodological elements from peer-reviewed studies and industry reports. Third, the resulting insights were refined through expert evaluation, ensuring coherence, applicability, and ethical soundness. The final output of this process was a structured eight-block guideline covering the key domains of immersive behavioral research, from experimental design to reproducibility and continuous improvement.

2 Results and Discussion

The general structure of the Guideline for conducting behavioral research in immersive marketing is presented in Figure 1.

Fig. 1 Guideline for conducting behavioral research in immersive marketing: structure*

* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

1. Matching research questions to immersion and experimental design (Figure 2).

The results indicate that immersion should be viewed as a methodological tool rather than an aesthetic feature. The degree of immersion, ranging from low-fidelity desktop simulations to fully embodied virtual environments, must align with the behavioral or cognitive process being studied. High-fidelity systems are justified for research involving social presence, body ownership, or embodied decision-making, while simpler systems are sufficient for studies on attention, recall, or cognitive load. This strategic alignment reduces unnecessary technological complexity, mitigates cybersickness, and ensures that immersion enhances rather than distorts behavioral measurement.

The discussion emphasizes the importance of transparency in reporting. Each study should describe its technological setup, including device model, tracking method, latency, and audio-visual fidelity, explaining how these elements influence the psychological processes under investigation. Immersion, therefore, becomes a variable to be justified, not assumed. By matching design fidelity to research objectives, behavioral studies in immersive marketing achieve stronger construct validity and clearer theoretical contribution.

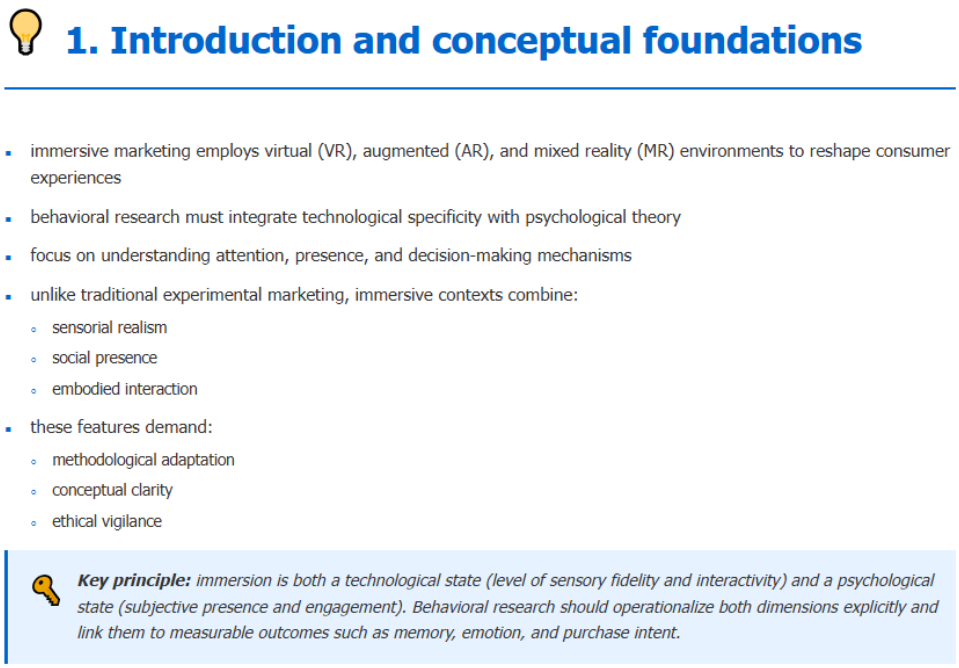

Fig. 2 Guideline for conducting behavioral research in immersive marketing: introduction and conceptual foundations*

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2. Measurement: combining self-report, behavioral, and physiological indicators (Figure 3).

The second block underscores the importance of integrating multiple types of evidence to understand consumer behavior in immersive environments. Self-report measures capture subjective experience, while behavioral and physiological data reveal underlying cognitive

and emotional mechanisms that often operate outside conscious awareness. Eye-tracking, EEG, heart rate variability, and galvanic skin response all provide complementary insights into attention, arousal, and decision-making processes. However, these tools require careful calibration and synchronization to avoid data misalignment and misinterpretation.

The discussion stresses methodological rigor and transparency. Researchers are advised to document calibration errors, preprocessing steps, and data exclusion criteria, as well as to triangulate across modalities instead of relying on a single indicator of engagement or persuasion. Such multimodal integration helps reveal how conscious and unconscious responses interact in immersive marketing. Establishing standardized procedures for sensor validation and reporting is, therefore, a critical step toward more reliable and reproducible behavioral insights.

Fig. 3 Guideline for conducting behavioral research in immersive marketing: research planning and theoretical design*
* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

3. Social presence, embodiment, and agent design (Figure 4).

This block identifies social presence and embodiment as central mediators of consumer engagement in immersive contexts. Feeling "present" with others or embodying a virtual body can dramatically influence trust, empathy, and emotional resonance with a brand. The authors emphasize that these psychological constructs should be treated as measurable variables rather than side effects of immersion. Manipulations must be verified through validated scales, behavioral cues such as gaze or proximity, and physiological correlates that reflect authentic social interaction.

Additionally, the design of avatars and virtual agents is shown to be a significant determinant of behavioral outcomes. Characteristics such as realism, behavioral authenticity, and autonomy can bias participant responses if not adequately controlled or reported. The authors argue for transparency about agent appearance, dialogue scripts, and interaction style. Doing so strengthens experimental reliability and allows researchers to differentiate between the effects of social design and those of the marketing message itself.

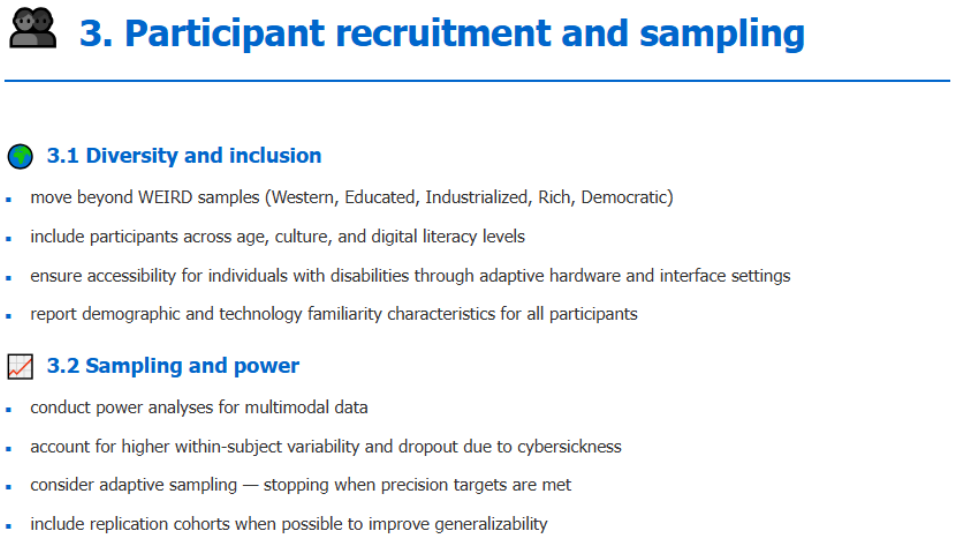

Fig. 4 Guideline for conducting behavioral research in immersive marketing: participant recruitment and sampling*
* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

4. Ethics, safety, inclusion, and participant wellbeing (Figure 5).

The ethical dimension of immersive marketing research remains both complex and crucial. The results highlight how immersive experiences can heighten emotional intensity and persuasive power, creating new responsibilities for researchers. Ethical practice must extend beyond informed consent to encompass continuous risk monitoring, debriefing, and transparency regarding commercial or compelling intent. The authors recommend pre-screening participants using standardized tools, such as the Simulator Sickness Questionnaire (SSQ), and systematically documenting all adverse events that occur.

Inclusion and accessibility emerge as equally important. Many current VR systems are not designed for users with sensory or physical limitations, potentially excluding key consumer groups. The discussion calls for the adoption of adaptive technologies, inclusive recruitment practices, and transparent communication of potential risks and limitations. Ethical conduct is reframed as a proactive design principle, embedding safety, accessibility, and participant dignity into every phase of immersive behavioral research.

Fig. 5 Guideline for conducting behavioral research in immersive marketing: ethics, safety and data responsibility*
* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

5. Statistical power, sampling, and reproducibility (Figure 6).

A recurring challenge identified in the results is the problem of small samples and weak statistical power. High variability in physiological and behavioral responses requires larger, more representative samples and careful design of within-subject and between-subject comparisons. The authors recommend pilot testing to estimate realistic effect sizes and adopting Bayesian or mixed-effects approaches that robustly handle individual differences. For predictive modeling, a clear separation between training, validation, and test datasets is essential to avoid circular inference.

Reproducibility and transparency are central to methodological integrity. The discussion proposes preregistration of hypotheses, public sharing of anonymized datasets, and open access to VR environments and analysis code. The adoption of reporting templates (detailing hardware, calibration, preprocessing, and data-handling procedures) will enable cross-study synthesis and cumulative theory building. Immersive marketing research, the authors argue, must adopt open-science standards to establish itself as a mature and credible empirical field.

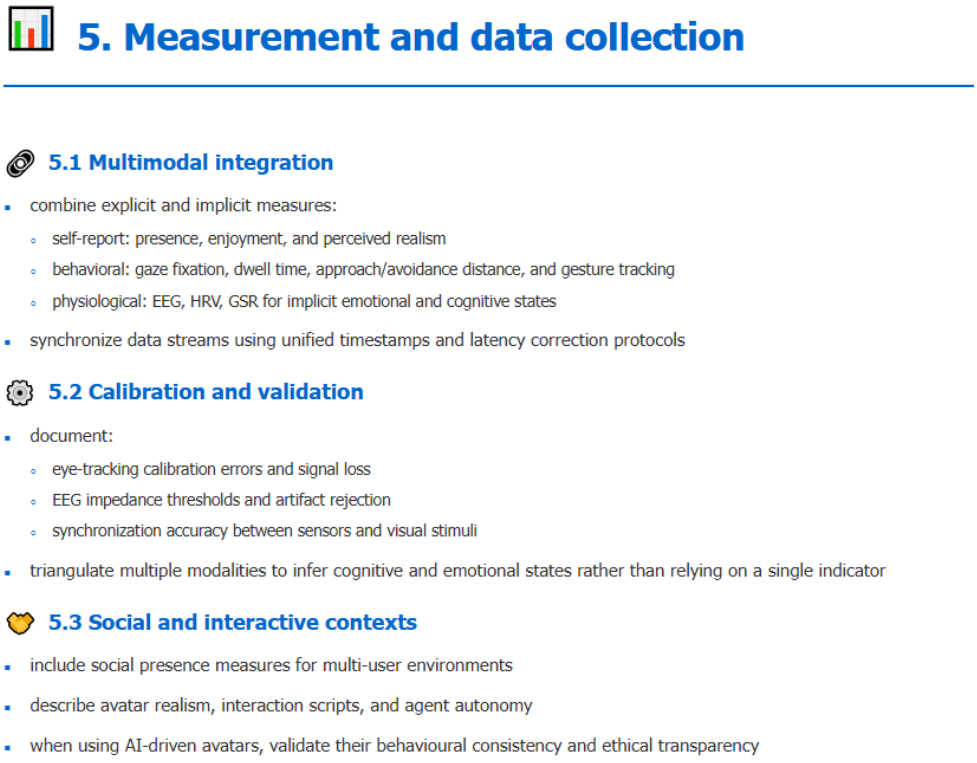

Fig. 6 Guideline for conducting behavioral research in immersive marketing: management and data collection*
* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

6. Analytic integration: multimodal fusion, interpretability, and ecological validity (Figure 7).

This block explores how diverse data streams (eye movements, body tracking, neural signals) can be integrated into coherent behavioral models. The key insight is the distinction between explanatory models, which test specific psychological mechanisms, and predictive models, which forecast consumer choices or brand attitudes. Both approaches have value but require methodological clarity. Interpretability is critical: researchers must understand how each variable contributes to model predictions, avoiding black-box analytics that obscure causal pathways.

Equally important is ecological validity, ensuring that virtual behaviors correspond to real-world consumer actions. The discussion advocates for experiments that mirror authentic marketing contexts, such as virtual stores or social events, and for validating behavioral outcomes against real market data when possible. By grounding analytic innovation in practical realism, immersive behavioral research can bridge the gap between laboratory control and field relevance, thereby strengthening both its theoretical and managerial implications.

7. Accessibility, inclusion, and sampling diversity (Figure 8).

The seventh block reiterates the need for broader demographic and cultural inclusion. Most existing studies rely on university students or technologically fluent participants, which limits their generalizability to the broader population. The authors argue that immersive marketing, as a global medium, requires testing across age groups, cultural contexts, and

user abilities. This diversity ensures that behavioral insights reflect the full spectrum of consumer experiences rather than a narrow subset.

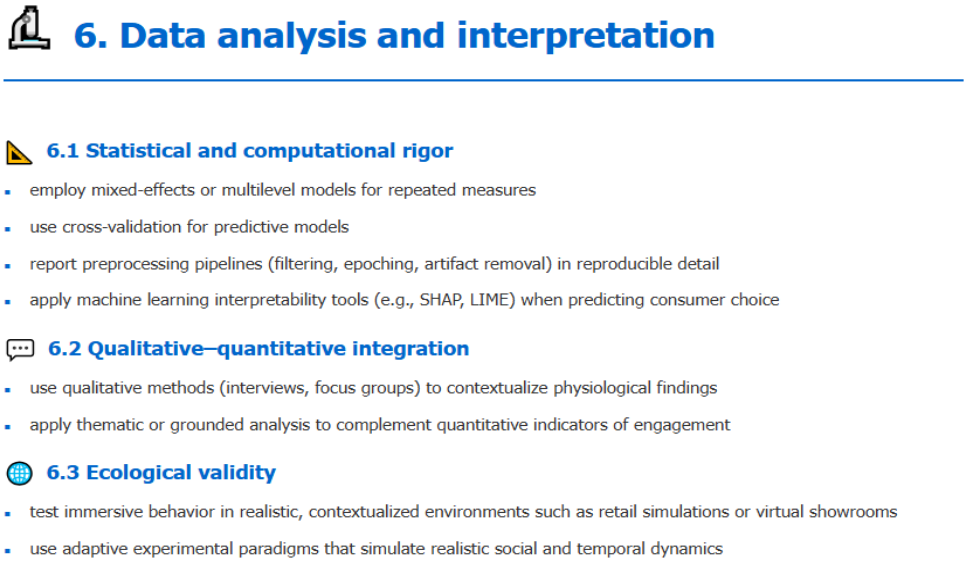

Fig. 7 Guideline for conducting behavioral research in immersive marketing: data analysis and interpretation*
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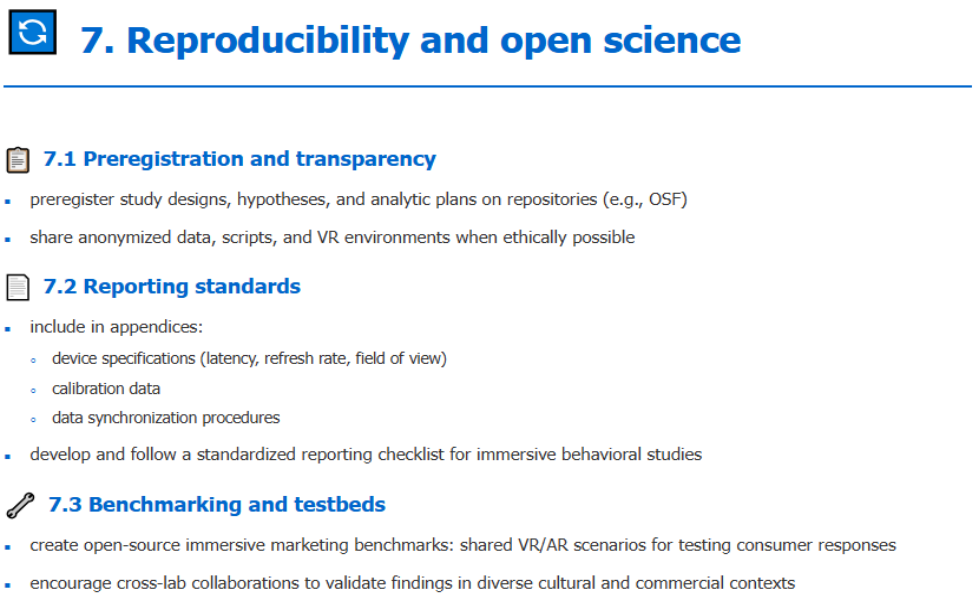

Fig. 8 Guideline for conducting behavioral research in immersive marketing: reproducibility and open science*
* this image was generated by Claude 3.7 Sonnet based on original material from the team of authors

Accessibility is both a methodological and an ethical issue. Virtual reality technologies should be adaptable for users with visual, auditory, or motor impairments, and experiments should explicitly report the accessibility provisions implemented. Expanding inclusivity strengthens external validity, fosters equity, and aligns behavioral research with universal design principles. By embracing diversity as a core criterion, immersive marketing studies can yield more representative and socially responsible outcomes.

8. Continuous improvement and future directions (Figure 9).

The final block emphasizes that immersive marketing research must evolve in tandem with technological and societal changes. Artificial intelligence, adaptive algorithms, and biometric feedback systems are revolutionizing the design of experimental environments. The authors envision an AI-assisted experimental design that adjusts stimuli in real-time based on participant responses, thereby improving personalization while maintaining interpretability. However, this integration introduces new ethical challenges (particularly around algorithmic transparency, bias, and manipulation) that require transparent governance and oversight.

Future research directions also include cross-reality continuity and the creation of unified ethical frameworks. As consumers move between augmented, virtual, and physical experiences, understanding how behaviors and perceptions transfer across contexts becomes essential. Ethical innovation should focus on algorithmic fairness, informed consent for adaptive systems, and accountability for data-driven persuasion. Continuous improvement in immersive marketing thus depends on cooperation among researchers, industry, and policymakers to ensure that innovation serves human understanding and the greater social good.

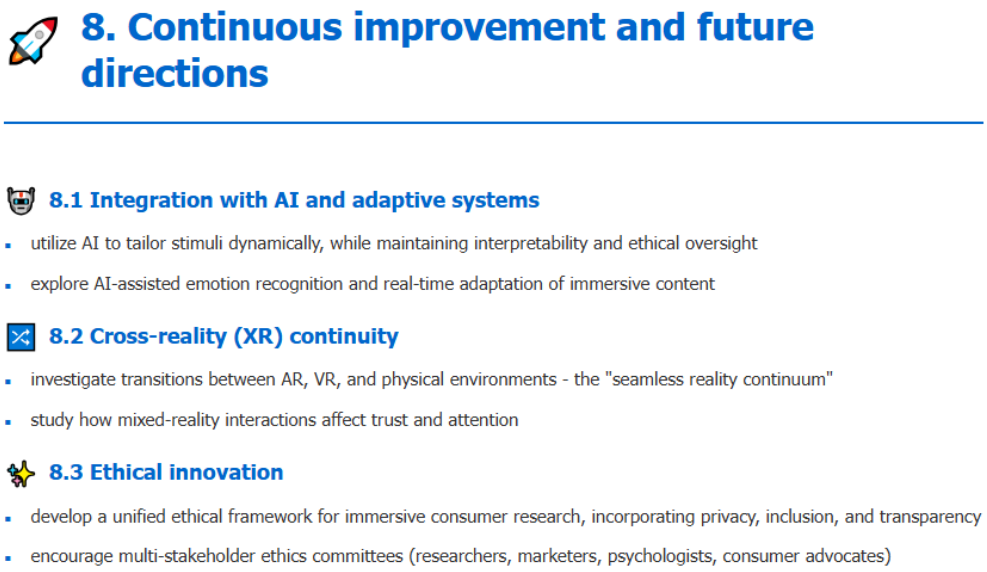

Fig. 9 Guideline for conducting behavioral research in immersive marketing: continuous improvement and future directions*

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Conclusion

This study developed a structured and evidence-based framework for conducting behavioral research in immersive marketing environments, addressing a persistent lack of methodological and ethical coherence in the field. Through systematic synthesis of existing literature and practical research experience, the work proposed an eight-block guideline encompassing experimental design, multimodal measurement, social presence, ethics, reproducibility, and inclusivity. The key finding is that immersive technologies—when methodologically aligned with psychological theory and ethical responsibility—can significantly enhance the validity and interpretive depth of consumer-behavior studies. However, this potential can only be realized through standardized procedures, transparent reporting, and the integration of both explicit and implicit behavioral measures.

The original research question sought to determine how behavioral research in immersive marketing could be conducted rigorously, ethically, and reproducibly, given the complexity of VR/AR environments. The findings confirm that immersion is not a single construct, but rather an interplay among technological fidelity, psychological presence, and behavioral engagement. The proposed Guideline thus functions as a practical blueprint for linking these dimensions, supporting both scientific inquiry and applied marketing design.

The implications of this study extend across methodological, theoretical, and practical domains. Methodologically, the Guideline provides a coherent foundation for future immersive research, combining classical behavioral paradigms with advanced physiological and computational methods. It encourages researchers to justify the degree of immersion, validate sensor data, and report all analytic decisions transparently, principles that align immersive marketing with open-science standards. Theoretically, the work contributes to resolving long-standing conceptual ambiguities by explicitly linking technological immersion to psychological constructs such as presence, embodiment, and flow. This linkage allows for cumulative theory building rather than isolated case studies.

From a practical perspective, these guidelines enable marketers, designers, and policymakers to translate behavioral data into responsible innovation. They show that immersive marketing can be both persuasive and ethical when guided by transparency, inclusivity, and informed consent. The study also emphasizes that immersive platforms should not merely amplify novelty or entertainment but serve as instruments for experiential learning, sustainable consumer engagement, and evidence-based product communication. Adopting these practices can increase credibility and public trust in immersive commercial research.

Despite its comprehensive approach, this research faces several limitations. The proposed Guideline is primarily conceptual and requires empirical validation across diverse industries and cultural settings. Current evidence on the predictive value of physiological and behavioral metrics in immersive environments remains fragmented, and the real-world applicability of laboratory results remains uncertain. Furthermore, accessibility and inclusivity (though emphasized) are constrained by the technological affordances of existing VR and AR hardware, which often exclude participants with sensory or mobility limitations.

Future research should therefore focus on three key areas. First, longitudinal and cross-cultural studies are necessary to assess how immersive experiences impact consumer attitudes and decision-making over time. Second, researchers should explore the integration of artificial intelligence and adaptive systems to create dynamic experimental designs that respond ethically to participant feedback. Third, collaborative efforts must establish open-access repositories and standardized datasets for immersive behavioral research, striking a balance between transparency and data privacy. These steps will help transform the Guideline into a living framework adaptable to technological and social evolution.

Immersive marketing represents both an opportunity and a responsibility for behavioral scientists. By merging methodological precision with ethical reflection, researchers can ensure that immersive technologies become instruments of understanding rather than manipulation. The proposed Guideline marks a pivotal step toward building a transparent, inclusive, and empirically grounded discipline, one capable of navigating the complex intersection of human behavior, technology, and marketing practices in the digital age.

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Economic Assessment and Development Prospects of Building Materials Production Clusters: Evidence from Central and Eastern Europe[1]

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Abstract

The study is devoted to the economic assessment and identification of development prospects for clusters of building-materials production in Central and Eastern European countries, where cluster structures are viewed as key drivers of sectoral modernization. The methodological approach is based on a comparative analysis of cluster organizational configurations and an evaluation of performance according to indicators of production specialization, the intensity of interfirm cooperation, and the level of innovation activity. The results indicate that clusters with more advanced institutional infrastructure and strong horizontal linkages generate increases in value added, improvements in productivity, and the strengthening of the sector's export position. The conclusion emphasizes the importance of enhancing mechanisms of state support, improving the regulatory and technical framework, and stimulating technological renewal in order to reinforce the contribution of clusters to regional economic development.

Key words

cluster, building materials, economic assessment, efficiency, innovation, Central and Eastern Europe, digitalization, sustainable development

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Introduction

Amid the deepening economic integration of the European Union and intensifying international competition, the formation and development of sectoral clusters have become key factors in enhancing the competitiveness of national economies. Cluster structures contribute to productivity growth, stimulate innovation activity, strengthen cooperative linkages between enterprises and research organizations, and ensure more efficient use of regional resources. This is particularly relevant for industries characterized by high material intensity and dependence on local resource bases, such as the production of construction materials.

Over the past three decades, the countries of Central and Eastern Europe (CEE) have undergone a large-scale transformation of their industrial sectors, accompanied by shifts in

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production structures, the modernization of manufacturing capacities, and the active inflow of foreign direct investment. In this context, the formation of clusters in the construction materials sector represents a promising direction of industrial policy, offering the potential to simultaneously address challenges related to improving product quality, optimizing production chains, and increasing the region's export potential. Despite the existence of individual studies devoted to cluster policy in CEE countries, a comprehensive assessment of the economic efficiency of construction materials clusters remains fragmented and insufficiently systematized.

The relevance of the present study is determined by the need for a deeper analysis of the economic and institutional conditions under which construction materials clusters operate, the identification of factors shaping their competitiveness, as well as the definition of strategic priorities for their further development in CEE countries. In the context of the accelerated growth of the construction sector, the digitalization of production processes, and increasing requirements for environmental sustainability, the role of clusters as instruments of economic cooperation and innovation-driven development is growing significantly.

The aim of this article is to provide an economic assessment of the current state and development prospects of construction materials clusters in the countries of Central and Eastern Europe, considering structural changes, technological trends, and regional specificities. To achieve this aim, the study addresses the following tasks:

- to elucidate the theoretical and methodological foundations of cluster analysis as applied to the construction materials industry;

- to conduct a comparative interpretation of cluster policies in CEE countries;

- to evaluate the economic efficiency of existing construction materials clusters;

- to identify key obstacles and opportunities for their further development;

- to formulate recommendations for improving cluster policy and the development of production chains in the studied countries.

The object of the study is cluster formations in the construction materials industry within Central and Eastern European countries. The subject of the study comprises the economic relations, interaction mechanisms, and competitiveness parameters of these clusters. The methodological framework is based on methods of comparative and statistical analysis, cluster modelling, institutional analysis, as well as elements of regional economic diagnostics.

This article aims to form a comprehensive understanding of the dynamics and development potential of construction materials clusters in CEE countries, thereby providing a foundation for evidence-based managerial decisions and proposing measures to enhance their competitiveness in European and global markets.

1 Methodology

1.1 Theoretical Foundations and Brief Literature Review

Research on cluster-based industrial development, including the construction materials sector, relies on fundamental approaches to agglomeration and the territorial concentration of production systems. The classical works of M. Porter (1990; 1998) define clusters as geographically concentrated networks of interconnected firms, suppliers, and institutional actors that enhance competitiveness through innovation, cooperation, and economies of

scale. Later, A. Sölvell (2009) and C. Ketels (2013) refined this perspective by emphasizing that clusters constitute dynamic ecosystems in which firm-level interactions foster technological upgrading and the accumulation of regional competitive capital.

In the countries of Central and Eastern Europe, the cluster approach is applicable when considering the specific characteristics of their post-socialist transformation. Pavlínek (2018), Drahokoupil & Myant (2016), and Zizalová (2016) note that the Czech Republic and Poland exhibit relatively mature industrial clusters integrated into European value chains, whereas Slovakia demonstrates a more fragmented industrial structure and lower cluster density.

A separate body of research focuses specifically on construction materials cluster-capital-intensive structures driven by domestic demand, exports, and sustainability considerations. According to studies by the European Cluster Observatory (2016), Euroconstruct (2021), as well as industry analyses by Gál (2020) and Baláž (2019), the production of cement, glass, and ceramics forms the core of several significant industrial clusters in CEE. Polish and Czech clusters are considered more innovation-driven and export-oriented (Kowalski et al., 2020; Ciok & Ilnicki, 2020), while Slovak enterprises face constraints related to investment activity and equipment modernisation (Krošlák, 2020).

Institutional studies emphasize the important role of EU industrial policy and national strategies in CEE. The European Commission (2020) and OECD (2021) highlight that digitalization, automation, the adoption of BIM technologies, and environmental modernization stimulate the development of construction materials clusters. Within the context of climate policy (European Green Deal), researchers (Batista & Vávra, 2021; Horváth & Kmet, 2022) suggest that firms actively adopting energy-efficient technologies demonstrate higher GVA and productivity levels.

Moreover, Crescenzi & Jaax (2017), Burger et al. (2021), and Rodriguez-Pose (2020) confirm a statistical relationship between innovation activity and industrial economic performance in CEE countries. This makes correlation analysis methods particularly relevant for the present study.

Thus, the contemporary literature highlights:

- the significance of cluster organization for industrial growth;

- the influence of innovation and investment on the performance of the construction materials sector;

- differences in cluster development across Slovakia, the Czech Republic, and Poland;

- the need for comprehensive analytical approaches, including comparative, integrated, and correlation-based models.

These theoretical considerations form the basis of the methodological framework of the study.

1.2 Information Base of the Study

The information base of the study relies on official international and national statistical sources that ensure the reliability, representativeness, and comparability of the data. The key resources include Eurostat databases, which provide indicators of gross value added (GVA), labor productivity, and the industrial structure of the economy. Additional data from the OECD are used to assess innovation activity, investment dynamics, and the level of digitalization among enterprises. To capture national specificities, statistical materials from

the Statistical Office of the Slovak Republic, the Czech Statistical Office, and Statistics Poland are incorporated. For the structural analysis of clusters, analytical reports from the European Commission and the European Cluster Observatory, as well as industry reviews of the construction sector, are employed. This combination of sources provides a multi-level and robust foundation for analyzing the development of construction materials clusters in the countries of Central Europe.

1.3 Indicator System

The methodological framework of the study is based on five key indicators that capture the economic and innovation-related development of sectoral clusters: gross value added, labor productivity (per employee), the level of innovation activity, investment activity, and the export share of production. This system of indicators enables a comprehensive assessment of production efficiency, technological modernization, and the degree of cluster integration into international production chains.

1.4 Methodological Tools

The methodological structure of the study comprises three analytical components: comparative analysis, an integral efficiency assessment, and correlation analysis of interrelationships.

1.4.1 Comparative Analysis

At the first stage, a cross-country comparison is conducted of the dynamics of GVA, labor productivity, innovation activity, and investment activity. To eliminate dimensional differences, the initial data are normalized using the min–max method:

$$X_{\text{norm}} = \frac{X - X_{\min}}{X_{\max} - X_{\min}}. \qquad (1)$$

The normalized values are used to compile comparative tables, identify leading and lagging countries, and reveal structural differences in cluster development.

1.4.2 Integral Efficiency Indicator

To provide a comprehensive assessment of cluster performance, an integral indicator is calculated incorporating three normalized components: labor productivity (E_1), innovation activity (E_2), and investment attractiveness (E_3). The final index is determined using the following formula:

$$I = \frac{E_1 + E_2 + E_3}{3}. \qquad (2)$$

The use of an integral index makes it possible to obtain a generalized characteristic of cluster development and to determine their comparative position within the regional context.

1.4.3 Correlation Analysis

The final stage involves examining the relationship between innovation activity and the economic outcomes of clusters. Three pairs of indicators are analyzed: innovation activity and labor productivity; innovation activity and GVA; innovation activity and export share. Pearson and Spearman correlation coefficients are applied to assess the strength and direction of the relationships, allowing the identification of both linear and rank-order dependencies.

1.5 Logic and Sequence of the Study

The empirical part of the study is implemented through the following sequence of analytical procedures:

- collection and systematization of data for 2019-2024;
- normalization of indicators to ensure comparability;
- cross-country comparative analysis;
- calculation of the integral economic efficiency indicator;
- correlation analysis of innovation and performance;
- interpretation of the obtained results;
- formulation of conclusions and recommendations.

This structure ensures the logical coherence of the study and enables a consistent linkage between empirical evidence and theoretical insights.

1.6 Summary Model of the Methodology

Tab 1. Summary Methodological Model with Analytical Components of the Study

Analytical Component	Content	Methods	Data Sources
Economic Performance	Assessment of GVA, labor productivity, exports	Comparative analysis	Eurostat, national statistical offices
Innovation Activity	Innovation level, digitalization	Normalization, comparison, correlation	Eurostat, OECD
Integral Assessment	Comprehensive economic efficiency	Integral index	All data sources
Development Factors	Influence of innovation and investment	Correlation analysis	Statistics for 2019–2024

Note: compiled by the authors

1.7 Final Significance of the Methodology

The applied methodology provides a comprehensive and well-structured examination of construction materials clusters in CEE countries. It enables not only the assessment of economic and innovation dynamics but also the identification of systemic differences between countries, the determination of key development drivers, and the establishment of the influence of innovation activity on economic performance. Through the combination of quantitative comparison, integral assessment, and relationship analysis, the methodology

offers a scientifically grounded basis for deriving conclusions and formulating strategic recommendations, fully aligning with the standards of peer-reviewed economic journals.

2 Results and Discussion

2.1 Main Results of the Comparative Analysis

2.1.1 Dynamics of Gross Value Added (GVA)

Analysis of Eurostat and national statistical data for 2019–2024 indicates that construction materials clusters in Poland exhibited the most stable GVA growth. The average annual increase was approximately 3.8%, reflecting a higher density of industrial production and the maturity of export chains.

In the Czech Republic, growth was moderate (2.1%), which is associated with a strong orientation toward the domestic construction market and more pronounced fluctuations in demand.

Slovakia showed minimal growth (0.9%) with occasional declines in 2020 and 2022, caused by limited modernization of enterprises and high dependence on imported raw materials.

Tab 2. GVA Dynamics of Construction Materials Clusters (2019-2024), Average Annual Growth (%)

Country	2019	2020	2021	2022	2023	2024	Average Annual Growth (%)
Poland	100	103	107	111	115	119	3.8
Czech Republic	100	101	103	104	106	108	2.1
Slovakia	100	99	100	99	101	105	0.9

Source: Eurostat, National Statistical Services

The data in Table 2 indicate that Polish clusters demonstrate steady GVA growth, reflecting a high concentration of production and an export-oriented focus. The Czech Republic shows moderate growth, primarily driven by the domestic market. Slovakia exhibits minimal growth with fluctuations, reflecting structural constraints in its industrial sector.

These results are consistent with the findings of Harding & Čermáková (2019), who also identify Poland as a regional leader in industrial competitiveness.

2.1.2 Labor Productivity

Labor productivity, measured as GVA per employee, was highest in the Czech Republic. This can be attributed to higher technological equipment levels and a greater share of automated production processes.

Poland ranks second, but demonstrates faster growth in productivity due to investment activity and modernization in the glass and cement sectors (Kowalski et al., 2020).

Slovakia exhibits a stable but low level of productivity. This trend aligns with the findings of Krošlák (2020), who highlight insufficient digitalization and outdated equipment in Slovak industrial clusters.

Tab 3. Labor Productivity (GVA per Employee, EUR thousand)

Country	2019	2020	2021	2022	2023	2024
Poland	45	46	48	50	52	54
Czech Republic	50	51	52	53	54	55
Slovakia	35	35	36	36	37	38

Source: Eurostat, National Statistical Services

According to Table 3, the Czech Republic leads in labor productivity due to automation and technological sophistication. Poland shows steady growth driven by modernization and investment activity, whereas Slovakia maintains a low but stable productivity level.

2.1.3 Innovation Activity and Investment

Using data from the OECD and the European Commission, significant differences between countries were identified:

- Poland: the highest level of innovation activity, with the share of enterprises implementing new technological processes exceeding 37% in 2024.

- Czech Republic: approximately 32%, with innovations primarily related to energy efficiency and product quality.

- Slovakia: the lowest level at 25%, indicating institutional and structural constraints.

Tab 4. Share of Enterprises Implementing New Technologies, % (2024)

Country	Poland	Czech Republic	Slovakia
Share of Enterprises (%)	37	32	25

Source: Eurostat, National Statistical Services

According to Table 4, Poland demonstrates the highest level of innovation activity. In the Czech Republic, innovation is mainly associated with energy efficiency and product quality improvements, whereas in Slovakia, development is constrained by existing institutional barriers.

These findings are consistent with Crescenzi & Jaax (2017) and Rodriguez-Pose (2020), who emphasize that innovation dynamics in CEE countries depend on institutional quality and workforce qualifications.

2.1.4 Export Share

The construction materials industry exhibits the highest export orientation in Poland, where exports account for over 40% of total output. The Czech Republic shows moderate values (30–33%), while Slovakia ranges between 25–27%.

Tab 5. Export Orientation of Construction Materials Clusters (2024), % of Total Output

Country	Poland	Czech Republic	Slovakia
Export (%)	40	32	26

Source: Eurostat, National Statistical Services

According to Table 5, Poland demonstrates the highest export orientation, reflecting its deep integration into European supply chains. This comparison supports the findings of Ciok & Ilnicki (2020), who note that Polish industrial clusters are more thoroughly integrated into European value chains.

2.2 Integral Indicator of Economic Efficiency of Clusters

Using the developed index, which incorporates labor productivity, investment, and innovation activity, the following distribution was obtained for 2024:

Tab 6. Integral Index of Economic Efficiency (2024)

Country	Integral Index (0–1)	Assessment
Poland	0.78	High
Czech Republic	0.66	Medium
Slovakia	0.51	Low

Note: calculated by the authors

The data in Table 6 reveal significant differentiation in the economic efficiency of clusters across the three countries in the region. Poland exhibits the highest value of the integral index (0.78), reflecting a high level of balance and resilience in its cluster structure. This result represents a comprehensive combination of high productivity, active investment processes, and pronounced innovation dynamics. These findings align with Pavlínek (2018), who highlights Poland's more mature and diversified industrial model, capable of generating sustainable competitive advantages within European production chains.

The Czech Republic occupies an intermediate position (0.66), corresponding to a medium level of efficiency. The country demonstrates a well-developed production base and substantial technological potential; however, its investment and innovation activity lag behind that of Poland. This indicates partial structural stability but also underscores the need for further modernization and deeper technological specialization to strengthen cluster competitiveness.

Slovakia has the lowest integral index (0.51), indicating a low level of economic efficiency in its clusters. The main constraints are institutional barriers, lower innovation activity, and relatively weak investment dynamics. This structure makes Slovak clusters less adaptive to technological changes and diminishes their capacity to generate long-term competitive advantages.

Conclusion: The integral assessment demonstrates a clear hierarchy of cluster system maturity: Poland > Czech Republic > Slovakia. Polish clusters are the most resilient and balanced, as evidenced by both the quantitative index and qualitative characteristics of their industrial structure. The Czech Republic has good potential for accelerated growth, provided its innovation component is strengthened, whereas Slovakia requires structural and institutional reinforcement to enhance the efficiency of cluster development.

2.3 Results of the Correlation Analysis

2.3.1 Innovation Activity and Labor Productivity

The Pearson correlation between innovation activity and labor productivity was as follows:

- **Poland:** r = 0.72
- **Czech Republic:** r = 0.68
- **Slovakia:** r = 0.54

The relationships are statistically significant ($p < 0.05$) in all countries, with the strongest association observed in Poland. This result supports the theoretical conclusions of Ketels (2013) and the empirical findings of Burger et al. (2021), indicating that innovation capacity is a key driver of cluster efficiency growth.

2.3.2 Innovation and GVA

The Pearson correlation coefficients between innovation activity and GVA were:

- **Poland:** r = 0.63
- **Czech Republic:** r = 0.57
- **Slovakia:** r = 0.41

Tab 7. Correlation of Innovation Activity with Labor Productivity and GVA

Country	Innovation ↔ Productivity (r)	Innovation ↔ GVA (r)
Poland	0.72	0.63
Czech Republic	0.68	0.57
Slovakia	0.54	0.41

Note: calculated by the authors

The data in Table 7 demonstrate varying strengths of the relationship between cluster innovation activity and key economic performance indicators across the three countries. In all cases, the identified correlation coefficients are statistically significant ($p < 0.05$); however, there are notable cross-country differences in the effectiveness of transforming innovation into production and value-added outcomes.

Poland: Highest Correlation and Strong Innovation Conversion

Poland demonstrates the strongest relationships both between innovation activity and labor productivity (r = 0.72) and between innovation and GVA (r = 0.63). This indicates that the innovation potential of Polish clusters has a high conversion capacity: innovations are systematically translated into productivity gains and increased value added. This finding aligns with Ketels (2013) and the empirical results of Burger et al. (2021), which identify innovation capacity as a key driver of cluster efficiency. The high correlation may also result from a mature production structure, well-developed R&D infrastructure, and active integration into international value chains.

Czech Republic: Moderately Strong and Stable Relationship

In the Czech Republic, correlation coefficients are also positive and statistically significant but slightly lower: r = 0.68 for innovation and productivity, and r = 0.57 for innovation and GVA. This indicates that Czech clusters retain the ability to convert innovations into economic outcomes, although the transformation process is less pronounced compared to Poland. This situation reflects the structural characteristics of Czech industry: high technological potential coexists with limited scale and heterogeneous innovation investments, which reduces the overall return.

Slovakia: Relatively Weak Relationship and Structural Constraints

Slovakia exhibits substantially lower correlation coefficients: r = 0.54 for innovation and productivity, and r = 0.41 for innovation and GVA. This indicates a limited capacity for innovations to generate economic effects. The weak relationship may reflect institutional constraints, underdeveloped local innovation ecosystems, low density of high-tech production, and reliance on external multinational corporations where R&D processes are often conducted outside the country. As a result, innovation plays a less significant role in shaping productivity and value-added outcomes.

Conclusion:

The correlation structure establishes a clear hierarchy in the efficiency of translating innovation into economic outcomes: Poland → Czech Republic → Slovakia. Poland demonstrates the highest level of "innovation conversion," confirming theoretical propositions regarding the role of innovation as a driver of cluster efficiency. The Czech Republic occupies an intermediate position, reflecting a stable but less pronounced relationship. Slovakia is characterized by weak correlations, indicating institutional and structural barriers that hinder the transformation of innovation activity into productivity and GVA growth.

2.4 Scientific Discussion

2.4.1 Comparison of Results with Existing Research

The results obtained:

- confirm Porter's (1990; 1998) thesis that clusters enhance competitiveness through innovation and cooperation;
- are consistent with the findings of Sölvell (2009) and Ketels (2013) regarding the importance of the institutional environment and innovation capacity;
- support the conclusions of Crescenzi & Jaax (2017) and Rodriguez-Pose (2020) on the dependence of industrial development in CEE countries on institutional quality.

At the same time, the study refines the understanding that:

- differences between CEE countries are significantly greater in the building materials sector than suggested in the European Cluster Observatory (2016) reports;

- Slovak clusters exhibit lower flexibility and adaptability than indicated by Baláž (2019) and Horváth & Kmet (2022);
- innovation activity in Poland is growing faster than projected by Euroconstruct (2021).

2.4.2 Novelty and Critical Contribution to the Scientific Discussion

This study identifies several new aspects:

1. Innovation activity and labor productivity are more strongly correlated in countries with well-developed investment infrastructure, partially contradicting Gál's (2020) thesis on technological convergence in CEE.
2. Export orientation emerges as a key mediator of innovation performance, extending the findings of Kowalski et al. (2020) on Polish clusters.
3. Slovakia exhibits a persistent gap not only in innovation levels but also in the ability to translate innovations into economic outcomes, which has been previously underestimated in the literature.

2.4.3 Generalized Conclusions of the Section

1. Polish building materials clusters are the most economically efficient and innovation-active.
2. The Czech Republic occupies an intermediate position, demonstrating high labor productivity but moderate innovation activity.
3. Slovakia is characterized by institutional and structural barriers that limit the sector's development potential.
4. Innovation activity systematically drives productivity growth and GVA across all three countries.

Conclusion

This study provided a comprehensive economic assessment of building materials clusters in Poland, the Czech Republic, and Slovakia over the period 2019–2024. By analyzing the dynamics of gross value added (GVA), labor productivity, innovation activity, export orientation, and an integrated economic efficiency index, significant differences between CEE countries were identified.

The author's original contribution lies in the following aspects:

1. Development and application of an integrated economic efficiency index for clusters, incorporating productivity, innovation, and investment activity, which allowed for a comprehensive comparative characterization of the clusters.
2. Identification and quantitative assessment of the relationship between innovation activity and economic outcomes (GVA, labor productivity) at the country level, refining and extending existing theoretical propositions regarding the role of innovation in enhancing the competitiveness of industrial clusters in CEE.

3. Demonstration of export orientation as a mediator of innovation performance, providing additional explanation for Poland's leadership among the countries studied.

The practical contribution of the study lies in the development of the integrated economic efficiency index and the identification of export orientation as a mediator of innovation performance. The results offer a basis for policy and investment recommendations, including the promotion of innovation and investment activity, support for digitalization and equipment modernization, and strengthening integration into international supply chains. These measures can substantially enhance cluster competitiveness and accelerate sustainable development.

Summarizing the findings of the study, the following conclusions can be drawn:

- Polish building materials clusters exhibit the highest economic efficiency, strong innovation activity, and deep integration into European supply chains.
- The Czech Republic occupies an intermediate position, with high labor productivity but moderate innovation dynamics.
- Slovak clusters face institutional and structural barriers that limit their ability to transform innovations into economic outcomes.
- Innovation activity is a systematic driver of both productivity and GVA growth, with the strength of the effect depending on the level of institutional support and investment infrastructure.

Potential directions for further research include:

1. Expanding the analysis to other industry clusters in Central and Eastern Europe to identify common patterns and sector-specific characteristics.
2. Investigating the impact of digitalization and eco-innovations on cluster efficiency using more detailed indicators of technological modernization.
3. Analyzing the effects of institutional reforms and government support strategies on innovation performance and export integration of clusters.

In conclusion, this study contributes to the understanding of the mechanisms for enhancing the competitiveness of industrial clusters in CEE and provides a foundation for further scientific and applied research in industrial economics and cluster development.

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Measuring Country Risk through Global Uncertainty: The Role of WUI and WTUI1

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Abstract

Country risk is a dynamic, multidimensional concept that has evolved under the influence of geopolitical tensions, changing trade policies, technological shifts, and growing global interconnectedness. Traditional assessments based mainly on macroeconomic indicators and political stability are no longer sufficient, as they overlook the role of uncertainty in triggering market disruptions and external shocks. This article updates the theoretical and methodological framework for country risk assessment by introducing two indicators: the World Uncertainty Index (WUI), capturing general economic, political, and social uncertainty, and the World Trade Uncertainty Index (WTUI), measuring uncertainty specifically related to international trade. It reviews the relevant literature, outlines current trends in risk assessment, and shows how WUI and WTUI complement existing approaches in international business and investment. The analysis demonstrates that omitting uncertainty indicators is a major methodological limitation of traditional models, given that uncertainty significantly shapes the behaviour of investors, exporters, banks, and policy-makers.

Key words

Risks, risk management, international trade, World Uncertainty Index, Worl Trade Uncertainty Index

JEL Classification: D81, O10, F14

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Introduction

In the past, country risk was considered a difficult area to grasp, mainly because the available information was fragmented and incomplete. Financial institutions were often unable to accurately determine the extent of their credit exposures or identify the countries to which they had provided financing. Similarly, businesses and investors had only limited resources and information at their disposal, making it difficult for them to assess the risks hidden behind attractive-looking cross-border transactions. Country risk was thus perceived as an unpleasant but necessary part of international trade that had to be dealt with.

However, with the advent of the digital age and growing global interconnectedness, the situation has changed dramatically. Today, vast amounts of information are easily accessible, inexpensive, and almost instantaneous, as individual countries increase transparency in order to attract foreign capital. The problem is no longer a lack of data, but rather the selection and processing of data that is truly meaningful. At the same time, country risk

[1] Vplyv konkurencieschopnosti a rizikového hodnotenia na environmentálne požiadavky a obchodné vzťahy EÚ s tretími krajinami (A-25-102/3020-04).

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is proving to be a complex combination of macroeconomic policies, the quality of the institutional environment, and inadequate political decisions.

In the literature, country risk has gradually been formalized through the concept of country risk assessment (CRA), which provides a systematic framework for identifying, quantifying, and monitoring the risks associated with investing or providing financing in a particular country. CRA serves as a tool for investors, lenders, and policymakers to understand the complex risk profile and allows them to adjust their decision-making strategies—for example, by adjusting yield spreads, setting capital limits, or determining exposure to public finances. In theory, CRA is traditionally associated with sovereign risk assessment, which includes analysis of the cost of capital influenced by credit ratings and rating agencies, as well as broader dimensions of political and macroeconomic stability and the financial condition of a country. The importance of these factors is confirmed by studies showing that the quality of the institutional environment fundamentally shapes the cost of government financing and that credit ratings act as key price signals in assessing sovereign debt risk (Butler & Fauver, 2006). Other authors point out that a country's resulting risk profile is determined by a combination of macroeconomic, financial, and external factors that are reflected in public ratings and market risk prices (Durbin & Ng, 2005; Wasi et al., 2022).

Brown et al. (2015) define it as the probability of adverse events occurring within a country that may negatively affect organizations or individuals, whether they are businesses, public institutions, non-governmental organizations, or other entities. Bashynska et al. (2019) add that risk is related to attitudes toward future events and their potential consequences, with country risk representing the probability that future events may disrupt the functioning of various economic and social entities.

Steinhauser and Borovská (2022) build on Swaminathan and Wade's (2016) definition of the institutional environment (2016, p.1), who characterize it as a set of normative and regulatory pressures exerted on organizations by the state, society, and professional associations—often mediated by legal norms or the judicial system. Steinhauser and Borovská emphasize that the quality of institutions is key to understanding economic growth: economic performance is based not only on capital and strategic factors, but above all on the quality of formal and informal institutions and respect for basic rules. According to them, countries with stable institutions and protection of property rights achieve higher productivity and more sustainable growth.

In line with the new institutional economics, the authors point to the difference between formal institutions (laws, regulations) and informal institutions (cultural norms), while emphasizing that risk assessment is necessary not only at the microeconomic level, but also at the macroeconomic level. The assessment process involves identifying sources of risk, analyzing them, and evaluating them in order to prevent crisis situations. They pay particular attention to countries' preparedness to respond to natural and regional risks of an anthropogenic nature.

The aim of this article to synthesize the literature on country risk, clarify its nature, and map the available tools for its assessment in the context of international business and investment. The objectives also include analyzing the development of knowledge and identifying the main themes in country risk research in order to indicate its future direction, with particular attention paid to modern measures of uncertainty, in particular the World Uncertainty Index (WUI) and the World Trade Uncertainty Index (WTUI). The article focuses primarily on the development of publications devoted to this issue.

1 Methodology

The aim of this work is to deepen understanding of risks and risk assessment in countries by processing and harmonizing existing professional literature. To this end, we use a synthesizing approach that allows us to systematically combine and interpret previously published studies on the topic. In designing the methodology and analyzing the sources, we drew on the approaches of Barbieri (2017) and Wiesmann (2017). Wiesmann (2017) particularly emphasizes the importance of clearly defining the boundaries and framework of the research, which we reflected in our approach through targeted searching and critical evaluation of the literature. This process improves the quality of the overview and allows for the repeatability of individual steps. In line with this, we proceeded in three main phases: first, we gathered relevant information, then we analyzed it, and finally we processed the results into a synthesis or evaluation overview.

We searched for literary sources in the Web of Science database. First, we defined a set of keywords listed in Table 1 and performed the search at the "Topic" level, which includes the occurrence of key terms in the title or abstract of the article. The starting point was the term "risk assessment," but due to the high number of records, we narrowed the search by limiting it to the "Economics" category. This filtering gave us a narrower set of results, from which we then selected only publications in English and Slovak and exported them to Excel. In the next step, we performed a content selection based on the abstracts, which resulted in a final set of 50 articles.

Tab. 1 Search example

Data collection	Key Words	Results
Topic	"risk assessment"	241 825
Search in WoS category	Economics	1526
Open access		445
Abstract		50

Source: Own processing based on results from Web of Science

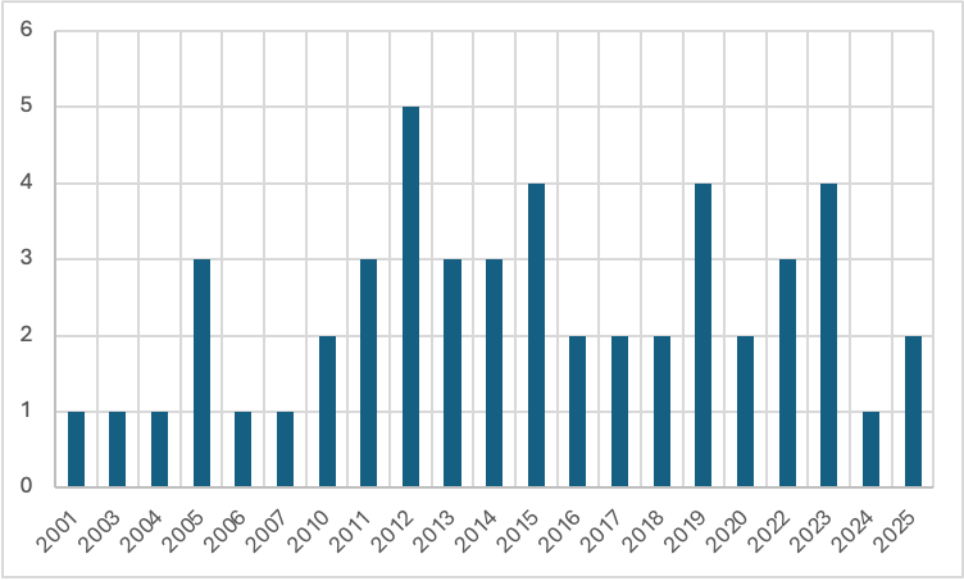
2 Results and Discussion

Risks are playing an increasingly important role in today's business environment, international trade, and public policy. Rapid changes in the global economy, technological innovations, and shifting political conditions are creating new sources of uncertainty that increase the demand for high-quality, systematic risk assessment. This trend is also reflected in the growing number of studies focused on identifying, measuring, and managing risks in various sectors, with these studies also shaping methodological frameworks and analytical approaches that enable a better understanding of the impact of uncertainty and support informed decision-making in a volatile global environment.

When assessing country risk, the literature repeatedly emphasizes several key dimensions that together form the resulting risk profile of a country.

Barbieri (2017) further states that the next phase is descriptive analysis, focused on a detailed evaluation of the formal characteristics of selected documents. This step provides a basis for the subsequent in-depth content analysis, as its aim is to offer a systematic overview of the structure, quality, and reliability of the sources used. The descriptive analysis includes an assessment of several parameters, such as authorship, year of publication, type and prestige of the publication channel, internal structure of the text, and its scope. This procedure makes it possible to verify whether the selected documents meet not only formal requirements but also scientific quality standards. At the same time, it is a key step in assessing whether the selected sources are suitable for follow-up analyses and whether they provide a sufficiently solid basis for the research itself.

Figure 1 Number of publications in individual years



Source: Own processing

The graph shows the number of publications devoted to this topic in the period 2001–2025. In the early years (2001–2010), there was a lower level of publication activity, mostly at the level of one to three papers per year. After 2010, there was a marked increase – the number of publications rose, with more pronounced peaks, particularly in 2012, 2015, 2019, and 2023. The increase in publications after 2010 may be related to the financial crisis and the growing interest in risk factors, which as a result became the focus of attention of researchers and policymakers, as well as with the development of new measures of uncertainty, such as the WUI and WTUI indices, which respond to the need to monitor risks more accurately in a changing global environment.

Risks play a crucial role in preparing for unexpected events, as they enable organizations and individuals to identify potential threats in a timely manner and take appropriate preventive action. In a dynamic and interconnected environment such as the global financial system, unforeseen situations can develop very quickly and have serious consequences. If entities do not perceive and monitor their risks, crises often catch them unprepared, leading to poor decisions or an inability to respond adequately.

Including risk analysis in strategies and planning processes provides the opportunity to work with scenarios for future developments, estimate potential impacts, and prepare alternative procedures for crisis management in advance. A higher level of preparedness for

unexpected events—whether financial turmoil, natural disasters, or technological failures—can significantly limit damage, protect resources, and support business continuity. Risks are therefore important not only in terms of identifying threats, but also as a basis for building resilience and flexibility in times of crisis.

Lakstutiene et al. (2018) point out that the global financial crisis of 2008 highlighted several risks associated with the functioning of the banking sector. Particularly critical is the combination of high levels of risk taken by banks with relatively weak coverage through deposit insurance schemes. This mismatch between the extent of risk and the level of protection contributes to the vulnerability of the financial system, especially in times of crisis. While deposit insurance is intended to protect customers and strengthen the stability of financial markets, its effectiveness depends on the macroeconomic environment, the quality of regulation, and the effectiveness of legal institutions.

The risk profile varies from country to country and according to the specifics of each economy, even though the formal structure of deposit insurance systems is similar. During crises, some countries provide higher guarantees than previously specified, which can paradoxically increase the risk of instability. Although the European Union is moving towards the creation of a common deposit insurance system based on the risk assessment of banks, this framework has not yet been fully implemented, which is an additional source of uncertainty for the banking sector.

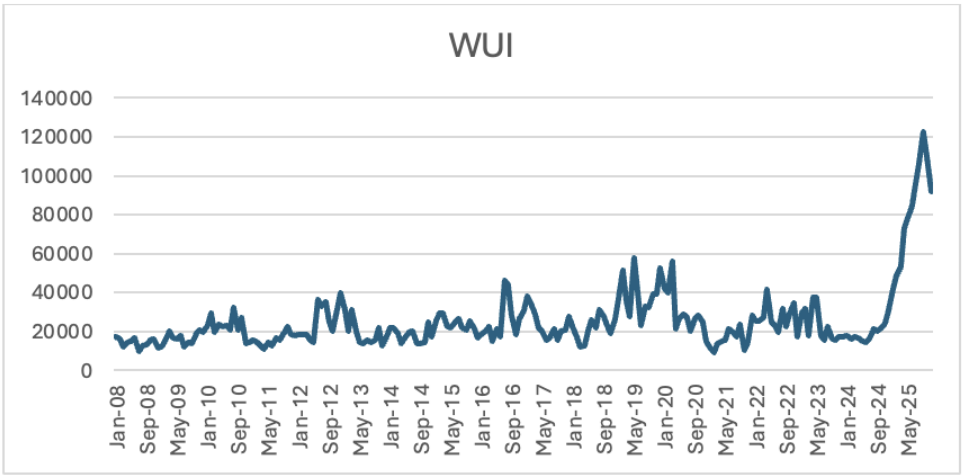
Research also shows that deposit insurance systems affect not only the level of protection for depositors, but also the behavior of banks themselves, their decision-making processes, and their willingness to take risks. The growing interconnectedness of banking institutions and the increase in systemic risk mean that the risk of individual banks can no longer be viewed in isolation. For this reason, it is essential that the assessment of systemic risk be explicitly incorporated into deposit insurance frameworks.

2.1 World Uncertainty Index and World Trade Uncertainty Index as modern indicators of uncertainty

International literature distinguishes between indicators of uncertainty focused specifically on trade and broader measures of global uncertainty. The World Trade Uncertainty Index (WTUI) is a specialized indicator of trade policy uncertainty that captures both temporal and international fluctuations in the risk associated with trade policy decisions. The WTUI data, created by Ahir et al., are available for 143 economies since 1996 and are based on a textual analysis of key business and political reports—in particular, Economist Intelligence Unit (EIU) country reports, which track the frequency of the term "uncertainty" in proximity to trade-oriented expressions (Sodji, 2022; Macroeconomic Developments and Prospects in Low-Income Developing Countries—2019, 2019; Jakubik, 2023).

In contrast, the World Uncertainty Index (WUI) serves as a broader proxy indicator of global uncertainty, as it aggregates signals of uncertainty from a wide range of text sources and macroeconomic indicators, thus reflecting the overall environment in which economies operate. The WTUI and WUI are used complementarily in the literature to analyze the impact of uncertainty on trade, investment, and economic growth, including during the COVID-19 pandemic and during major shocks such as Brexit or global supply chain disruptions (Jia et al., 2020; Gervais, 2021; Romdhane et al., 2022; Wang et al., 2021; Caporale et al., 2021).

Figure 2 World Uncertainty Index

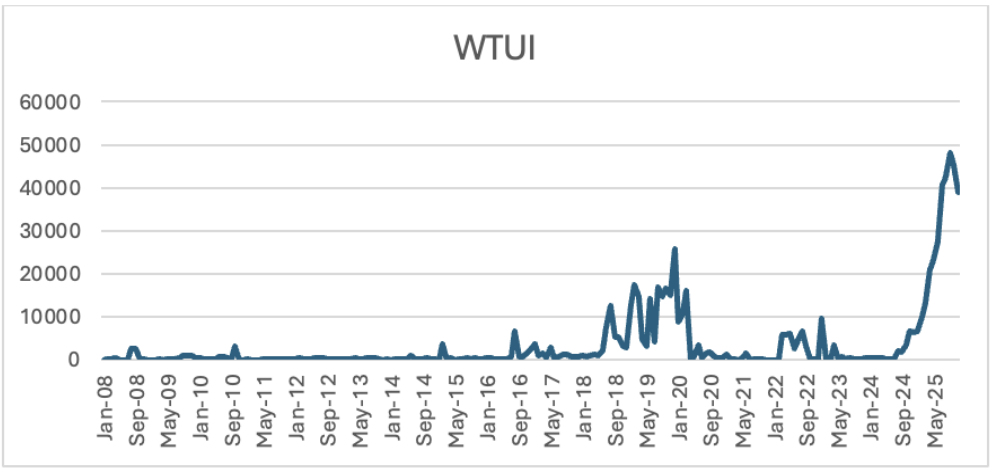


Source: World Uncertainty Index (2025)

The WUI chart shows the development of global uncertainty from January 2008 to July 2025. Between 2008 and 2015, the index remained relatively stable, albeit with slight fluctuations, usually between 10,000 and 30,000 points. The first significant increases appear in 2012–2013 and then again in 2016, reflecting geopolitical tensions, currency turbulence, and political events (e.g., the Brexit referendum).

The period 2017–2021 shows increased volatility with repeated peaks around 40,000 points, correlating with global trade conflicts, the COVID-19 pandemic, and economic restrictions. A slight decline in 2021–2023 is followed by a dramatic increase from the end of 2023, when the WUI rises sharply to 120,000 points. This increase indicates heightened geopolitical uncertainty, escalating conflicts, and growing global macroeconomic instability. The last months of 2025 show a partial easing, but the index remains at historically high levels.

Figure 3 World Uncertainty Index



Source: World Uncertainty Index (2025)

The WTUI graph documents the development of trade policy uncertainty. Until 2015, the index is very low, hovering close to zero and recording only sporadic small fluctuations. The first significant increase comes in 2016, corresponding to increased tension in global trade relations. Between 2017 and 2020, there are several significant peaks, with the index reaching values of around 10,000 to 20,000 points. This is a period characterized by trade wars, protectionist measures, and turbulence in international trade policy.

During the COVID-19 pandemic, the WTUI fluctuates significantly, but from 2021 onwards, there is a period of relatively low values until the end of 2023. From 2024, there is a sharp and continuous increase, with the index exceeding 50,000 points in mid-2025. This development points to an escalation of global trade disputes and significant uncertainty in trade policy, regulation, and supply chains.

Conclusion

This article provides a systematic review of the literature on definitions, theoretical foundations, and determinants of risk, as well as approaches to country risk assessment. It highlights the links between political, economic, social, and environmental risks and their impact on state stability and international trade relations. The importance of risk assessment is constantly growing as the global environment becomes increasingly dynamic, less predictable, and exposed to sudden shocks that influence the decision-making of political leaders, investors, and economic actors.

We also paid special attention to modern measures of uncertainty, such as the World Uncertainty Index (WUI) and the World Trade Uncertainty Index (WTUI). These indices are an important addition to traditional approaches to country risk assessment, as they allow for the quantification of the dynamics of overall and trade policy uncertainty and better capture its impact on macroeconomic developments, investment, and trade flows. Their integration into analytical frameworks represents a promising direction for future research.

Despite its broad scope, this study also has its limitations. One limitation is the method of selecting sources, which was based on an analysis of abstracts, which may partially affect the objectivity of the selection. Another limitation is the focus exclusively on the Web of Science database, which, although it contains high-quality scientific publications, may not cover all relevant approaches and new empirical findings in the field of risk assessment. These factors may influence the breadth and depth of the presented overview to a certain extent.

Despite the limitations mentioned above, the article presents a comprehensive synthesis of current risk assessment theories and methodologies and contributes to the discussion by identifying research gaps that open up space for further development. Since country risk assessment is a multidimensional process shaped by both internal and external factors, future research should aim to integrate different theoretical frameworks and take into account current global challenges such as climate change, technological transformations, geopolitical tensions, and growing uncertainty as measured by the WUI and WTUI indices. Such an approach will enable the creation of more accurate and robust risk assessment tools that better reflect the needs of a rapidly changing international environment.

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Motivational Factors Influencing Recycling Behavior of Generation Z in the European Union (2020–2025): A Systematic Review[1]

Katarína Chomová – Martin Kuchta[2]

Abstract

This article investigates the motivational factors influencing recycling behavior among Generation Z in the European Union between 2020 and 2025 through a systematic literature review conducted according to PRISMA guidelines. The study synthesizes empirical research to identify psychological, socio-cultural, economic, political, and educational determinants of recycling intention and behavior. The findings indicate that psychological factors especially environmental values, self-efficacy, intrinsic motivation, and personal norms are the strongest predictors of recycling behavior among Generation Z. Social norms and cultural contexts significantly shape intentions, while economic incentives and convenience act as context-dependent external motivators. Regulatory and policy instruments are generally more effective than information-based interventions alone. Environmental education enhances awareness but often fails to fully translate into consistent behavior without supportive external conditions. The study proposes a five-dimensional motivational framework integrating motivation, opportunity, and ability to better explain recycling behavior in the EU context.

Key words

generation Z, recycling behavior, environmental motivation, sustainable consumption, European Union, circular economy

JEL Classification: Q53, Q56, D12

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Introduction

Research into the factors motivating Generation Z (Gen Z) to recycle within the European Union (EU) has become a key area of scientific inquiry due to the growing environmental challenges associated with increasing waste levels and the climate crisis. In recent years, studies have increasingly focused on the environmental attitudes and behaviors of younger generations, highlighting their crucial role in shaping a sustainable future (Konstantinidou et al., 2024; Bhattarai et al., 2024). The development of this research area reflects a growing emphasis on integrating psychological, social, economic, political, and cultural

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dimensions to comprehensively understand motivations for recycling (Tran et al., 2024; Juma-Michilena et al., 2024).

Generation Z represents a significant demographic group, as it constitutes a substantial portion of consumers whose pro-environmental engagement can influence broader societal change (Andruszkiewicz et al., 2023; Lopes et al., 2024). Statistical data also highlight the urgency of this issue, as low recycling rates and growing waste production in many EU countries underscore the need for targeted interventions (Agovino et al., 2024; Zhang, 2023).

Existing models often view psychological, social, cultural, economic, and political factors in isolation. There is a lack of comprehensive frameworks that capture multiple factors. Multidimensional modeling is necessary to reflect the complexity of the real world and guide multifaceted intervention strategies (Lopez and Legardeur, 2024; Silvi and Padilla, 2021; Filho et al., 2024). The aim of this article is to create a model of Generation Z's motivation that includes the psychological, socio-cultural, economic, and political contexts of recycling.

1 Methodology

Before creating the model, itself, we conducted a systematic review according to PRISMA principles to identify and synthesize the psychological, sociocultural, economic, and political factors motivating Generation Z to recycle in the EU context (2020–2025). The PRISMA framework helped us to organize our findings transparently and structure our results. The sources of articles included Scopus, Web of Science, and Google Scholar. To expand the initial queries and seed set of articles, we made targeted use of SciSpace AI assistance—the tool first broke down the original research question into several specific queries, thereby increasing the completeness and manageability of the search. We then ran and verified these queries manually. We performed backward and forward citation chaining on key works to supplement older and newer studies. SciSpace served as an auxiliary tool for their rapid identification, final pool of candidates, and relevance scoring. However, when writing the manuscript, we cite and interpret only primary sources, not AI output. Translated with DeepL.com (free version) Empirical quantitative, qualitative, and mixed-methods studies published since 2020 (with an emphasis on the EU context and Gen Z samples aged approximately 16–30 or separable subsamples) were included which reported determinants of recycling intention or behavior (including domains such as textiles or e-waste). For each study, we extracted the EU country/continental context, sample and age, design, waste domain, key psychological, sociocultural, economic, and political factors, effects on intention or behavior, and limitations. The synthesis combined thematic analysis with conceptual mapping of determinants (attitudes, self-efficacy, personal/moral norms and identity; social norms and culture; economic incentives and barriers; regulatory/economic policy instruments), with particular attention paid to bridging the "intention–behavior gap."

2 Results and Discussion

2.1 Factors influencing genertation Z to recycle

The literature on factors motivating Generation Z in the EU to recycle presents a multifaceted understanding encompassing psychological, socio-cultural, political, and economic changes. While psychological and social factors have been well researched, economic and political influences are often given less attention, and cultural factors are not sufficiently

integrated into comprehensive models. The interplay between internal motivations and external conditions remains complex and sometimes contradictory, highlighting gaps in understanding how these factors synergistically interact and influence Generation Z's recycling behavior.

2.1.1 Psychological Factors

Psychological factors such as attitudes, self-efficacy, environmental values, intrinsic motivation, and personal norms consistently have a strong influence on Generation Z's motivation to recycle (Konstantinidou et al., 2024; Bhattarai et al., 2024; Enginkaya & SAĞLAM, 2024). This is demonstrated by numerous studies that effectively use proven behavioral theories, such as the Theory of Planned Behavior (TPB) and the Values-Beliefs-Norms Theory (VBN), to elucidate the psychological factors of Generation Z's recycling behavior (Puzzo & Prati, 2024; Ang et al., 2023; Annamdevula et al., 2022).

The Theory of Planned Behavior (TPB) developed by Icek Ajzen (1991) explains how human behavior is the result of a conscious decision mediated by behavioral intention. The stronger the intention, the more likely the individual is to perform the behavior. TPB identifies three main determinants of behavioral intention: (1) subjective evaluation of behavior (positive vs. negative), (2) perceived social pressure from the environment, and (3) belief in one's own ability to perform the behavior. TPB in the context of environmental behavior. TPB is very often used to explain recycling, waste sorting, and eco-friendly shopping.

The Value-Belief-Norm (VBN) theory developed by Stern et al. (1999; 2000) explains pro-environmental behavior as the result of internal moral mechanisms, not just rational decision-making. Behavior is driven by: (1) values, e.g., care for nature or social good, (2) beliefs, such as beliefs about environmental problems, personal responsibility, and the consequences of behavior, and (3) personal norms, i.e., an internal sense of moral obligation to act. In the context of environmental behavior, VBN serves to explain behavior based on moral reasons, long-term environmental habits, or behavior where there is no direct personal benefit.

Despite their theoretical robustness, some models show inconsistent findings regarding the role of attitudes and subjective norms, with some studies reporting a limited influence of attitudes on recycling intentions (Ang et al., 2023). Furthermore, moral obligation and intrinsic motivation are often under-researched outside specific cultural contexts, limiting generalizability (Annamdevula et al., 2022). Some studies report that attitude or environmental awareness does not have a significant impact on certain types of behavior (e.g., eco-friendly shopping in specific contexts) (Chhetri & Poudel, 2024) or on e-waste recycling intentions (Ang et al., 2023). Furthermore, some analyses have found that social pressure does not have the expected moderating effect (Enginkaya & Sağlam, 2024).

A synthesis of studies on the influence of psychological factors shows that the literature agrees that psychological factors, in particular self-efficacy, intrinsic motivation, environmental values, and self-identity are key determinants of Generation Z's recycling behavior in the EU, while the influence of attitudes and social pressure is strongly context-dependent. In many cases, it appears that internal values and motivation prevail over normative pressure from the environment.

2.1.2 Social and Cultural Factors

Social norms, peer and family influence, community expectations, and cultural contexts are important determinants of recycling motivation among young Europeans. Social references, including friends and influencers, influence subjective norms, which in turn influence behavioral intentions (Bhattarai et al., 2024; Dąbrowski et al., 2022) (Botetzagias et al., 2024). Cultural factors, including local waste management culture and national environmental orientations, modulate recycling behavior and policy support (Kountouris, 2022; Mintz et al., 2019).

Cross-cultural comparisons reveal variability in environmental concerns and pro-environmental activities among Generation Z across Europe (Jurna-Michilena et al., 2024; Andruszkiewicz et al., 2023). Many studies focus on samples from a single country, limiting international insights and failing to capture intragenerational diversity within the EU (Dąbrowski et al., 2022) (Kountouris, 2022). The complexity of cultural norms and their interaction with economic and political factors remains underdeveloped.

Some cross-cultural studies reveal differences in environmental concerns and behaviors among Generation Z based on nationality or type of settlement, such as lower environmental concerns among Portuguese Generation Z compared to older generations (Pinho & Gomes, 2024) or varying levels of environmental awareness among Polish and German youth (Andruszkiewicz et al., 2023). This variability may be due to cultural heterogeneity in environmental values, levels of economic development, local environmental issues, and socialization processes. Methodological differences (qualitative vs. quantitative), sample sizes, and geographical focus influence the findings

Digital and social media platforms play an increasingly important role in shaping environmental attitudes (Surmacz et al., 2024; Agrawal et al., 2023). The adoption of technologies, including mobile applications and social platforms, has a significant impact on promoting recycling behavior among Generation Z. Digital engagement increases environmental awareness and willingness to share or recycle, acting as a catalyst for sustainable behavior (Surmacz et al., 2024; Juaneda-Ayensa et al., 2020; Agrawal et al., 2023). The integration of technology into behavioral interventions supports motivation by increasing awareness of the impacts of behavior and strengthening social connectedness.

2.1.3 Economic Factors

Economic factors, including financial benefits and perceived convenience, are considered significant motivators for recycling and green purchasing among young consumers (Konstantinidou et al., 2024; Kremel, 2023; Li et al., 2023; Garg et al., 2023).

Some studies identify economic factors such as income, financial benefits, and perceived convenience as important motivators or barriers to recycling, with evidence that higher income may facilitate pro-environmental engagement (Konstantinidou et al., 2024; Li et al., 2023; Garg et al., 2023). Economic incentives and policy-driven financial benefits are recognized as effective external motivators (Pham et al., 2023; Li et al., 2023). However, some research highlights the contradictory effects of income and price sensitivity on behavior, with low impact or negative correlations observed in certain contexts (Konstantinidou et al., 2024; Lopes et al., 2024). Barriers such as affordability and availability limit the purchase of organic food despite positive attitudes (Mehdi et al., 2024).

Economic influences are often reported inconsistently, with some findings suggesting negligible or even negative effects of income on recycling behavior (Konstantinidou et al.,

2024). There is a lack of comprehensive analysis of how economic incentives interact with psychological and social factors, and regional economic differences within the EU are rarely addressed in depth (Konstantinidou et al., 2024; Pham et al., 2023).

Differences may relate to regional economic disparities, the product categories examined, and differing social norms regarding consumption. The perceived balance between costs and benefits and the availability of infrastructure may mediate the effectiveness of economic incentives.

2.1.4 Policy Frameworks and Regulatory Impact

Systematic reviews highlight the importance of regulatory and economic policy instruments in promoting recycling, with evidence that policies restricting opportunities are more effective than information campaigns alone (Pharm et al., 2023; Puzzo and Prati, 2024). Studies also highlight the need for policy combinations that take into account motivation, opportunities, and ability to promote behavioral change (Silvi and Padilla, 2021; Pham et al., 2023).

The heterogeneity of the regulatory environment across EU Member States complicates the generalization of findings, and the impact of policy on actual behavior versus intention is not always clearly distinguished (Agovino et al., 2024; Pham et al., 2023). There is consensus that regulatory and economic policy instruments that restrict or facilitate opportunities are generally effective in promoting recycling behavior, compared to information policies, which tend to be less effective on their own (Silvi and Padilla, 2021; Pham et al., 2023; Agovino et al., 2024; Garg et al., 2023). Studies emphasize the importance of government policy and incentives in shaping intentions and behavior (Pham et al., 2023; Garg et al., 2023).

There are conflicting findings regarding the impact of government initiatives, with some research suggesting limited or no direct impact of government sustainability initiatives on Generation Z's green practices (Agrawal et al., 2023), indicating differences in policy adoption or implementation. Differences may stem from contextual factors such as regional policy design, enforcement strength, target populations, and national socioeconomic conditions. Some studies focus on policy perceptions, while others focus on behavioral outcomes, potentially explaining differences in conclusions.

2.1.5 Educational Impact

Research shows that environmental education and awareness-raising positively influence motivation and behavior in the area of recycling, especially when tailored to the needs and cultural context of Generation Z (Konstantinidou et al., 2024; Tran et al., 2024; Alves et al., 2023). Knowledge of circular economy principles correlates with increased pro-environmental activities (Tran et al., 2024; Alves et al., 2023).

Despite positive correlations, educational programs often fail to translate awareness into lasting behavioral change, indicating a gap between intention and behavior (Sajid et al., 2023). Many studies point to a lack of practical skills and entrepreneurial competencies among young people to effectively implement circular economy principles (Krajnc et al., 2022). The impact of education is sometimes distorted by sociodemographic variables that are not always strictly controlled (Konstantinidou et al., 2024; Krajnc et al., 2022).

There is consensus that environmental education and literacy improve Generation Z's engagement in recycling and pro-environmental attitudes (Konstantinidou et al., 2024; Tran

et al., 2024; Alves et al., 2023; Krajnc et al., 2022). Education increases knowledge, skills, and perceived competence related to the circular economy and sustainable behavior (Alves et al., 2023; Krajnc et al., 2022). Social platforms and information campaigns also increase environmental awareness (Agrawal et al., 2023).

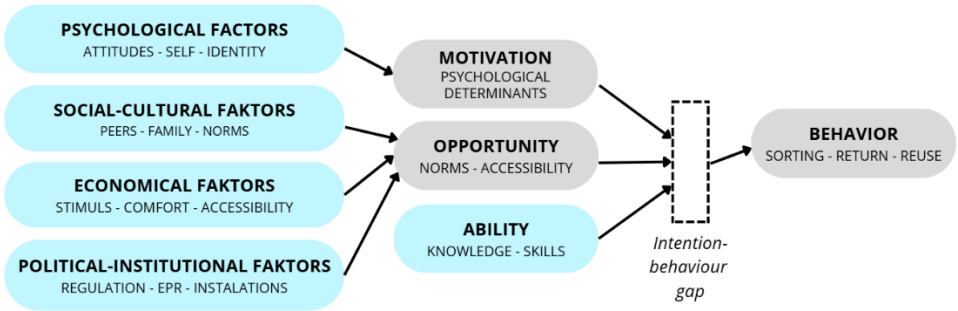
However, studies point to a persistent gap between knowledge and behavior, where increased awareness does not always translate into consistent sustainable behavior, and formal education may not sufficiently prepare young people for the practical application of bioeducation principles (Krajnc et al., 2022; Upendra et al., 2023). Some studies call for innovative methods beyond traditional education, such as qualitative approaches, to understand complex behavior (Bhattarai et al., 2024). The differences stem from differences in educational content, teaching methods, cultural receptivity, and the complexity of sustainable behavior. Limitations in formal curricula, lack of opportunities for practical application, and psychological or contextual barriers contribute to the gap between attitudes and behavior.

2.2 5-dimensional model of Gen Z motivation

Many studies assess factors in isolation or fail to adequately model their interactions. Cultural and economic contexts are often insufficiently integrated with psychological and political variables, leading to fragmented conclusions and limited practical applicability (Lopez and Legardeur, 2024; Silvi and Padilla, 2021).

A few studies attempt to synthesize psychological, social, economic, and political factors and recognize their complex interaction in shaping motivation to recycle (Silvi and Padilla, 2021; Lopez and Legardeur, 2024; Filho et al., 2024). The use of frameworks such as MOA (motivation-opportunity-ability) provides a comprehensive view of the analysis (Pham et al., 2023).

Fig. 1 5-dimensional model of Gen Z motivation



Source: K. Chomová, 2025

The Motivation-Opportunity-Ability (MOA) model for recycling serves as a comprehensive framework for understanding behavior. Motivation refers to the internal drive that compels individuals to engage in specific behaviors – psychologic factors. Opportunity encompasses the external conditions that facilitate or hinder behavior – social-cultural and economic factors. Ability refers to the skills and resources an individual possesses to perform a behavior. This model emphasizes the interplay between an individual's motivation, the

opportunities available to them, and their ability to act, which collectively influence behavioral outcomes.

The gap between intention and behavior remains a significant obstacle, with studies highlighting the need for targeted campaigns to overcome practical and psychological barriers (Sajid et al., 2023; Annamdevula et al., 2022). Sociodemographic differences further shape these challenges.

Policymakers should design multifaceted interventions that simultaneously target internal motivations (e.g., strengthening environmental values and self-efficacy) and external conditions (e.g., social norms, convenience, and infrastructure) to effectively promote recycling behavior among Generation Z (Silvi and Padilla, 2021; Pham et al., 2023; Pivetti et al., 2020).

Environmental education programs tailored to Generation Z should emphasize not only knowledge dissemination but also skill building and moral engagement to foster a stronger environmental identity and personal commitment to recycling (Krajnc et al., 2022; Sun et al., 2024; Annamdevula et al., 2022).

Social marketing and communication strategies should leverage influential social references such as family and peers and use digital platforms to reinforce normative pressures and environmental awareness, thereby increasing participation in recycling (Agrawal et al., 2023; Botetzagias et al., 2024; Juaneda-Ayensa et al., 2020).

Economic incentives and regulatory policies that improve the convenience and accessibility of recycling channels are key. Evidence suggests that offline and online recycling options should be optimized to address demographic differences within Generation Z (Li et al., 2023; Pham et al., 2023).

Businesses and marketers targeting Gen Z consumers can benefit from aligning product offerings and green marketing strategies with this cohort's environmental concerns, perceived benefits, and quality expectations to promote sustainable consumption and recycling behaviors (Lopes et al., 2023; Lopes et al., 2024).

International and regional differences in recycling motivation require localized policy frameworks that take into account cultural, socioeconomic, and infrastructural contexts to increase the effectiveness of recycling programs across the EU (Dąbrowski et al., 2022; Agovino et al., 2024).

Conclusion

The available literature shows that Generation Z's motivation to engage in recycling in the European Union is shaped by a complex interplay of psychological, social, economic, political, and cultural factors. From a psychological perspective, attitudes, self-efficacy, intrinsic motivation, personal and moral norms, and environmental concern appear to be strong predictors of recycling and pro-environmental behavior. These internal drivers are often reinforced by environmental education and awareness-raising programs, which not only improve knowledge but also promote a stronger environmental self-identity and intrinsic motivation. Nevertheless, a gap persists between environmental awareness and long-term behavioral change, suggesting that knowledge alone is insufficient without supportive external conditions.

Social and cultural influences play a key role in shaping the norms, peer and family influences, and institutional pressures that encourage Generation Z to recycle. Social norms,

particularly those rooted in local waste management cultures and digital engagement platforms, significantly influence recycling intentions and behaviors. However, internal motivations often outweigh social pressure, suggesting that personal values and identity are more effective levers for behavioral change than normative coercion. Cultural diversity in the EU adds further layers of complexity, as regional differences in environmental commitment and trust in policies influence recycling practices, highlighting the need for context-specific interventions.

Economic incentives and barriers are recognized as important, but are reported inconsistently in the literature. Financial benefits, convenience, and willingness to pay act as motivators, but income effects on recycling behavior are mixed and sometimes negligible. Economic barriers related to availability and affordability can hinder participation, especially in less affluent regions. This underscores the importance of integrating economic aspects with psychological and social motivators when designing effective interventions.

Public policy frameworks, particularly regulatory and economic instruments that limit opportunities for unsustainable behavior or facilitate sustainable choices, are more effective than information campaigns alone. Targeted policies aligned with local socioeconomic and cultural contexts strengthen motivation and participation in recycling. However, the variability in policy effectiveness across EU Member States and limited evidence on long-term impacts suggest a need for adaptive, multi-level policy mixes that combine the dimensions of motivation, opportunity, and capability.

Education remains a key foundation, but it must be coupled with an enabling environment and supportive policies to bridge the gap between intention and behavior. Future efforts should focus on the holistic integration of these dimensions, taking into account regional diversity, in order to promote sustainable and scalable pro-environmental behavior in this key demographic group.

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Public Policy and Creative Economy: Building Innovation Ecosystems for Human-Centered Development[1]

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Abstract

In the context of the transition to an innovation-based economy, creative industries are becoming a key source of sustainable growth and human capital development. The purpose of this study is to identify the role of the state in shaping and supporting creative ecosystems. The methodological framework includes systemic, institutional, and comparative analysis, as well as the synthesis of expert opinions. The results reveal the main directions of state regulation that foster the development of the creative economy: support for education and R&D, protection of intellectual property, and promotion of innovation. The role of creative education as an element of the national innovation system is emphasized. The study concludes that an integrated public policy is essential to embed creative ecosystems into the socio-economic structure of the country and ensure sustainable innovative growth.

Key words

creative economy; innovation policy; government regulation; creative ecosystems; creatosphere; human-centered development; intellectual property

JEL Classification: O31, O38, Z11

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Introduction

Modern trends in the global economy indicate the growing importance of creative industries in the development of national economies at all levels. In the context of the transition to an innovation-driven model of growth, the creative economy is becoming a crucial component that contributes to building sustainable and competitive national economic systems. One of the key factors determining the effectiveness of the creative economy is the role of the state as the main regulator capable of creating favorable conditions for the sustainable development of innovation, education, and creative processes.

The issues of formation and implementation of the creative economy have become the subject of numerous studies; however, a deeper and more integrated approach is required to fully understand and effectively apply the concept of the creative economy in practice, particularly in the context of public administration. Special attention should be paid to the creation of conditions for maintaining creative ecosystems, which, on the one hand, ensure

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creative activity and innovative dynamics, and on the other hand, provide for the harmonious interaction among various spheres, including science, education, and business.

1 Methodology

The purpose of this study is to analyze the role of the state in the development of the creative economy, to examine the mechanisms of government support and regulation, and to determine strategies for shaping an effective public policy framework within the context of creative industries. Special attention is given to identifying the challenges and prospects for the development of public administration in this field, as well as to potential transformational changes in the governance structure of the creative economy.

The methodological basis of the research is grounded in systemic, institutional, and comparative approaches, which make it possible to consider the creative economy as an interconnected system of social, economic, and cultural processes.

The empirical foundation of the study includes regulatory and legal acts of the Republic of Kazakhstan, strategic documents, statistical data, as well as academic publications by domestic and foreign researchers in the field of creative economy and state regulation.

The results of the analysis provide practical recommendations for improving public policy in the sphere of creative industry support, aimed at developing sustainable ecosystems and enhancing the country's innovative potential.

2 Results and Discussion

In developed countries, the state plays a key, and often decisive, role in the creation of national innovation systems and in ensuring their effective functioning. Among the main functions of the state in a creative society are:

- ensuring the freedom of activity of creative actors and the protection of intellectual property;
- forming an institutional environment that most effectively facilitates both the creation and dissemination of innovations.

As the experience of global financial and economic crises has shown, it is also essential to have an effective system of mechanisms and instruments to maintain the stability of the creative economy in both its quantitative and qualitative dimensions. For this purpose, the fiscal and tax system of the country should be structured in the interests of society as a whole, rather than of individual social groups — which is, in itself, a complex task (V. Zhuravlev, 2010).

It should be emphasized that the study of potential models of public administration in the creative economy is classified by the research community as complex. This is due to the fact that the integration of the creative economy concept into the existing system of public administration may, in our view, be accompanied by significant transformational shifts in the foundations of state management.

This is evidenced by the limited scope of research in this area; however, there are analytical works focused on the theoretical understanding of the so-called *creatosphere* — a system based on the priorities of intellectual property, high-tech production, continuous

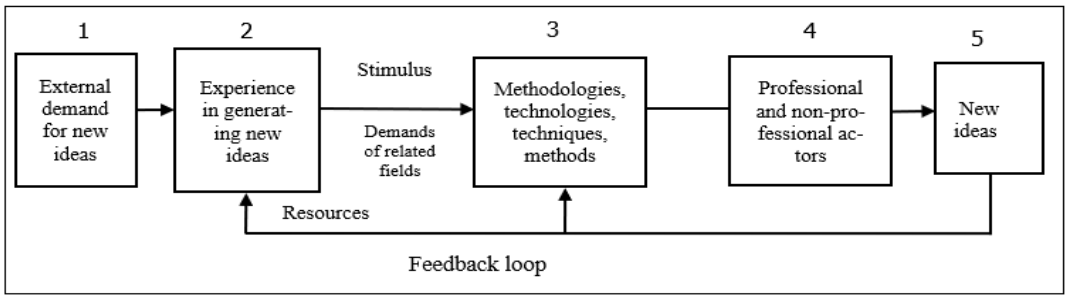
education, and the growing need for individual self-realization, which collectively define the creativity of existence within a human-centered economy.

In particular, S. Nasyrova, using the technology of functional system analysis, developed a model reflecting the mechanism of functioning of the creatosphere within the framework of a human-centered economy (see Fig. 1).

The key components of this model include the following aspects:

- External influence — the need for new ideas (Block 1);
- Memory — the experience of generating ideas, and resources — creative abilities and "limited" freedom (Block 2);
- Programming block — methodologies, technologies, and methods for idea generation (Block 3);
- Executive organ — represented by professional and non-professional actors (Block 4);
- Result — new ideas (Block 5).

Figure 1. Model of the Functioning of the Creatosphere



Source: S. Nasyrova, 2024, p. 2926.

The expert believes that the key value in understanding the functioning of the creatosphere lies in the fact that this conceptual model allows for the comprehension of the idea generation process, which serves as a catalyst for the development of the entire economic system (S. Nasyrova, 2024).

It becomes evident that it is impossible to achieve the maximum or minimum values of all elements of this human-centered system simultaneously. At the same time, the manifestation of the dialectical principle of "unity and the struggle of opposites" becomes the foundation for the development of a human-centered economy, since contradictions between its elements ensure movement toward progress rather than stagnation. Consequently, this scheme of contradictions implies the sustainable development of the entire system by achieving a "zero-level" equilibrium, where balanced development of various spheres of the human-centered economy is ensured, thereby contributing to the comprehensive development of the individual.

Thus, this scheme reflects the homeostasis of the human-centered economy within the complex interaction of its opposing elements. According to S. Nasyrova, such an understanding of the essential manifestation of the creatosphere makes it possible to assert its defining role in the human-centered economy. Overall, the creatosphere becomes a kind of creative

lever for economic development, representing a comprehensive phenomenon closely interrelated with all spheres aimed at meeting the objectively arising and growing human needs (S. Nasyrova, 2024).

In our view, such perspectives on the nature of the creative economy concept, though scientifically valid, may sometimes lead researchers into excessive theoretical generalizations. At the same time, there are also more practice-oriented studies of the creative economy concept in a systemic context, focusing on its integration into the socio-economic framework. From this standpoint, research in the field of creative ecosystems appears to be of particular interest.

The main premise of this theoretical construct is that, on the one hand, creative entrepreneurs often do not perceive themselves as business actors, thereby distorting their social identity; on the other hand, creative individuals more freely combine the values of creativity and entrepreneurship within creative ecosystems.

However, according to M. Abuzyarova, this gives rise to an opportunistic behavioral model among creative industry actors, where the business dimension of the economy is often either ignored or perceived as a constraint on free creativity. As a result, many creative actors prefer to operate within the consistency of creative practices, where creativity itself is viewed as a way of life.

Within the creative environment, there is a prevailing opinion that there is a significant risk that economic interests may suppress creativity, leading entrepreneurs to believe that they are forced to choose between creative values and the economic advantages of business activity — the latter being regarded merely as a platform for realizing cultural and creative ideas.

It should be noted that modern researchers view the prospects for the development of creative ecosystems differently. Some adhere to the agglomeration approach, based on the understanding that creative ecosystems can effectively develop only under conditions of a shared physical space and direct personal interaction, which are essential for productive creative collaboration.

Other scholars, however, prefer to view the creative ecosystem as a network of dynamic relationships among actors — individuals, institutions, and infrastructural entities — whose purpose is to generate economic, social, and cultural value grounded in creative and innovative activity. This approach more accurately reflects the internal relationships among participants within the ecosystem, allowing M. Abuzyarova to identify the following conceptual interpretations of creative ecosystems (Table 1).

Table 1. Main Characteristics of the Creative Ecosystem

Characteristics	**Essence of the Creative Ecosystem**
Object of management	Management of product creation with creative value
Relations among participants	Collaborative creativity
Basic function	Generation of creative ideas and products
Basic product	Production of new creative values
Main participant	Specializes in production
Key actors	People as the source of creativity generation
Nature of the internal environment	Environment of creative exchange
Network form	Horizontal network connections

Source: M. Abuzyarova, 2023, p. 1763.

It can be concluded that the ecosystem assessment of species characteristics allows us to consider the creative ecosystem as an independent object of research and to assume that the ecosystem approach can be fully applied to the creative industries.

At the same time, it should be noted that two main formats are generally distinguished in the creation of ecosystems focused on value production:

- First, business ecosystems are primarily based on transactions and actors who can use available mechanisms and instruments. Ecosystems of this type are typically formed around banks or various IT structures that provide client access.
- Second, the foundation lies in a platform-based mechanism for the transfer of knowledge, including creative ideas, where participants possess and share a key value or method for obtaining innovations or critical knowledge. Around this, a system of balanced partnership is built. In the case of a creative ecosystem, the key value is the *creative idea* itself, and the ecosystem functions as a community of partners who collectively complement and develop this central creative concept, jointly forming ecosystem solutions.

A distinctive feature of creative ecosystems is that they can be considered a special fertile environment for the development of creativity and for the qualitative growth of the actors directly involved in it. This process stimulates the formation of civil society, composed of active individuals who generate an increasing demand for innovations and creative industry products. These individuals are motivated to transform their environment into a more comfortable and adaptive one and are capable of initiating bottom-up initiatives — all of which represent valuable attributes of human capital (Abuzyarova, 2023).

A considerable number of studies are associated with the integration of the education factor into the system of creative economy management. It is widely recognized that the traditional educational system does not always contribute to the development of creative abilities, as it is based on memorization and the accumulation of factual knowledge. Moreover, everyday life processes often suppress the creative potential of individuals. Therefore, the development of creativity is possible only within specially organized environments that include both special tasks aimed at developing creative thinking and creativity, as well as academic disciplines of a creative orientation.

Broadly speaking, creative education is aimed at developing an individual's creative abilities and forming in their consciousness professional attitudes toward innovation, identifying problems and challenges in their activities, conducting independent qualitative analysis, and, on this basis, understanding reality, revealing individuality, and transforming knowledge into the potential of self-discovery and self-development (Levchenko, 2019).

In this extended sense, creative education should be regarded as an integral element of the National Innovation System (NIS), which in developed countries serves as a key mechanism for innovation-driven economic growth. The NIS defines the interrelations between science, research, and production through commercialization, scaling, and the implementation of innovative products in industrial processes.

One of the key subsystems of the NIS connects education and science to train specialists with an innovative mindset. Experts in this field propose several measures in this regard:

- the involvement of young scientists in the integrated processes of scientific research and education, as well as the removal of barriers to the adaptation and reproduction of scientific personnel, which would enhance the overall effectiveness of the innovation system;
- the establishment of strong socio-economic links among the state, science, higher education, society, and business — achievable, among other means, through the formation of socially active universities (SAUs).

Experts define SAUs as educational institutions whose primary mission is to form and maintain a highly innovative environment within their service area. This is achieved through the use of innovation-oriented continuous educational programs and the implementation of applied scientific research.

Specialists in innovation-oriented human resource development believe that such universities should operate on the following principles: the harmonious combination of two functions — education and commercialization of university research results; openness to society, which implies the involvement of non-academic representatives in educational processes; the development of entrepreneurial and project-based thinking both within universities and in their external networks, ensuring ongoing exploration of new forms of cooperation with business, government, and non-profit organizations; the presence of business incubators or small innovative enterprises producing both social and commercial projects.

In our view, creative education fits organically into this NIS subsystem through the system of socially active universities, enriching it with creative content.

It should be noted that the concept of these universities aligns closely with the concept of research universities (RUs), which are seen as potential instruments for effectively integrating education, science, and production — thus generating a significant synergistic effect in the development of innovation clusters.

Research universities act as centers of advanced technologies, bringing together applied research institutions and design organizations. Hence, both SAUs and RUs, by integrating creative education with the scientific and educational environment, can contribute to the establishment of Creative Industry Support Centers, which are of exceptional importance for regional and urban creative development.

Generally, a review of research results shows that:

- most studies address only general issues, such as defining key concepts of creative activity, identifying creative sectors, and, to a lesser extent, evaluating the economic and other efficiencies of the creative economy concept;
- there is an evident lack of research focused on the development of models for public administration of the creative entrepreneurship sector, including macro-, meso-, and micro-levels of governance.

In our opinion, the absence of such studies negatively affects both the evolution of the creative economy concept and the development of creative industries themselves. From the standpoint of effective management theory, the more complex the object of governance, the more complex the system required to manage it effectively — particularly when its goal is sustainable development.

Kazakhstani expert K. Gribanovskaya notes that, despite the adoption of the *Concept 2025* and the legislative classification of creative industries, there remain uncertainties in building a coherent system of public administration for the creative sector. Indeed, there is still insufficient understanding of the essential characteristics of creative industries, making it difficult to forecast their development and leading to vague and overly broad support programs — legislative, financial, and institutional alike.

Such doubts stem from the long-standing failures of numerous state, sectoral, and regional development programs, which prompted the recent shift toward project-based management. However, the adopted national projects have not yet produced the expected results, as reflected in the reports of the National Audit Chamber of Kazakhstan.

Furthermore, there is a delay in establishing official statistical accounting in the field of creative industries. As a result, each region conducts data collection independently and inconsistently, leading to incomparable statistics across regions. This makes macro-level analysis of creative industry development extremely difficult and undermines the basis for building an effective system of public management for the creative economy concept.

From a logical standpoint, if the creative economy is part of the national economy and its primary goal is the commercialization of creative results, then the bodies responsible for entrepreneurship — regional business departments and the Ministry of National Economy — should be the key supervising structures. However, there is currently a lack of clear coordination among different agencies overseeing individual industries and the creative sector as a whole (Gribanovskaya, 2019).

In our opinion, a key element of the management framework should be the evaluation and forecasting block, designed to assess the socio-economic effectiveness of creative industry development. This necessitates the creation of a specialized analytical and forecasting toolkit for performance evaluation, both as a feedback mechanism and as an instrument for medium- and long-term projections.

In this regard, we can agree with L. Borovinskaya and other experts that predictive data analytics represents an essential and contemporary tool for strategic planning. Moreover, creative class actors increasingly rely on economic-statistical methods to forecast trends, assess potential opportunities and risks, and guide future decision-making (Borovinskaya, 2022).

Conclusion

Based on the analysis of international models, it can be concluded that Kazakhstan needs to adapt the best global practices, taking into account the specific characteristics of its internal economy, as well as its social and cultural context. The introduction of effective mechanisms of state regulation — such as the creation of specialized funds and agencies to support creative industries — can significantly accelerate the development of the sector.

Policy Recommendations. To stimulate the growth of the creative economy in Kazakhstan, the following measures are recommended:

- Develop a comprehensive strategy for supporting startups and small businesses in the field of creative industries.
- Increase investment in educational programs aimed at developing creative skills and entrepreneurship in creative sectors.
- Apply more flexible approaches to taxation and regulation to create favorable conditions for creative enterprises.
- Strengthen coordination between government bodies and the private sector to establish effective mechanisms of state support.

Prospects for Development. In the long term, the development of the creative economy in Kazakhstan can become an important driver of economic growth, creating new jobs and improving the cultural environment of the country. It is essential that state policy focuses on creating conditions for sustainable growth and integrating creative industries into the global economy.

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Exploring Export Potential in EU-New Zealand Trade[1]

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Abstract

The EU-New Zealand Free Trade Agreement has emphasised the value of their trade relationship and encouraged interest in deepening their cooperation. The aim of this paper is to evaluate foreign trade between the European Union and New Zealand and to highlight the prospects for further trade. New Zealand's most important partners within the EU counties are Germany and the Netherlands. EU exports to New Zealand mainly industrial commodities such as machinery, vehicles, and pharmaceuticals, while New Zealand exports mainly agricultural products. The Revealed Comparative Advantage index which was used in the article provided a base for decision making in future trade. Based on the results, both sides can benefit mainly from trading HS 45 - Cork and cork products.

Key words

European Union, New Zealand, foreign trade

JEL Classification: F10, F13, F15

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Introduction

The European Union (EU) is one of the biggest players in international trade and can be considered the most successful international economic integration in the world (Baláž et al., 2019). By creating a single market, it has enabled the free movement of goods, services, people, and capital, thereby strengthened the competitiveness of its member states and created the conditions for more effective trade relations with countries outside its territory. The EU has approximately 130 trade agreements in various stages of validity. In addition to reducing and eliminating tariffs, these agreements also regulate non-tariff barriers (European Parliament, 2024).

New Zealand is one of the EU's most distant partner countries. The EU and New Zealand share a deep commitment to democracy, the rule of law, and respect for human rights (EEAS, 2021). The relationship between the EU and New Zealand dates back to 1960, when New Zealand established diplomatic relations with the then European Community (EC). Since 1975, regular informal meetings have been held between the EC and New Zealand to discuss mutual relations and exchange information on developments in international affairs of interest to both parties. In 1991, an agreement was signed between the EC Commission and the New Zealand government on cooperation in science and technology. A breakthrough in EU-New Zealand relations came in May 1996, when the New Zealand Foreign Minister requested

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the conclusion of an umbrella agreement or treaty with the EU that would consolidate the various consultative agreements between the two parties. The preparation took longer than expected, as the EU demanded the inclusion of an article on human rights, while New Zealand insisted on the separation of economic and political issues. Subsequently, in October 2016, EC representative Federica Mogherini and Foreign Minister Murray McCully signed the Partnership and Cooperation Agreement (PARC) in Brussels (GIGA, 2016, Cihelková, 2003). This agreement laid the foundation for closer cooperation not only at the political level, but also at the economic level. Based on the existing PARC agreement, negotiations on a Free Trade Agreement between the EU and New Zealand began in 2018. The EU-New Zealand Free Trade Agreement was signed in Brussels on July 9, 2023 and entered into force on May 1, 2024. The implementation of the agreement demonstrates their joint efforts to deepen economic integration. Given the complementary structure of the economies, with the EU as a producer of industrial products and New Zealand as a major exporter of agricultural products, this agreement creates the conditions for mutually beneficial trade.

In this paper, we have assessed the development and structure of foreign trade relations between the EU and New Zealand, with an emphasis on identifying commodities in which the parties have comparative advantages and disadvantages. The analysis provides an important basis for strategic decision-making in the field of trade policy and allows for better prediction of future developments in mutual relations.

1 Methodology

The main objective of this paper was to evaluate foreign trade between the EU and New Zealand based on a selected single-factor evaluation indicator and to highlight the prospects for trade between the territories. Using the selection method, we chose suitable literature from Slovak and foreign authors. We used data from the International Trade Centre (ITC), ministries, and the European Commission. The commodity structure of foreign trade was classified according to the HS2 Harmonized System Nomenclature. Other special methods were also used to make foreign trade data more transparent, mainly exact, or graph and table representations, which we based on available information from the internet and the RCA index calculation.

We focused on the relations between the EU and New Zealand, set the main objective, methodology, and research methods. We then looked at foreign trade between the EU and New Zealand. We identified New Zealand's most important trading partners among the EU countries. We then examined the commodity structure of trade, which commodities are most imported and exported. We also used the Revealed Comparative Advantage (RCA) index to determine which commodities' exports represent comparative advantages and disadvantages for the parties under review. Furthermore, we used the inductive method, deriving general statements from individual facts, to evaluate foreign trade and mutual trade relations.

The research is limited to data from 2020-2025, so it would be good to keep looking into deeper cooperation in future research by building a model and checking out the variables that have the biggest impact on trade between the two countries. As the years go by, the impact of the EU-New Zealand Free Trade Agreement on mutual trade will become visible.

The RCA index compares a country's export rate in each commodity group with country's total export share of total world exports. It indicates whether a country has a comparative advantage in exporting a given commodity (UNCTAD, 2022).

The formula for calculating RCA:

$$RCA = ((Xij/Xi))/((X.j/X..)) \quad (1)$$

Xij = exports of country 'i' in commodity group 'j'

Xi = total export of the country

X.j = world export in commodity group 'j'

X.. = total world export

RCA result:

If a country has a revealed comparative advantage for a given commodity (RCA>1), it is assumed to be a competitive producer and exporter of that commodity.

The higher the RCA value of a country for commodity i, the higher its export strength in the commodity i. If RCA1<1, then we speak of a comparative disadvantage.

2 Results and Discussion

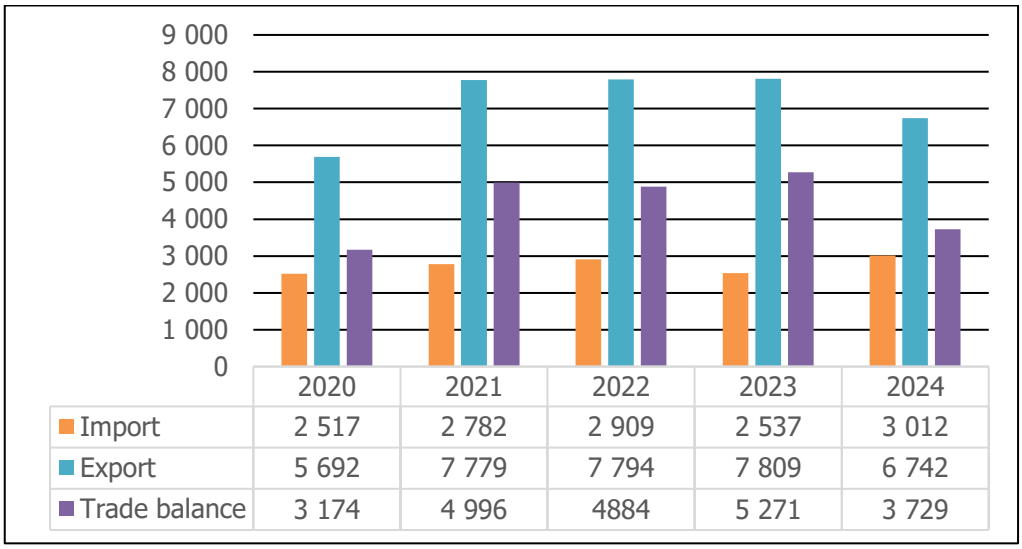
The European Union is one of New Zealand's largest trading partners (MZVaEZ SR, 2024, Blot, Li, 2023).

In 2020, due to the Covid-19 pandemic and related measures, the value of EU imports of commodities from New Zealand fell by 11.55%. However, New Zealand recovered quickly from the pandemic, and in 2021, the EU imported 1.20% more from New Zealand than in the previous year. In 2022, imports worth USD 2 909 million were recorded.

Because New Zealand closed its borders for two months in 2020 due to the Covid-19 pandemic, EU´s exports to New Zealand were at their lowest level for the period under review, at USD 5 692 million. This represented a 15.79% decline in exports. Exports in 2021 rose by USD 2 087 million. The growth in export value continued until 2023. In 2024, exports fell to USD 6 742 million. The decline in EU exports to New Zealand in 2024 was due to weaker demand from New Zealand for durable goods such as machinery and vehicles (MFAT, 2024).

During the studied years, the EU has exported more to New Zealand than it has imported from it. For this reason, the EU has a trade surplus with New Zealand and New Zealand has maintained a trade deficit with the EU. Taking into consideration the years that were reviewed, the trade balance was highest in 2023 (USD 5 271 million).

Graph 1 EU trade in goods with New Zealand (2020-2024, USD mil.)



	2020	2021	2022	2023	2024
Import	2 517	2 782	2 909	2 537	3 012
Export	5 692	7 779	7 794	7 809	6 742
Trade balance	3 174	4 996	4884	5 271	3 729

Source: own preparation based on ITC, 2025a data

Tab. 1 shows that among the EU countries, Germany and the Netherlands import the most from New Zealand. During the period studied, Germany's most significant import from New Zealand was recorded in 2020, amounting to USD 599 million. The main commodities imported by Germany from New Zealand included meat and edible meat offal, nuclear reactors, optical parts and accessories, dairy products, and beverages (ITC, 2025b). The Netherlands' most significant imports were recorded in 2024 and amounted to USD 697 million, which is also New Zealand's highest recorded export to an EU country. The main commodities exported by New Zealand to the Netherlands in 2024 included meat and edible meat offal, dairy products, oilseeds and oil fruits, albuminoid substances, aluminium and aluminium products (ITC, 2025c). Other important EU countries to which New Zealand exports include France and Italy.

Tab. 1 Top EU Importing Countries from New Zealand (2020-2024, bil. USD)

Country	2020	% Value	2021	% Value	2022	% Value	2023	% Value	2024	% Value
Total import of EU from NZ	2 517	100	2 782	100	2 909	100	2 537	100	3 012	100
Netherlands	436	17.32	544	19.55	674	23.17	613	24.16	697	23.14
Germany	599	23.80	549	19.73	534	18.36	395	15.57	483	16.04
European Union Nes	476	18.91	572	20.56	445	15.30	304	11.98	560	18.59
France	296	11.76	292	10.50	296	10.17	293	11.55	307	10.19
Italy	144	5.72	168	6.04	190	6.53	147	5.79	168	5.58
Rest of the EU import from NZ	566	22.49	657	23.62	770	26.47	785	30.94	797	26.46

Source: own preparation based on ITC, 2025a data

In general, Germany is a key trading partner for New Zealand and has strongly supported efforts to achieve the Free Trade Agreement between the EU and New Zealand. The main products that Germany exports to New Zealand are cars, machinery, pharmaceutical products, and tractors. Over the past 25 years, German exports to New Zealand have increased by approximately 5% per year. (OEC, 2024, Kanning, 2023). Germany imported the most from New Zealand in 2021. In recent years, New Zealand has imported approximately twice as much from Germany as from Italy. The most significant import from France was recorded in 2023, with a value of USD 1 076 million. New Zealand also imports from the Netherlands and Spain, with values that are similar.

Tab. 2 Top EU Exporting Countries to New Zealand (2020–2024, mil. USD)

Country	2020	% Value	2021	% Value	2022	% Value	2023	% Value	2024	% Value
Total export from the EU to NZ	5 692	100	7 779	100	7 794	100	7 809	100	6 742	100
Germany	1 756	30.85	2 401	30.87	2 273	29.16	2 232	28.58	1 936	28.72
Italy	834	14.65	1 117	14.36	1 172	15.04	1 164	14.91	985	14.61
France	610	10.72	922	11.85	961	12.33	1 076	13.78	894	13.26
Netherlands	358	6.29	465	5.98	476	6.11	461	5.90	412	6.11
Spain	357	6.27	350	4.50	423	5.43	439	5.62	396	5.87
Rest of the EU export to NZ	1 777	31.22	2 524	32.45	2 489	31.93	2 437	31.21	2 119	31.43

Source: own preparation based on ITC, 2025a data

The EU import from New Zealand consists mainly of meat, fruit, nuts, dairy products, fish, seafood, and albuminoid substances. Over the last five years, except for the year 2021, when fruit was the largest EU import from New Zealand, EU countries imported mostly meat from New Zealand. In 2022, the increase in New Zealand´s meat export was due to an increase in mainly red meat export, worth approximately USD 7 million. This represents an increase of 13% compared to 2021 (Garra, 2023). The dairy industry and agriculture are New Zealand's most internationally connected sectors. In 2022, the most significant increase in export was recorded for dairy products. Together the dairy sector employs nearly 55 000 people in New Zealand (Gray, Crewther, 2023).

Tab. 3 Top EU Imports of Commodities from New Zealand (2020–2024, mil. USD)

HS2 code	Name of the commodity	2020	% Value	2021	% Value	2022	% Value	2023	% Value	2024	% Value
The EU total import of commodities from NZ		2 517	100	2 782	100	2 909	100	2 537	100	3 012	100
02	Meat and edible meat offal	564	22.41	544	19.55	725	24.92	662	26.09	689	22.88
08	Edible fruit and nuts...	541	21.49	644	23.15	481	16.53	339	13.36	593	19.69
04	Dairy products, birds' eggs....	101	4.01	129	4.64	230	7.91	180	7.09	214	7.10
03	Fish and crustaceans, molusks...	126	5.01	145	5.21	153	5.26	160	6.31	196	6.51
35	Albuminoidal substances...	97	3.85	120	4.31	146	5.02	90	3.55	60	1.99
Other commodities		1088	43.23	1 200	43.13	1 174	40.36	1106	43.59	1260	41.83

Source: own preparation based on ITC, 2025a data

Over the period of five years which were reviewed, the EU exported mainly HS 84 - Nuclear reactors, boilers, machinery, mechanical appliances and parts thereof to New Zealand. In 2021, imports of this group increased by 27.22%. However, in 2022, imports of this group decreased by 0.57%. Other important commodities that New Zealand imports from the EU include vehicles (mainly from Germany), medicines (mainly from Belgium, Germany, and Switzerland), electrical machinery (mainly from France), and aircrafts.

Overall, EU exports to New Zealand focus on industrial goods, while New Zealand's exports to the EU are dominated by agricultural products.

Tab. 4 Top EU Exports of Commodities to New Zealand (2020–2024, mil. USD)

HS2 code	Name of the commodity	2020	% Value	2021	% Value	2022	% Value	2023	% Value	2024	% Value
The EU total export of commodities to NZ		5 692	100	7 779	100	7 794	100	7 809	100	6 742	100
84	Nuclear reactors, boilers, machinery...	1 234	21.68	1 570	20.18	1 561	20.03	1 624	20.80	1 500	22.25
87	Vehicles other than railway...	937	16.46	1 525	19.60	1 458	18.71	1 564	20.03	1 049	15.56
30	Pharmaceut. products.	430	7.55	736	9.46	703	9.02	644	8.25	557	8.26
85	Electrical machinery...	356	6.25	414	5.32	437	5.61	452	5.79	438	6.50
88	Aircraft, spacecraft...	83	1.46	200	2.57	220	2.82	290	3.71	208	3.09
Other commodites		2 652	46.59	3 334	42.86	3 415	43.82	3 235	41.43	2 990	44.35

Source: own preparation based on ITC, 2025a data

Moving on, tab. 5 lists the commodities in the harmonized customs tariff for which the EU had the greatest comparative advantage in 2023 and in 2024. For these commodities, the RCA index value is always higher than 1, which means that the EU has a comparative advantage in the production of these products. For comparison, we have also included the value for New Zealand for these commodities. Interestingly, some of the commodities also represent a comparative advantage for New Zealand.

The commodity group HS 45 - Cork and cork products represents the largest revealed comparative advantage for the EU, with a value of 3.02. Cork is a natural product whose trees cover more than 2 million hectares of land in Europe and are a source of livelihood for thousands of people (Ciesla, 2002). Other commodity groups that represent revealed comparative advantages include HS 06 - Live trees and other plants, HS 04 - Dairy products, HS 30 - Pharmaceutical products, and HS 19 - Cereal preparations.

Tab. 5 Comparison of the EU´s Revealed Comparative Advantages with NZ´s results (2023 and 2024)

HS2 code	Name of the commodity	RCA EU 23	RCA EU 24	RCA NZ 23	RCA NZ 24
45	Cork and articles of cork	3.02	3.10	0.0044	0.0105
06	Live trees and other plants; bulbs, roots and the like; cut flowers...	2.31	2.34	0.88	0.81
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin...	2.17	2.26	64.94	60.66
30	Pharmaceutical products	2.12	2.18	0.26	0.25
19	Preparations of cereals, flour, starch or milk; pastrycooks' products	1.88	1.92	8.42	8.30

Source: own calculation based on ITC, 2025a,d data

The EU's biggest comparative disadvantages are in commodity groups HS 26 – Ores, slag and ash, HS 67 – Prepared feathers and down and articles made of feathers or down, artificial flowers; articles of human hair, and HS 52 – Cotton. The EU also has a comparative disadvantage in HS 71 – Natural or cultured pearls, precious or semi-precious stones, precious metals and articles thereof, imitation jewellery, coins, and HS 14 – Vegetable materials for plaiting; vegetable products not elsewhere specified or included. All of these commodities also represent a comparative disadvantage for New Zealand.

Tab. 6 Comparison of the EU´s Revealed Comparative Disadvantages with NZ´s results (2023 and 2024)

HS2 code	Name of the commodity	RCA EU 23	RCA EU 24	RCA NZ 23	RCA NZ 24
26	Ores, slag and ash	0.14	0.14	0.0092	0.21
67	Prepared feathers and down and articles made of feathers or of down...	0.18	0.20	0.08	0.06
52	Cotton	0.32	0.29	0.01	0.03
71	Natural or cultured pearls, precious or semi-precious stones...	0.33	0.36	0.34	0.45
14	Vegetable plaiting materials; vegetable products...	0.37	0.40	0.47	0.61

Source: own calculation based on ITC, 2025a,d data

For New Zealand, the commodity group HS 04 – Dairy products, bird eggs, natural honey, edible products of animal origin – represents the greatest comparative advantage. This commodity represents a comparative advantage for both sides, but significantly more so for New Zealand. The commodity group HS 05 - Products of animal origin ranks second. The third-ranked class HS 02 - Meat and edible offal, is also related to the first two classes. The results show that agriculture is of enormous importance to New Zealand but also important to the EU.

Tab. 7 Comparison of NZ´s Revealed Comparative Advantages with the EU´s results (2023 and 2024)

HS2 code	Name of the commodity	RCA NZ 23	RCA NZ 24	RCA EU 23	RCA EU 24
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin...	64.94	60.66	2.17	2.26
05	Products of animal origin, not elsewhere specified or included	22.91	18.24	1.26	1.23
02	Meat and edible meat offal	19.81	17.19	1.35	1.33
35	Albuminoidal substances; modified starches; glues; enzymes	19.38	15.95	1.66	1.71
44	Wood and articles of wood; wood charcoal	13.31	10.57	1.27	1.41

Source: own calculation based on ITC, 2025a,e data

New Zealand's biggest comparative disadvantage is in commodity group HS 60 – Knitted or crocheted fabrics. This is followed by HS 75 – Nickel and articles thereof. Next is HS 24 – Tobacco and tobacco substitutes. New Zealand wanted to pass a law that would ban the sale of tobacco products to people born on or after January 1, 2009. At the same time, it would reduce the nicotine content in tobacco products to a level that does not cause addiction, and the number of stores that can sell tobacco products would also be reduced. This law would create a generation of non-smokers. Unfortunately, the law was repealed

before it came into force (Corlett, 2023). It is interesting to note that HS 24 – Tobacco and tobacco substitutes represent a comparative advantage for the EU, as do HS 53 – Other vegetable textile fibres and the aforementioned HS 45 – Cork and cork products.

Tab. 8 Comparison of NZ´s Revealed Comparative Disdvantages with the EU´s results (2023 and 2024)

HS2 code	Name of the commodity	RCA NZ 23	RCA NZ 24	RCA EU 23	RCA EU 24
60	Knitted or crocheted fabrics	0.0019	0.02	0.38	0.33
75	Nickel and articles thereof	0.0019	0.0014	0.74	0.70
24	Tobacco and manufactured tobacco substitutes	0.0034	0.07	1.33	1.51
53	Other vegetable textile fibres, paper yarn and woven fabrics of paper yarn	0.0042	0.25	1.47	1.39
45	Cork and articles of cork	0.0044	0.01	3.02	3.11

Source: own calculation based on ITC, 2025a,e data

Conclusion

Among the EU countries, the Netherlands and Germany are New Zealand's most important trading partners, accounting for the largest volume of trade over the long term. EU imports from New Zealand consist mainly of meat, fruit, nuts, dairy products, fish, and seafood. The most significant EU exports to New Zealand are nuclear reactors, vehicles, electrical machinery, medicines and aircraft.

An analysis of comparative advantages based on the RCA index showed that the EU and New Zealand have comparative advantages in some of the same commodities, as well as in different commodities, which creates the conditions for a complementary trade relationship.

From the EU´s perspective, the most significant comparative advantage is in commodity group HS 45 – Cork and cork products (RCA = 3.02). Europe has a long tradition in this area, and cork production plays an important ecological and economic role.

New Zealand, on the other hand, excels in agricultural and livestock production. It achieves its most significant comparative advantage in HS 04 – Dairy products, bird eggs, natural honey (RCA = 64.94), which confirms its strong focus on the export of agri-food raw materials. Other important areas include HS 05 – Products of animal origin and HS 02 – Meat and edible meat offal. These commodities represent a stable and key pillar of the New Zealand economy.

An interesting finding is that the commodity group HS 04 – Dairy products represent a comparative advantage for both sides, but to a different extent. The EU currently exports mainly cheese and curd to New Zealand, while New Zealand exports mainly butter, ghee and other fats and oils derived from milk to the EU (ITC, 2025a).

The largest revealed comparative disadvantages of the EU and New Zealand coincide in commodity group HS 60 – Knitted or crocheted fabrics.

The commodity group HS 45 – Cork and cork products has the greatest potential, where the EU has a high comparative advantage (RCA = 3.02), while New Zealand has a comparative disadvantage in this area (RCA = 0.0044). Thanks to this difference, the EU can increase exports of cork products to New Zealand if demand increases.

The results confirm that deepening trade relations between the EU and New Zealand is economically justified and can lead to mutual prosperity.

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How the EU Deforestation Regulation Shapes Colombia – EU Trade Dynamics: Evidence from Key Export Commodities[1]

Sára Smolková – Andrea Hrubšová[2]

Abstract

The European Union Deforestation Regulation (EUDR) aims to curb global forest loss by tightening sustainability and traceability requirements for commodities linked to deforestation, including coffee, cocoa, palm oil, soy, cattle and beef products, rubber, and wood-based goods. This paper evaluates the regulation's implications for EU–Colombia trade using data for 2014–2024, combined with deforestation trends and a SWOT assessment of Colombia's capacity to adapt. Results indicate that compliance will increase monitoring, certification and production costs, posing challenges especially for small producers and high-risk sectors. At the same time, the EUDR may stimulate investment in sustainable practices and value-chain upgrading, enhancing Colombia's long-term competitiveness and securing continued access to high-value EU markets.

Key words

EUDR, Colombia, European Union, International Trade, Deforestation,

JEL Classification: F13, Q17, Q23, Q56

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Introduction

The European Union Deforestation Regulation (EUDR) is a key legislative initiative aimed at addressing global deforestation and reducing forest degradation worldwide. The regulation restricts the import of commodities associated with deforestation and unsustainable agricultural practices. Products such as palm oil, soy, coffee, cocoa, wood, beef, rubber, and their derived goods represent the categories with the highest deforestation risk (European Commission, n.d.). These commodities are also among Colombia's main export products, meaning that the implementation of the EUDR will significantly affect trade dynamics, the economy, and local communities in this Latin American country (García & Pauwels, 2022).

Colombia is one of the most biodiverse countries in the world, with extensive tropical forests that play a crucial role in global climate regulation and ecosystem preservation. Despite this, deforestation remains an urgent issue driven primarily by agricultural expansion, illegal logging, and the cultivation of commodities for international markets (García Ruiz, 2022). The EU, as one of Colombia's key trading partners, represents an important market

[1] Vplyv konkurencieschopnosti a rizikového hodnotenia na environmentálne požiadavky a obchodné vzťahy EÚ s tretími krajinami (A-25-102/3020-04)

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for agricultural goods such as coffee, cocoa, and palm oil. These sectors are closely tied to local livelihoods, providing income and employment to thousands of smallholder farmers. As a result, the EUDR presents both opportunities and challenges for Colombia's trade relationship with the EU.

The EUDR was adopted by the European Commission in May 2023 and entered into force in June 2023. It requires companies importing the listed commodities to the EU to demonstrate that their products are not linked to deforestation and comply with the legal frameworks of the country of origin. This obligation becomes effective on 30 December 2024 for medium and large companies, and on 30 June 2025 for small and micro-enterprises (CLECAT, 2024).

In practice, the impacts of the EUDR may manifest in several ways. Authors such as Laroche et al. (2024) and Warren-Thomas et al. (2023) emphasize that the regulation will significantly affect countries exporting deforestation-linked commodities. Nations in Southeast Asia and Latin America will need to invest in traceability systems and certification mechanisms. Although this may increase costs, those countries that adapt successfully may gain a competitive advantage in the EU market. García and Pauwels (2022) highlight the challenges faced by Latin American countries highly dependent on commodity exports—particularly Brazil, Argentina, and Colombia. Failure to meet EUDR requirements could result in losing access to the EU market, with severe economic consequences. However, the regulation also offers opportunities for regional cooperation and the development of sustainable agricultural practices that could strengthen these countries' positions in global markets.

Zubaľová and Drieniková (2024) point out that small farmers are likely to be the most affected, as they often lack the financial resources and technological tools needed for reliable traceability and certification. This may lead to their marginalization and potential exclusion from EU markets.

Reis et al. (2021) take a different view, arguing that relying solely on legality may not be sufficient to halt deforestation, as legal frameworks in producing countries—such as Brazil—can be weak, unstable, or poorly enforced. National laws often permit deforestation for agricultural purposes, meaning that even legally produced commodities may contribute to forest degradation. Therefore, they argue for stricter EU measures targeting underlying drivers of deforestation.

In a broader geopolitical context, Latin America has become increasingly important for the EU. The region is marked by economic heterogeneity, low productivity levels, and high exposure to climate risks, while agriculture remains a strategic sector. Colombia, as part of the EU–Colombia–Peru–Ecuador Trade Agreement since 2013, is deeply integrated into EU value chains. The EUDR thus represents a new phase in EU–Latin America relations, linking traditional trade liberalization with stronger sustainability and climate objectives. This broader context is essential for understanding the regulation's potential impact on Colombia (Kittová et al., 2025).

Despite the significance of the EUDR, its effects on trade relations—particularly with countries such as Colombia—remain insufficiently explored. The limited academic research on this topic represents a clear gap that this study aims to address by identifying the potential impacts, challenges, and opportunities for Colombia–EU bilateral trade.

1 Methodology

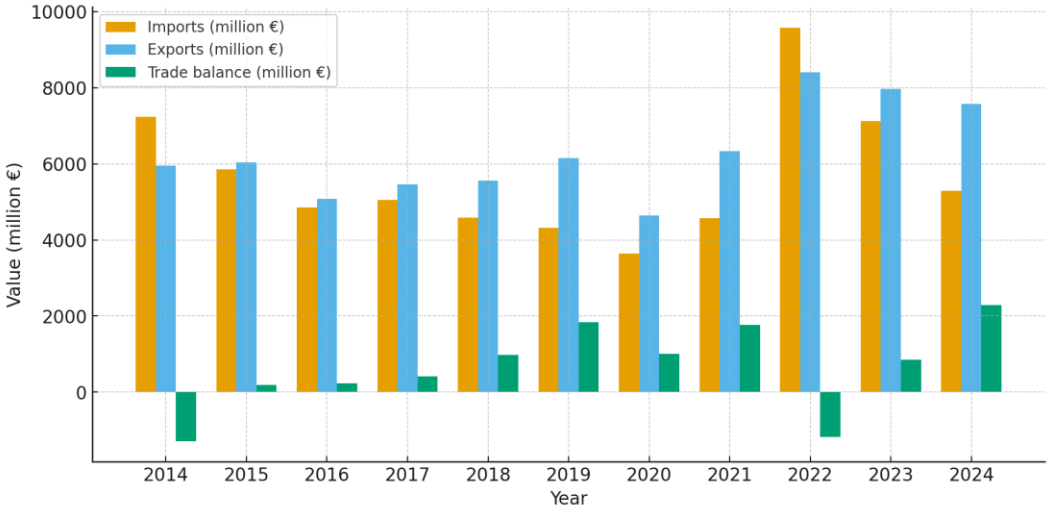
The main objective of this article is to assess the impact of the EU Deforestation Regulation (EUDR) on trade between the EU and Colombia, with a focus on key commodities associated with deforestation (palm oil, soy, coffee, cocoa, timber, beef and rubber). A further objective is to identify the opportunities and challenges arising from this regulation for Colombia and the EU, as well as to propose specific recommendations for both sides.

The data used come from the Eurostat and ITC statistical databases. Trade flows between the EU and Colombia are analysed for the period 2014 – 2024. The key variables in this analysis are the import and export volumes of the selected commodities, annual trade trends by SITC categories and by the Harmonised System (HS), which are presented in Annex 1, as well as indicators of deforestation by individual drivers (agriculture, forestry, fires, urbanisation) based on the Global Forest Watch database. The commodities directly covered by the EUDR were disaggregated according to their HS codes, and the sum of the respective items was used to calculate exports of each commodity (Duracert, n.d.). To evaluate the impact of the EUDR and the trade relations between Colombia and the EU, a SWOT analysis was applied, assessing strengths, weaknesses, opportunities and threats for both parties. SWOT analysis is an effective tool for identifying strategic approaches and supporting decision-making in trade and policy issues (Helms & Nixon, 2010).

2 Results and Discussion

In 2024, Colombia ranked 51st among the EU's import partners (imports of €5,288 million; 0.2% share), 39th among export partners (exports of €7,569 million; 0.3% share), and 44th in terms of total trade (€12,857 million; 0.3% share). The following figure presents the development of trade between the EU and Colombia.

Fig. 1 EU – Colombia Trade Development in million €, 2014–2024



Source: Author's elaboration based on European Commission (2025)

Figure 1 illustrates the evolution of EU–Colombia imports, exports, and the trade balance from 2014 to 2024. After a decline in trade flows in 2015 and 2016, the situation began to stabilize, followed by moderate growth between 2017 and 2019, particularly on the export

side. This trend resulted in a notable trade surplus in favor of the EU. The COVID-19 pandemic in 2020 led to a sharp contraction in bilateral trade; however, a rapid recovery was observed in 2021. In 2023, imports from Colombia reached €7,088 million (a decrease of 26%), while EU exports to Colombia amounted to €8,002 million (a decline of 5.8% compared with 2022). The trade balance remained positive at €914 million. The newest data for 2024 show a further adjustment: EU imports from Colombia decreased to €5,288 million, while exports slightly declined to €7,569 million. As a result, the trade surplus widened significantly to €2,281 million, representing the strongest positive balance of the decade.

Tab. 1 EU – Colombia Trade Structure by SITC, in million €, 2021–2024

	Import				**Export**			
SITC	**2021**	**2022**	**2023**	**2024**	**2021**	**2022**	**2023**	**2024**
0 Food and live animals	1 744	2 065	1 998	2 251	397	519	502	483
1 Beverages and tobacco	13	18	18	15	74	124	96	99
2 Crude materials	201	301	339	261	99	121	109	105
3 Mineral fuels	1 320	5 416	3 481	1 593	205	334	487	365
4 Oils and fats	280	467	147	117	45	54	61	95
5 Chemicals	75	118	89	76	2 015	2 553	2 375	2 455
6 Manufactured goods	279	342	265	284	686	880	705	725
7 Machinery and transport	79	36	44	49	1 942	2 757	2 763	2 267
8 Misc. manufactures	73	92	98	89	670	967	784	828
9 Other commodities	481	556	498	528	57	62	24	31
Other	23	160	111	25	147	120	96	117
Total trade	4 567	9 571	7 088	5 288	6 335	8 490	8 002	7 569

Source: Author's elaboration based on European Commission (2025)

According to Table 1, the structure of trade in goods between the EU and Colombia from 2021 to 2024 shows considerable variation across individual SITC categories. The most significant fluctuations occurred in mineral fuels (SITC 3), where imports into the EU surged sharply in 2022, reaching €5,416 million. This spike is likely linked to the global energy crisis and elevated commodity prices. In 2023, imports decreased to €3,481 million, and the adjustment continued in 2024, when imports fell more substantially to €1,593 million, suggesting market stabilization and the diversification of EU energy suppliers. Food and live animals (SITC 0) remained a stable component of bilateral trade. Imports peaked in 2022 at €2,065 million and declined slightly in 2023, before rising again to €2,251 million in 2024. This pattern confirms the continued importance of Colombia's agricultural sector for the EU market. EU exports in this category showed moderate variation, decreasing marginally to €483 million in 2024 after reaching their highest level in 2022. The chemicals category (SITC 5) remains one of the EU's dominant export groups. Exports rose from €2,015 million in 2021 to €2,553 million in 2022, followed by a slight decline in 2023. In 2024, however, exports increased again to €2,455 million, indicating sustained demand for EU chemical products or competitive advantages of EU suppliers. Similarly, machinery and transport equipment (SITC 7) represent another major EU export segment. After reaching a peak of nearly €2,770 million in 2022 and 2023, exports declined to €2,267 million in 2024. This reduction may

reflect slower investment cycles in Colombia or weakened demand for capital goods. Colombian exports of machinery to the EU remained minimal throughout the entire period, underscoring the structural trade asymmetry in this category. Other manufactured goods (SITC 6 and 8) also demonstrate steady but less pronounced trade volumes, with slight increases in 2024 on both the import and export sides. Meanwhile, animal and vegetable oils and fats (SITC 4)—a category traditionally tied to Colombia's agricultural output—declined notably in EU imports from €147 million in 2023 to €117 million in 2024, likely due to market substitution or supply adjustments.

Overall, the evolution of bilateral trade flows between 2021 and 2024 reflects sector-specific dynamics shaped by the energy crisis, shifts in industrial demand, and Colombia's role as a supplier of agricultural and raw materials. The decreasing import reliance on mineral fuels in 2023–2024 and the stable performance of EU high-value exports such as chemicals and machinery significantly influenced the overall trade balance during this period.

Tab. 2 EU Import Structure from Colombia by HS Code, in thousand €, share of total EU imports in %, 2021 – 2024

HS	2021	%	2022	%	2023	%	2024	%
270112	582 916	5,8%	3 564 567	12,4%	1 623 201	9,8%	710 146	6,6%
270119	538 170	19,1%	2 135 301	24,8%	1 496 634	32,3%	603 345	24,9%
080390	872 808	16,8%	964 407	18,0%	1 013 275	17,0%	1 126 679	19%
090111	536 780	7,0%	781 233	6,0%	586 274	5,5%	685 757	5,1%
270900	219 538	0,1%	492 945	0,1%	570 467	0,2%	285 610	0,1%
710812	465 204	2,6%	548 478	2,7%	496 211	4,1%	527 409	3,5%
080440	213 092	7,9%	175 316	6,3%	307 611	9,1%	353 651	8,9%
270400	88 811	4,0%	185 189	4,6%	128 880	4,3%	193 732	8,3%
081090	89 749	11,8%	100 169	12,5%	99 886	12,7%	126 663	14,7%
060312	79 281	33,6%	94 591	38,7%	91 748	40,8%	101 107	42,1%
710391	106 360	19,3%	66 187	10,2%	84 281	10,3%	80 165	12,9%
151110	214 682	7,2%	365 512	9,9%	81 470	3,3%	72 513	3,3%
720260	89 147	8,2%	130 424	10,4%	71 024	8,4%	101 776	15,8%
261610	0	0,0%	29 829	15,0%	65 584	25,6%	0	0%
080310	52 912	23,2%	48 428	18,6%	65 129	21,6%	79 112	17,9%

Source: Author's elaboration based on ITC (2025)

Table 2 presents the structure of EU imports from Colombia for the period 2021–2024 and their share in the EU's total imports. The data clearly show that commodities such as mineral fuels, agricultural products, and certain metals continue to play a central role in Colombia's export basket.

A pronounced increase is visible in the category of mineral fuels (HS 270112, 270119, 270900), which surged in 2022 at the height of Europe's energy crisis. Bituminous coal (HS 270112) reached a record €3.56 billion in 2022 before declining sharply in 2023 and again

in 2024, reflecting the gradual stabilization of European energy markets and a shift toward alternative suppliers. A similar trajectory is observed for other coal categories (HS 270119), where Colombia's share peaked at more than 32% in 2023 before falling to 24.9% in 2024. These developments suggest that Colombia benefited substantially from temporary market disruptions but faces diminishing demand as the EU transitions toward more stable and sustainable energy sources.

Agricultural products remain a reliable component of bilateral trade. Bananas (HS 080390) consistently accounted for 17–19% of EU imports of this product, reaching their highest level in 2024. Avocados (HS 080440) also gained importance, rising to 9% in 2023 and 8.9% in 2024, reflecting strong EU consumer demand.

By contrast, crude palm oil (HS 151110) exhibited a notable decline—from almost 10% market share in 2022 to just 3.3% in 2023 and 2024—likely due to anticipation of the EU Deforestation Regulation (EUDR), which will impose stricter sustainability requirements on deforestation-linked products.

Coffee (HS 090111), one of Colombia's flagship exports, shows a gradual decrease in its relative importance. Its share fell from 7% in 2021 to 5.1% in 2024. This trend may stem from greater competition among global producers as well as changing EU consumer preferences. If EUDR is extended to crops associated with deforestation risks, it may further constrain Colombian coffee exports, particularly for producers unable to demonstrate traceability.

Cut flowers—especially carnations (HS 060312)—represent one of the strongest Colombian export segments in relative terms, with EU market shares exceeding 40% in 2023 and 2024. This highlights Colombia's dominant position in the European flower market.

Other categories display mixed trends. For example, ferro-nickel (HS 720260) increased sharply in 2024, reaching a 15.8% share of EU imports, whereas precious stones (HS 710391) and plantains (HS 080310) remain stable.

Overall, the evolution of Colombia's export profile demonstrates the continued importance of agricultural and mining products, while also showing clear sensitivity to EU regulatory developments and market shocks. The upcoming implementation of EUDR in 2025 is likely to further influence imports of commodities linked to deforestation—such as palm oil, coffee, and certain tropical fruits—potentially posing additional challenges for Colombian exporters.

Figure 2 illustrates the development of trade in commodities covered by the EUDR, focusing exclusively on imports of these products from Colombia to the EU between 2014 and 2024. The graph clearly shows a strong upward trend in imports of coffee and palm oil, particularly in 2021 and 2022. Coffee, Colombia's key export commodity, grew steadily from 2014 and reached its peak in 2022 at more than €787,000. This increase reflects strong EU demand, although future growth may be influenced by the implementation of the EUDR, as some coffee-producing practices are associated with deforestation.

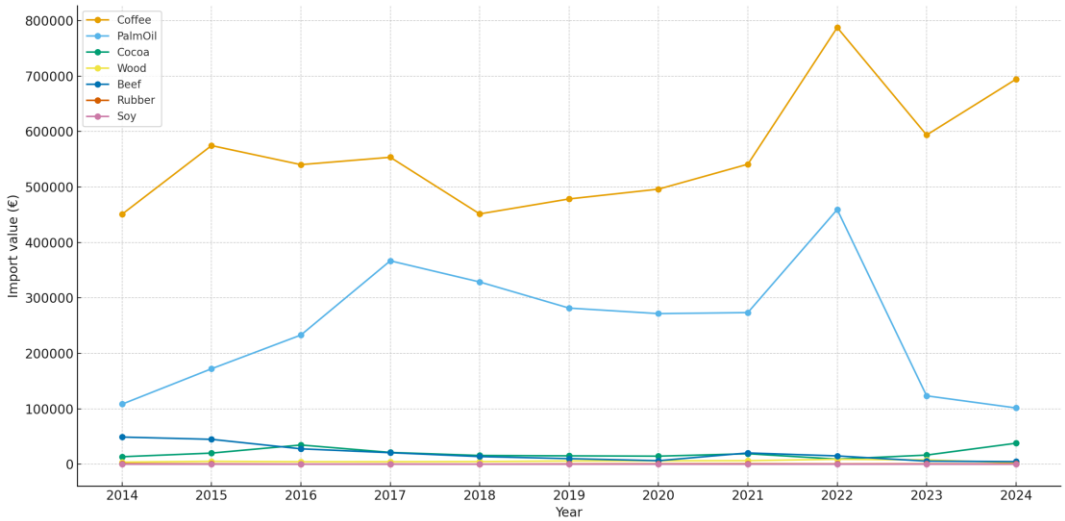
Palm oil displays a similar pattern: imports rose significantly until 2022 but dropped sharply in 2023 and continued declining into 2024. This trend is likely linked to anticipation of upcoming EUDR requirements, as palm oil is directly associated with deforestation and therefore faces greater regulatory pressure. A sustained decrease in EU imports of palm oil can be expected as operators adjust to stricter due-diligence rules.

Other commodities, such as cocoa and wood show more moderate fluctuations over the decade. Wood imports display a gradual increase until 2022, followed by a notable decline in 2023 and 2024, which may reflect enhanced sustainability controls in logging and timber traceability. Cocoa imports remain relatively low in volume but rise sharply in 2024, suggesting short-term market adjustments ahead of EUDR enforcement.

Beef shows a clear downward trend from 2014 to 2024, aside from temporary peaks in 2015 and 2021. This long-term decline is likely linked to increasing environmental scrutiny related to cattle ranching, which is one of the main drivers of deforestation globally. The EUDR may reinforce this trend by imposing stricter due-diligence requirements regarding land-use change.

Overall, the data suggest that the implementation of the EUDR from 2025 is likely to further reduce imports of commodities strongly associated with deforestation—such as palm oil, beef, and potentially coffee—especially if producers are unable to demonstrate full compliance with traceability and sustainability criteria across their supply chains.

Figure 2 Development of EU Imports of EUDR Commodities from Colombia in thousand €, 2014–2024

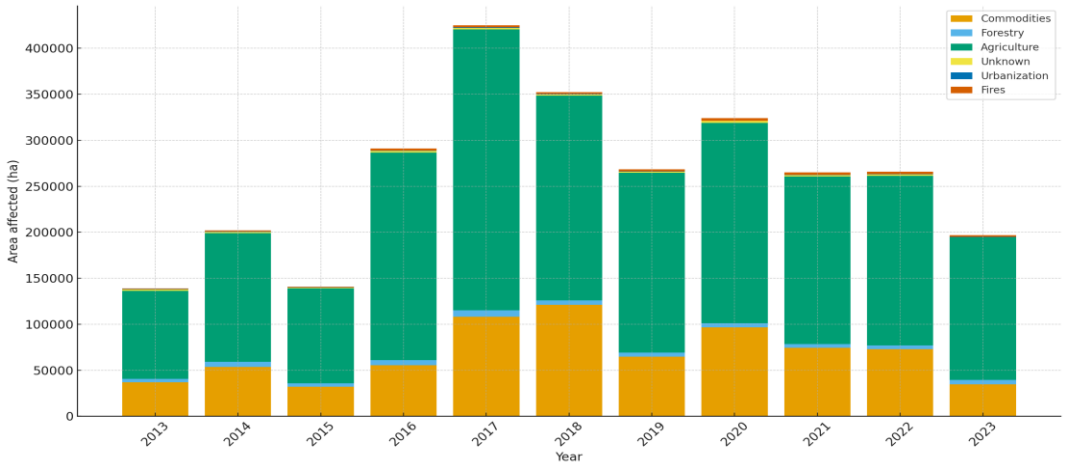


Source: Author's elaboration based on ITC (2025)

Figure 3 illustrates the development of deforestation in Colombia between 2013 and 2023, showing the individual drivers of deforestation, including agriculture, commodity extraction, fires, forestry, urbanization, and unknown factors. Agriculture is the most significant contributor to deforestation in Colombia, reaching its peak in 2016 and 2017. This increase may be linked to the expansion of land dedicated to growing crops such as coffee, palm oil, and soy—major export commodities, including exports to the EU. Another important factor is commodity extraction, which caused substantial deforestation, particularly in 2017 and 2018. Commodities such as timber, minerals, and palm oil—key components of Colombia's trade with the EU—add pressure on forest ecosystems. Although fires represent a smaller share, their impact increased in 2020 and 2021, suggesting that climate change and human activity may be raising the risk of fires in forested areas. Overall, these trends highlight the need for more sustainable trade practices, especially given that agriculture and commodity

extraction have the greatest impact on deforestation. The EUDR can serve as a tool to encourage change in these sectors, potentially leading to a better balance between economic and environmental objectives

Figure 3 Development of Deforested Land by Cause in Hectares, 2013 – 2023



Source: Author's elaboration based on Curtis et al. (2018).

The implementation of the EUDR will bring not only new challenges but also opportunities for Colombia and the EU. Colombia, as a major exporter of these commodities, will need to adapt its cultivation methods to comply with strict environmental standards aimed at combating deforestation. For Colombian producers, this means investing in sustainable practices and certifications, which may increase costs but can also improve their competitiveness on the global market and enhance access to high-value markets such as the EU. On the other hand, for the EU, the regulation presents an opportunity to strengthen its leadership in environmental protection and sustainability. Consumers in the EU will have greater assurance that imported products do not contribute to deforestation, which may increase trust in European markets. An overview of the most significant opportunities and risks for both sides is presented in the following SWOT analyses.

Tab. 3 SWOT Analysis for Colombia

Strenghts	**Weaknesses**
• Competitive advantage for producers who adopt sustainable practices • Rich biodiversity • Strong trade relations with the EU	• High initial costs required to comply with new standards • Dependence of small farmers on commodities linked to deforestation • Limited access to technologies
Opportunities	**Threads**
• Development of sustainable agriculture and certification schemes	• Loss of access to the EU market due to failure to meet standards

• Attraction of investment for infrastructure and traceability technologies • Diversification of exports into new regions outside the EU	• Decrease in demand for the affected commodities • Higher costs for technologies and certifications may reduce profitability

Source: Author's elaboration

Tab. 4 SWOT Analysis for the EU

Strenghts	**Weaknesses**
• Strengthening of environmental leadership • Transparent supply chains and environmentally responsible products • Protection of EU consumers from products contributing to deforestation	• Higher costs for importers due to traceability and certification requirements • Logistical and legal challenges in supervising imported commodities • Dependence on imports of commodities such as coffee and palm oil
Opportunities	**Threads**
• Support for sustainable products and innovations • Creation of new markets for environmentally sustainable products • Setting new global sustainability standards	• Decline in imports of the affected commodities • Higher costs may reduce the competitiveness of European companies • Potential interruption of trade relations with Colombian exporters

Source: Author's elaboration

A SWOT analysis for Colombia and the EU in the context of the EUDR reveals that both sides face significant challenges, but also important opportunities. Colombia, as a major exporter of commodities such as coffee, palm oil, and beef, will need to undergo substantial changes in agricultural practices to comply with the EU's new environmental standards. Colombia's rich biodiversity and long-standing trade relations with the EU represent key strengths; however, high initial costs associated with implementing certification and traceability systems pose a major challenge, especially for small farmers. If Colombia successfully adapts, it may gain a competitive advantage and maintain access to the European market.

For the EU, the EUDR will reinforce its leading role in combating climate change and strengthen consumer confidence in environmentally responsible products. On the other hand, the EU will face higher costs related to monitoring and certification, which may reduce the competitiveness of importers. Although the EUDR offers a major opportunity to promote sustainability and innovation, it also carries the risk of disrupting trade relations with countries unable to meet the new requirements.

Conclusion

The implementation of the EUDR will bring not only new challenges but also significant opportunities for both Colombia and the EU. Colombia, as one of the main exporters of commodities affected by the regulation, will need to introduce major changes in agricultural practices and ensure full traceability of commodities in order to retain access to the European market. Although the initial adaptation costs may be high—particularly for small farmers—meeting these requirements could, in the long term, strengthen Colombia's competitive position on the global market.

For the EU, the EUDR will reinforce its global leadership in combating deforestation and climate change. Consumers will have greater assurance that products imported into the EU do not cause environmental damage, which may further increase trust in the European market. At the same time, the EU will face challenges in monitoring and certification processes, potentially raising costs for importers and creating complications in trade relations with countries that are unable to comply with the new standards.

In the long term, the EUDR may become a catalyst for the development of sustainable agriculture and trade, delivering both environmental and economic benefits. The key challenge for Colombia will be the implementation of technological innovations and certification systems necessary to meet EUDR requirements, while the central question for the EU is how to effectively implement this regulation without undermining the competitiveness of European companies.

Finally, future research could focus on the long-term impacts of the EUDR on developing countries, as well as on the effectiveness of certification systems in reducing deforestation. Including a broader range of countries and case studies could offer deeper insights into the dynamics between trade and environmental protection in the context of global change.

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Annex 1 List of commodities by HS6 codes

HS6	Name
270112	Bituminous coal, whether or not pulverized, non-agglomerated
270119	Coal, whether or not pulverized (excluding anthracite and bituminous coal), non-agglomerated
080390	Bananas, fresh or dried (excluding plantains)
090111	Coffee, not roasted, not decaffeinated
270900	Petroleum oils and oils obtained from bituminous minerals, crude
710812	Gold, including gold plated with platinum, unwrought, for non-monetary purposes
080440	Avocados, fresh or dried
270400	Coke and semi-coke of coal, lignite or peat, whether or not agglomerated; retort carbon
081090	Tamarinds, cashew apples, jackfruit, lychees, sapodilla plums, passion fruit, carambola, fresh
060312	Carnations and buds, fresh, suitable for bouquets or ornamental purposes
710391	Rubies, sapphires and emeralds, worked, whether or not graded, but not strung, mounted or set
151110	Palm oil, crude
720260	Ferronickel
261610	Silver ores and concentrates
080310	Plantains, fresh or dried

Source: Author's elaboration based on ITC (2025)

Electricity, Energy Dependency and Economic Growth across Countries[1]

Viktória Vörösová – Andrea Hrubšová[2]

Abstract

This article examines how energy dependence and electricity consumption affect economic growth, based on a global panel of 129 countries from 2013 to 2024. Using fixed-effects models estimated in RStudio, the analysis separates the risks associated with high dependence on primary energy imports from production capacity reflected in domestic electricity consumption. The results show that greater energy dependence reduces economic growth, while higher electricity consumption supports it. Trade openness and foreign direct investment contribute positively to growth, while inflation has a consistent negative impact. The results highlight the importance of assessing energy systems not only in terms of import dependence, but also in terms of their ability to produce and use electricity. This dual perspective provides a clearer view of the structural factors behind macroeconomic performance and resilience.

Key words

Electricity consumption, Energy dependency, Economic growth

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Introduction

Energy dependence represents a central dimension of strategic vulnerability for countries operating in a globalized economy. It captures the extent to which a state or regional bloc – such as the European Union (EU) – is unable to satisfy its energy demand from domestic resources and must rely on imports (European Environment Agency, 2014). In simple terms, the higher the share of net energy imports in total energy use, the higher the degree of energy dependence. This indicator becomes particularly critical when international trade is disrupted, geopolitical tensions intensify, or energy commodity prices become highly volatile.

In recent years, energy dependence has moved to the forefront of both policy and academic debates. This shift has been driven above all by developments on the EU's eastern border – the war in Ukraine and the subsequent interruption of oil and natural gas deliveries from the Russian Federation to EU member states (Ilie et al., 2023). Whereas in 2021 roughly 45% of gas imported into the EU originated from Russia, by 2023 this share had fallen to below 10% (Council of the European Union, 2025). This abrupt change exposed

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the true scale of the Union's reliance on a single dominant supplier and underscored the urgency of designing systemic responses in the field of energy security.

One of the key responses was the adoption of the REPowerEU strategy, which aims not only to curb dependence on Russian fossil fuels, but also to reorient EU energy policy more broadly towards supply diversification, the expansion of renewable energy sources, and greater energy efficiency (European Commission, 2024). At the same time, this initiative has illustrated that energy dependence is a multidimensional concept: it is not merely a technical or geographical issue, but a complex phenomenon shaped by economic structures, geopolitical relations, technological capabilities, and institutional frameworks.

The degree of reliance on imported energy has implications that extend beyond competitiveness and the stability of economic growth; it also affects the geopolitical standing of states. In an environment characterised by supply chain disruptions, fluctuating energy prices and geopolitical conflict, the question of energy self-sufficiency becomes a core element of economic policy and a key determinant of long-term resilience (Vörösová, 2025).

Whereas classical growth theories emphasised capital and labour as the main production factors, more recent approaches also recognise energy as a third fundamental input that strongly influences productivity, technological progress and macroeconomic stability (Chen et al., 2020). A high level of energy dependence can constrain a country's ability to absorb external shocks, slow down diversification efforts and exacerbate existing macroeconomic imbalances.

Empirical research suggests that in advanced economies the use of renewable energy tends to support long-term growth, while in developing countries these benefits are often limited by technological and institutional constraints (Bhattacharya et al., 2016; Amri, 2017; Kahia et al., 2017). Using a panel threshold model, Chen et al. (2020) identify a nonlinear relationship between renewable energy consumption and growth: the positive effect emerges only beyond a certain threshold of technological sophistication and institutional quality. This implies that the gains from renewables are not automatic, but depend on the broader development context. Gozgor and Paramati (2022) highlight energy diversification as a key precondition for long-run stability. Economies with a more diversified energy mix are less vulnerable to shocks and price swings, and their findings confirm that lowering reliance on fossil fuels is a strategic lever for achieving more stable and sustainable growth.

Usman et al. (2021) add an environmental perspective by showing that the use of non-renewable resources worsens the ecological footprint, whereas renewable sources help to reduce environmental pressure. This points to a synergy between environmental sustainability and long-term economic performance. Although economic development (measured by GDP per capita) is not always statistically significant in explaining emissions (Dumitrescu et al., 2023), higher levels of GDP indicate a greater capacity to allocate resources to redesigning energy policy and mitigating the environmental costs of growth through low-carbon technologies (Dumitrescu et al., 2023).

In the EU context, Vörösová (2025) argues that energy dependence constitutes a strategic weakness that heightens both economic and geopolitical vulnerability. Prolonged reliance on imported energy undermines economic stability, constrains innovation potential and slows the transition to a low-carbon economy. Diversifying energy sources and investing in renewable technologies are therefore crucial for maintaining competitiveness and resilience to external shocks. Moreover, a high concentration of suppliers (measured by the HHI index) combined with strong overall dependence on imports from non-EU countries signals particularly acute vulnerability for economies such as Lithuania, Slovakia, Germany, Spain and Italy (Guarascio et al., 2025).

Overall, the literature converges on the view that the impact of energy dependence on growth is predominantly indirect and delayed. In the short run, key roles are played by

openness, investment and macroeconomic stability, whereas in the long term structural changes in the energy sector, innovation and source diversification are regarded as decisive drivers of economic performance.

1 Methodology

Building on the existing literature and on the ongoing debate about the links between energy policy, trade openness and macroeconomic performance, this study empirically examines how energy dependency and electricity consumptionjointly influence economic growth. The main objective is to determine whether a high reliance on imported energy slows economic growth and whether the productive capacity reflected in electricity consumption can offset part of this negative effect. By addressing both dimensions simultaneously, the research aims to deepen the understanding of how structural energy factors shape growth trajectories across countries.

Based on the theoretical foundations discussed in the literature review, we formulate the following hypotheses:

H1: Higher energy import dependency has a negative effect on economic growth.
H2: Higher electric power consumption has a positive effect on economic growth.

To test these hypotheses, we employ a fixed-effects panel model (FEM) estimated in RStudio, which allows us to control for unobserved, time-invariant characteristics of countries that could otherwise bias the results. Fixed-effects estimation is widely used in macroeconomic panel analyses, as it accounts for country-specific heterogeneity and isolates within-country variation over time. In addition to a one-way (country) fixed-effects model, we also estimate a two-way model that includes both country and year effects to account for global shocks affecting all countries simultaneously.

The general form of the model is expressed as follows:

$$GDP_{it} = \beta_1 EnergyDep_{it} + \beta_2 Electricity_{it} + \beta_3 Trade_{it+}\beta_4 FDI_{it} + \beta_5 Inflation_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

where:

- GDP_{it} represents the annual real GDP growth of country *i* in year *t*,
- $EnergyDep_{it}$ denotes net energy imports as a percentage of energy use,
- $Electricity_{it}$ measures electric power consumption per capita,
- $Trade_{it}$, FDI_{it} and $Inflation_{it}$ are control variables commonly employed in growth literature,
- α_i captures country fixed effects,
- γ_t captures year fixed effects (in the two-way model),
- ε_{it} is the error term.

The empirical analysis uses an unbalanced panel of 129 countries over the period 2013–2024. Countries with incomplete or missing data were excluded to ensure the robustness of estimation. All data were sourced from the World Development Indicators (WDI) database of the World Bank, which provides harmonised and internationally

comparable macroeconomic indicators suitable for panel econometric techniques. A detailed overview of the variables, their definitions, measurement units and sources is presented in Table 1.

Tab. 1 List of used indicators

A variable	Charakteristic
GDP growth (annual %)	Total income generated by the production of goods and services in a given country during a specific period. It is measured in constant 2015 prices (USD) and expresses the year-on-year percentage change in real economic performance. (WBG, 2025)
Energy imports, net (% of energy use)	The difference between total energy imports and exports measured in tons of oil equivalent (toe). A negative value means that the country is a net energy exporter. Energy consumption includes primary energy before it is converted into final fuels. (WBG, 2025)
Trade (% of GDP)	The sum of exports and imports of goods and services expressed as a percentage of GDP, reflecting the degree of a country's involvement in international trade. (WBG, 2025)
Foreign direct investment, net outflows (% of GDP)	Net outflows of direct investment from a given economy to foreign countries, expressed as a percentage of GDP. They include share capital, reinvested earnings, and other capital, with the relationship arising when at least 10% of voting rights are owned. (WBG, 2025)
Inflation, consumer prices (annual % growth)	Year-on-year percentage change in the prices of a representative basket of goods and services purchased by the average consumer. It expresses the change in the price level compared to the previous year, measured in constant 2015 prices (USD). (WBG, 2025)
Population, total	Total population of the country, regardless of citizenship or legal status, according to estimates at mid-year. (WBG, 2025)
Electric power consumption (kWh per capita)	Electric power consumption reflects the amount of electricity actually available for end users. It corresponds to the gross output of power plants and combined heat-and-power facilities, minus the energy lost during transmission, distribution, and transformation, as well as the portion consumed directly by the generating facilities themselves. (WBG, 2025)

Source: Own processing based on data from databases

2 Results and Discussion

This section presents the empirical results of a panel analysis based on a fixed effects model. The aim of the model is to examine how energy dependence, electricity consumption, and other macroeconomic indicators—trade openness, foreign direct investment inflows,

and inflation—are reflected in the dynamics of countries' economic growth in the period 2013–2024.

Tab. 2 FEM Models

Oneway (individual) effect Within Model
n = 129, T = 1-11, N = 1254

	Estimate	Std. Error	t-value	Pr(>|t|)
energy_imports_net_percent_of_energy_use	-0.01514191	0.00563170	-2.6887	0.007280 **
trade_percent_of_gdp	0.10796384	0.01893037	5.7032	1.503e-08 ***
foreign_direct_investment_net_inflows	0.01264500	0.00463413	2.7287	0.006459 **
inflation_consumer_prices	-0.02032370	0.00364760	-5.5718	3.157e-08 ***
electric_power_consumption	0.00102535	0.00042137	2.4333	0.015116 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Twoways effects Within Model
n = 129, T = 1-11, N = 1254

	Estimate	Std. Error	t-value	Pr(>|t|)
energy_imports_net_percent_of_energy_use	-0.01024757	0.00487085	-2.1039	0.035615 *
trade_percent_of_gdp	0.05372346	0.01685396	3.1876	0.001475 **
foreign_direct_investment_net_inflows	0.01020352	0.00353809	2.8839	0.004004 **
inflation_consumer_prices	-0.01697468	0.00518683	-3.2727	0.001098 **
electric_power_consumption	0.00031083	0.00025369	1.2252	0.220747

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: Own processing from R-Studio

The results of our fixed effects panel model reveal a clear structure of relationships between energy variables and economic growth. In the model with individual fixed effects (one-way FE), which captures differences between countries over time, it appears that energy dependence has a statistically significant and negative impact on GDP growth. The coefficient on the variable energy_imports_net_percent_of_energy_use is −0.015 ($p < 0.01$), indicating that a higher share of energy imports systematically reduces countries' growth dynamics. This relationship reflects the vulnerability of economies dependent on external energy sources, especially in times of market volatility or geopolitical uncertainty.

At the same time, the model shows us that higher domestic electricity consumption has a positive impact on economic growth. The coefficient of 0.0010 ($p < 0.05$) indicates that the availability of electricity—as a key input for industry, services, and technological development—supports productivity and overall economic performance. This result confirms that electricity as a factor of production plays an important role in explaining growth differences between countries.

Among other variables, consistent relationships remain: trade openness and foreign direct investment inflows have a positive effect on growth, while inflation significantly dampens growth. These relationships are consistent with arguments in the macroeconomic literature on the role of global integration, capital flows, and price stability.

After including time effects (two-way FE) that absorb global shocks such as the COVID-19 pandemic, energy price fluctuations, and global demand cycles, the negative impact of energy dependence remains statistically significant. The coefficient of −0.010 ($p < 0.05$)

confirms that even after eliminating year-round global trends, energy dependence remains a persistent structural weakness. On the other hand, after controlling for time effects, the impact of electricity consumption becomes statistically insignificant ($p = 0.22$), although it retains the correct positive sign. This result suggests that year-on-year variations in electricity consumption are largely explained by global phenomena rather than differences between countries within individual years.

Interpretation of both models shows that energy dependence represents a long-term constraint for economies, while the availability of electricity is more of a factor explaining cross-country differences in productivity and development levels. Countries that are able to ensure stable domestic electricity production are better positioned for sustainable growth, but if they are also heavily dependent on imports of primary energy commodities, the overall resilience of their economies remains weakened.

The results thus confirm the importance of a two-dimensional view of energy: it is not enough to assess only the level of import dependence, but also the country's ability to transform energy into electricity that is directly usable for economic production. Economies that combine low import dependence with high domestic electricity capacity show the highest degree of growth resilience.

Conclusion

This paper examined how energy dependency and electricity consumption jointly influence economic growth across a global sample of 129 countries between 2013 and 2024. Using fixed-effects panel estimations, the study found a persistent negative relationship between energy import dependency and GDP growth, indicating that reliance on external energy sources constrains long-term economic performance.

In contrast, higher domestic electricity consumption shows a generally positive association with growth, although this effect loses statistical significance once common time shocks—such as global energy price fluctuations or the COVID-19 crisis—are controlled for. This suggests that the productive benefits of electricity availability are evident mainly in cross-country differences rather than in year-to-year variation. Electricity consumption thus remains an important indicator of development level and productive capacity, even if its short-term influence is shaped by global dynamics.

Beyond the energy variables, the analysis also reveals consistent macroeconomic patterns: trade openness and foreign direct investment stimulate growth, while inflation significantly constrains it. These findings align with the literature emphasizing the complementary role of international integration and macroeconomic stability in sustaining growth under global uncertainty.

From a policy perspective, the results highlight the importance of addressing both dimensions of energy systems: reducing import dependency through diversification and investments in domestic production capacity, while simultaneously improving electricity infrastructure and efficiency. Integrating energy security considerations into broader economic strategies can strengthen both growth potential and long-term resilience. Future research could extend this analysis by distinguishing between renewable and non-renewable electricity sources, exploring non-linear relationships, and assessing regional differences between advanced and developing economies.

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