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Innovation-Driven E-Commerce Growth in the EU: An Empirical Study of the Propensity for Online Purchases and Sustainable Consumption

Elżbieta Roszko-Wójtowicz [1,*], Gagan Deep Sharma [2,3,4], Barbara Dańska-Borsiak [5] and Maria M. Grzelak [1]

[1] Department of Economic and Social Statistics, University of Lodz, 90-214 Lodz, Poland; maria.grzelak@uni.lodz.pl
[2] Centre of International Programmes, Széchenyi István University, 9026 Győr, Hungary; gagan@ipu.ac.in
[3] University School of Management Studies, Guru Gobind Singh Indraprastha University, New Delhi 110078, India
[4] Graduate Studies and Research, Lebanese American University, Beirut 1102 2801, Lebanon
[5] Department of Spatial Econometric, University of Lodz, 90-419 Lodz, Poland; barbara.danska@uni.lodz.pl
* Correspondence: elzbieta.roszko@uni.lodz.pl; Tel.: +48-606-661-828

Abstract: The e-commerce sector has experienced significant growth in the past two decades, outpacing other economic sectors and contributing to sustainable consumption, increased labour productivity, competitiveness, consumer incomes, and GDP growth. This trend is expected to continue, making e-commerce a key driver of sustainable economic growth in Europe. This study aims to explore the relationship between a nation's innovation level and its population's inclination towards online shopping in various EU member states. It hypothesizes that higher innovation levels within a country lead to a greater tendency for online purchases. This study conducts a thorough analysis of the interplay between European economies' innovation levels and the e-commerce market's evolution. A composite innovation index was created using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodology, and panel data models were utilized to examine the dependencies, with data from Eurostat and the Global Innovation Index. The focus is on the period from 2019 to 2021, which was marked by unique market dynamics and the impact of the COVID-19 pandemic. The findings confirm the significant role of innovation in driving e-commerce expansion within the context of sustainable consumption, supporting the main hypothesis. This research also highlights the pandemic's positive effect on the e-commerce sector. The pandemic-induced changes in consumer behaviour, particularly due to social isolation and crises in certain economic sectors, have emphasized the importance of online shopping. Notably, the most active online shoppers are identified in the 25 to 54 age group, revealing a key demographic trend.

Keywords: sustainable consumption; e-commerce; innovation; economic growth; online shopping; COVID-19 pandemic; consumer behaviour; European Union

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1. Introduction

The proliferation and comprehensive use of information and communication technologies (ICTs) has brought many opportunities and challenges to companies, enabling the better utilisation of assets, improved supplier–customer relationships, and faster time-to-market innovations [1–3]. E-commerce has the potential to contribute to sustainable development in several ways. Firstly, it can reduce the carbon footprint associated with traditional retail through more efficient logistics and a decreased need for physical retail space. Secondly, e-commerce platforms can facilitate the sale of sustainable and ethically sourced products. Thirdly, the digital nature of e-commerce allows for better tracking and optimization of resource use, potentially leading to less waste. E-commerce has been posited as a more environmentally friendly alternative to traditional retail, largely due

to streamlined logistics and diminished reliance on brick-and-mortar stores. Research by Weber et al. [4] indicates that e-commerce could potentially reduce energy consumption and CO_2 emissions by up to 30% compared to conventional retail, thanks to factors like decreased consumer travel and centralized warehousing. However, these benefits are not guaranteed and hinge on various elements such as the efficiency of delivery networks, the materials used for packaging, and the volume of product returns. A more recent study by Viu-Roig and Alvarez-Palau [5] highlights the finding that last-mile delivery, often involving multiple trips to deliver a single product, can significantly increase the carbon footprint. Furthermore, the increase in packaging waste associated with e-commerce is a growing environmental concern, as noted by Escursell et al. [6]. Therefore, while e-commerce has the potential to be more environmentally friendly than traditional retail, this is not an inherent characteristic and depends heavily on the implementation of sustainable practices in various aspects of the e-commerce supply chain. The intensive development of the Internet and its increasing use in business, especially due to its global reach, has contributed to the development of the e-commerce market [7,8]. The origins of e-commerce date back to the 1980s, but significant development occurred in the 1990s. Today, e-commerce is an integral part of trade, driving economic growth [9]. The lack of geographical barriers is one of the main factors contributing to the growth of the e-commerce market, allowing entrepreneurs to reach customers worldwide [10,11].

The progressive development of e-commerce is changing the image of commerce, contributing to a shift in the function of traditional shops, which often become showrooms rather than shopping destinations [12,13]. More and more consumers are choosing to shop online instead of in stationary shops, resulting in an increased interest from businesses to move their operations online [9,14–16]. The growth of e-commerce has led to increased interest in this issue from the academic world. Forecasts predict further growth in the e-commerce sector, making it a topic of great importance and interest for researchers and practitioners [17,18]. Furthermore, according to the 'Global E-commerce Market: Industry Trends, Share, Size, Growth, Opportunities, and Forecasts 2022–2027' report by Research and Markets, the global e-commerce market reached a value of USD 13 trillion in 2021. The publisher expects the market to reach USD 55.6 trillion by 2027, with a CAGR of 27.4% during the forecast period of 2022–2027 [18].

The benefits of e-commerce development also have a significant impact on European economies. E-commerce holds significant potential for promoting sustainable consumption. However, realizing this potential requires a concerted effort from e-commerce companies, consumers, policymakers, and other stakeholders to address the challenges and fully leverage the opportunities presented by digital retail in fostering a more sustainable consumption model. According to a Eurostat report [19,20], the e-commerce sector in the European Union is experiencing steady growth, bringing benefits in the form of increased competitiveness, job creation, and innovation stimulation. Forecasts for 2024 indicate further growth of e-commerce in Europe, making this sector a key driver of economic growth. In recent years, companies/retailers (online retailers) have gained considerable knowledge and experience in the field of digitalisation, and the acceleration of this process was particularly evident in the context of the COVID-19 pandemic, which had a significant impact on the development of e-commerce and retail. In 2021, the European e-commerce market reached EUR 718 billion, with an annual growth rate of 13%, compared to EUR 633 billion in 2020. Forecasts for 2022 indicated that the growth trend would continue, with the growth rate tending to stabilise and estimated at 11%. E-commerce turnover was forecasted to reach EUR 797 billion in 2022. These results indicate the important role of e-commerce in the European economy and its growing importance for consumers [21].

In view of these forecasts, research into the e-commerce market is of paramount importance. It is required to explore mechanisms of the sector and identify factors influencing its growth in order to develop management strategies and economic policies to meet the challenges and opportunities of e-commerce development in the future. One of the key factors determining the growth of the e-commerce market is innovation in the broadest sense

relating to the economy, infrastructure, business operations, education, administration, and competence of society [22–24]. Studies show that e-commerce contributes to labour productivity, consumer purchasing power, and GDP [25,26]. There is therefore a need for research on the impact of innovation on the development of the e-commerce market, as changes in both of these areas are occurring in multiple directions and at a dynamic pace. In addition, the scope and scale of these changes in recent times has been significantly marked by the outbreak of the COVID-19 pandemic. The COVID-19 pandemic had a large impact on society and the economy, which translated into a change in consumer behaviour [27]. Social isolation and the crisis in selected economic sectors increased the importance of remote customer service channels, including e-commerce [28,29].

Thus, the identified research gap prompted us to investigate the relationship between a country's level of innovation and the propensity of residents to make online purchases in individual European countries. The following two specific objectives were subordinated to the realisation of the main objective:

Objective 1—Assessing changes in the e-commerce market in dynamic terms;
Objective 2—Assessing the impact of the COVID-19 pandemic on the development of the e-commerce market in selected European countries.

The main hypothesis is that a higher level of innovation in a country promotes a higher propensity for purchasing online. This article also formulates two specific hypotheses:

H1. *The age of consumers differentiates their propensity for buying online.*

H2. *The COVID-19 pandemic accelerated the development of the e-commerce market in selected European countries.*

To assess the relationship between e-commerce market development and innovation as well as the COVID-19 pandemic, panel data models were used to account for cross-country and cross-period variation. This constitutes a unique contribution of the authors to the study of e-commerce market development. The means of measuring e-commerce development (depending on the model) involved calculating the percentage of people who made online purchases overall or by age groups (demand side) and online sales of businesses (supply side). The impact of the pandemic was estimated by including zero–one variables for 2020 and 2021 in the models.

The level of innovation in European countries was expressed by the value of the authors' own synthetic measure. This measure is based on the methodology developed for the construction of the GII. However, the measure proposed in this paper is based on a narrower number of variables. One of the assumptions adopted in the construction of the authors' own measure was the selection of such independent variables among those included in the GII, which were statistically significantly correlated with the dependent variables in the econometric models.

2. Literature Review

As e-commerce reshapes the retail landscape, offering unparalleled convenience and accessibility, it also brings to the forefront the imperative of environmental sustainability. This transition aligns closely with the Sustainable Development Goals (SDGs) set by the United Nations, urging businesses to adopt more sustainable practices. A significant aspect of this shift is the adoption of sustainable supply chain management, a topic extensively discussed by Fahimnia et al. [30] in their work. They emphasize the importance of ethical sourcing, fair labour practices, and eco-friendly manufacturing in minimizing environmental impact. Additionally, reduction in packaging waste and carbon emissions through innovative methods is becoming increasingly critical in e-commerce. The role of e-commerce platforms in promoting sustainable fashion is also pivotal, potentially leading to more environmentally conscious consumer choices. This concept is further reinforced by Gerlich's [31] study, which highlights the growing trend of sustainable alternatives

facilitated by online platforms. Moreover, the article underscores the significance of responsible consumption and return policies in combating overconsumption, a crucial element in sustainable e-commerce. This trend is further explored in a study by Štofejová et al. [32], which discusses the environmental impacts of online shopping habits. Additionally, the importance of responsible consumption and return policies in e-commerce is emphasized, aligning with the findings of Oláh et al. [33] and Oláh et al. [34]. The integration of advanced technologies such as data analytics and AI for inventory optimization and waste reduction is another key strategy for aligning e-commerce with sustainable practices. Collaborative efforts with organizations focused on sustainability are essential in amplifying the impact of these initiatives. This holistic approach demonstrates that sustainable e-commerce is not merely a trend but an essential strategy for building a more sustainable and prosperous future, integrating business practices with environmental stewardship to reduce ecological footprints and inspire positive change across the industry [35].

The review conducted of the literature allows us to conclude that the main factor determining the spread of e-commerce is the increase in the number of people with access to the Internet [13,36–38]. In addition to Internet access, studies carried out by e-commerce market analysts distinguish further factors contributing to the development of this market [13,36,38–42]: the level of digital competence—computer literacy and the ability to use the Internet [43]; the usability and functionality of individual sales channels [37]; individual consumer approaches to shopping via computer networks [43]; as well as a wide and affordable range of courier services.

Economic factors play a key role in the development of e-commerce. Studies show that factors such as economic stability, the level of a society's income, inflation, as well as the cost of Internet access and delivery costs affect the development of e-commerce [44–46]. In addition, the researchers point to the importance of competition in the e-commerce market and government policies that may affect e-commerce regulations [47,48].

Legal factors are another important element determining the development of e-commerce. Transparent and effective legal frameworks for the protection of personal data, security of transactions, consumer rights, and protection of intellectual property are crucial for consumer confidence in e-commerce [49–53]. Additionally, regulations on taxes, duties, and import fees may affect the e-commerce market [54–56]. Additionally, the ability to enforce laws is equally important. E-commerce is inherently cross-border trade, and regulations and laws vary from jurisdiction to jurisdiction, which can create challenges [57,58].

Political factors also play an important role in the development of e-commerce. Political stability, government support for ICT infrastructure development, and initiatives that promote e-commerce can stimulate the development of this sector [59–61]. In addition, antitrust and competition regulation policies may affect the structure of the e-commerce market [62]. These regulations direct the dynamics of the market, affecting the introduction of innovations as well as competition between companies and, ultimately, consumer welfare [63]. Privacy and data protection regulations, which vary from country to country, also play a key role. They can affect consumers' perceptions of security and decisions to use e-commerce platforms [64–67].

Demographic factors also have a significant impact on e-commerce growth. The increase in the number of Internet users, the age structure of a population, urbanisation and the level of affluence of the population can affect consumer preferences and shopping behaviour [68,69]. In particular, younger generations who have grown up in a digital world are often more likely to use e-commerce, while older generations may have a more distant attitude towards it [70,71]. Additionally, research shows differences between countries in terms of purchasing preferences and adaptation to new technologies [61,72,73].

Educational factors are also an important determinant of e-commerce development. A society's level of education, including digital skills and Internet literacy, affects the level of acceptance and use of e-commerce services [74,75]. Studies show that training, educational programmes, and campaigns to raise digital awareness and competence can increase e-commerce penetration [76].

The breakdown of the determinants of e-commerce development presented above is not disjointed, as these various factors interact with one another. Research shows that there is a complex relationship between economic, legal/regulatory, political, demographic, and educational factors that reinforce one another (see Table 1). For example, an increase in Internet accessibility can affect economic development; at the same time, a regulatory policy can have an impact on the stability of the e-commerce sector, and demographic variables can influence shopping preferences. Consequently, understanding these interactions is crucial to the successful development and management of the e-commerce market.

The following table (Table 1) summarises the ten most important factors in the development of e-commerce in European countries based on an analysis of the scientific literature. The description of each factor includes the characteristics and cited sources used to substantiate its importance. In order to ensure the timeliness and reliability of the information, a variety of source materials were used, including the most recent scientific studies published in the last few years. These factors were carefully selected on the basis of their frequent appearance in the literature and their recognition as key to the development of e-commerce in the European context. The characteristics of each factor provide more detailed information on its particular importance.

The introduction of regulations concerning protection of personal data is extremely important for the development of e-commerce in European countries. Transparent and lawful privacy and data protection policies help build consumer trust and ensure secure online transactions. Custers, B., Calders, T., Schermer, B., and Zarsky, T. [65] analyse the problems and prospects of e-governance in regulating an information society.

The shift in consumer preferences toward online shopping is crucial to the development of e-commerce. Customers increasingly prefer the convenience and ease of online shopping, especially with the use of mobile devices. The rise in popularity of mobile devices is contributing to a shift in consumer preferences [77].

Technological innovations such as artificial intelligence (AI), data analytics, the Internet of Things (IoT), and blockchain are also important for the development of e-commerce. The use of these technologies contributes to personalising product recommendations, optimising logistics processes and enhancing the security of online transactions [78]. The development of technological infrastructure, including high-speed Internet and online payment systems, is crucial to the development of e-commerce. A high-quality Internet connection and seamless online payments are essential to ensure a smooth shopping process for online customers [72].

The increase in the number of online customers in European countries is a result of the increased availability and acceptance of e-commerce. Particularly among younger generations, the number of people with technological skills and the number of people using the Internet are rising, contributing to an increase in e-commerce's share of total trade [79]. The availability of a wide range of products online attracts customers to e-commerce. Customers now have access to a variety of products and can easily compare prices and product features before making a purchase. Access to a wide range of products also promotes the globalisation of e-commerce and enables international trade [80,81]. Providing a satisfying shopping experience is crucial to e-commerce success. Improvements in user experience (UX) and customer service contribute to increased customer loyalty. Personalised recommendations, ease of product search, streamlined website navigation, as well as fast and reliable product delivery are all elements that contribute to a positive consumer shopping experience [82].

Cross-sector cooperation, especially in the area of logistics and delivery, is important for the successful operation of e-commerce. Partnerships and cooperation between companies affect the efficiency of e-commerce, helping to optimise logistics processes, improve delivery speed, and increase customer confidence [16,83]. Cross-sector cooperation allows the expertise and resources of different companies to be leveraged to achieve synergies and e-commerce growth [84].

Table 1. Determinants of e-commerce development in European countries.

No.	Name of the Factor	Characteristics	Sources Cited
1	Development of technological infrastructure	The development of technological infrastructure, including high-speed Internet and online payment systems, is crucial to the development of e-commerce. High Internet penetration enables consumers to use e-commerce platforms and make purchases online. It is particularly important to ensure Internet access with sufficient speed and reliability to enable smooth and convenient shopping. Internet access is also important for e-commerce development in rural areas and more remote regions, where the number of traditional shops is small.	Gu, S., Ślusarczyk, B., Hajizada, S., Kovalyova, I, Sakhbieva, A. [72] Bińczak, T., Kaczmarek, F., Rybacki, J. [85] Nagy, S. [86] Rokicki, T. [87]
2	Personal data protection regulations	Transparent and legally compliant privacy and data protection policies contribute to building consumer trust and ensuring the security of online transactions. Effective regulation and data protection are essential for building consumer confidence in e-commerce. High data protection standards, such as the European Union's General Data Protection Regulation, are affecting the ways e-commerce companies collect, store, and process personal data.	Bińczak, T., Kaczmarek, F., Rybacki, J. [85] Vasileiadis, A. [50] Custers, B., Calders, T., Schermer, B., Zarsky, T. [65] Eid, M.I. [88]
3	Change in consumer preferences	The shift in consumer preferences toward online shopping has significant implications for the development of e-commerce. The number of online shoppers is increasing year by year. Customers increasingly prefer convenient and easy-to-use e-commerce platforms that allow them to purchase products and services from anywhere, at any time. The rise in popularity of mobile devices, such as smartphones and tablets, is also contributing to a shift in consumer preferences toward online shopping.	Naeem, M. [89] Nisar, T.M., Prabhakar, G., [90] Liang, T.P., Ho, Y.T., Li, Y.W., Turban, E. [77]
4	Availability of a wide range of products online	The availability of a wide range of products online attracts customers to e-commerce. Customers have access to a variety of products and can easily compare prices and product features before purchasing. Online shops can offer a wider selection than traditional ones, which attracts customers with different preferences and needs. The availability of a wide range of products also promotes the globalisation of e-commerce and develops international trade.	Ceyhan, A. [91] Alavi, S., Mehdinezhad, I., Kahshidinia, B. [92] Nisar, T.M. and Prabhakar, G. [90] Cho, Y.N., Im, I., Hiltz, S.R. [81] Hargittai, E. [79]
5	Technological innovations	Innovative technologies such as artificial intelligence (AI), data analytics, the Internet of Things (IoT), and blockchain are important for the development of e-commerce. The use of these technologies enables personalised product recommendations, improving the shopping experience, optimising logistics processes, and enhancing the security of online transactions. Technological innovations are helping to create innovative e-commerce business models, such as social commerce platforms and online marketplaces.	Zafar, A.U., Qiu, J., Li, Y., Wang, J., Shahzad, M. [93] Alavi, S., Mehdinezhad, I., Kahshidinia, B. [92] Schultz, D. E. [94] Zhao, Y., Zhou, Y., Deng, W. [95] Duan, Y., Gu, B., Whinston, A.B. [78]
6	Satisfying shopping experience	Providing a satisfying shopping experience is critical to e-commerce success. Improvements in user experience (UX) and customer service contribute to increased customer loyalty. Personalised recommendations, ease of product search, streamlined website navigation, and fast and reliable product delivery are all elements that contribute to a positive consumer shopping experience.	Tandon, U., Kiran, R., Sah, A.N. [96] Nisar, T.M. and Prabhakar, G. [90] Qu, W.G., Pinsonneault A., Tomiuk D., Wang, S. [97] The European Commission [98] Cardona, M., Duch-Brown, N., Francois, J., Martens, B., Yang, F. [99] Eid, M.I. [88] Ha, S. and Stoel, L. [82]
7	Education and digital awareness	A high degree of digital awareness and Internet literacy is crucial to the development of e-commerce. Improving digital education in society, including training in computer skills and the use of the Internet, contributes to increasing the number of online customers. An increase in the public's technological skills and a better understanding of the benefits of e-commerce are boosting e-commerce's market share.	Nagy, S. [86] Van Deursen, A., and Van Dijk, J. [100] Hargittai, E. [79] Anckar, B. [101] Hargittai, E. [102]

Table 1. *Cont.*

No.	Name of the Factor	Characteristics	Sources Cited
8	Acceptance of electronic payments	Acceptance of electronic payments plays a key role in the development of e-commerce. A high level of consumer confidence in online payments contributes to the growth of online shopping transactions. It is important to ensure the variety and security of available payment methods, such as credit cards, mobile payment systems, and electronic wallets. Good practices for protecting personal and transactional data are essential for building consumer confidence in electronic payments.	Tofan, M., and Bostan, I. [103] Charandabi, S.E., and Ghanadiof, O. [104] Krisnawati, M., Wienadi, J., Wiradinata, T. [105] Sutia, S., Fahlevi, M., Saparudin, M., Irma, D., Maemunah, S. [106] Nagy, S. [86] Maniam, B. [107]
9	Integrated logistics infrastructure and cross-sector cooperation	Integrated logistics infrastructure and cross-sector cooperation create favourable conditions for e-commerce development by optimising processes, reducing costs, and shortening lead times. An efficient delivery and logistics system enables efficient order processing and the fast delivery of products to customers. High-quality logistics services, such as shipment tracking, time flexibility, and returnability, contribute to consumer confidence in e-commerce. Investing in logistics infrastructure, developing cross-sector partnerships, and promoting public–private cooperation are essential for the successful operation of the e-commerce supply chain. This synergy requires a coordinated effort between different entities and an appropriate regulatory and policy framework.	Wang, C.N., Dang, T.T., Nguyen, N.A.T. [84] Kiba-Janiak, M., Cheba, K., Mucowska, M., and de Oliveira, L.K. [16] Jagoda, A., Kolakowski, T., Marcinkowski, J., Cheba, K., and Hajdas, M. [83] Vasileiadis, A. [50] Ratnasingam, P. [108]
10	Cost efficiency	Cost efficiency in the e-commerce sector is a key factor in the success of both sellers and customers. Cost management in e-commerce includes many aspects, such as optimisation of logistics processes, inventory management, as well as the effective use of technology and data. Innovations, such as the use of Big Data, can help optimise e-commerce distribution strategies, which in turn can lead to increased cost efficiency. In addition, a sustainable approach to e-commerce management that takes into account both economic and environmental aspects may contribute to the long-term profitability and sustainability of businesses. Therefore, it is crucial to understand and effectively manage the various cost elements in the e-commerce sector to achieve optimal cost efficiency.	Zhao, Y., Zhou, Y., Deng, W. [95] Izmirli, D., Ekren, B., Kumar, V. [109] Benlian, A., Hilkert, D., Hess, T. [110] Marchi, B., and Zanoni, S. [111] Kim, T.Y., Dekker, R., Heij, C. [112] Knickrehm, M., Berthon, B., Daugherty, P. [113]

Source: own elaboration based on the above-presented literature sources.

In conclusion, the table shows ten key factors in the development of e-commerce in European countries. These range from regulatory aspects to consumer preferences, technological innovations, technological infrastructure, and customer satisfaction. Understanding these factors and their importance can help companies and policymakers develop e-commerce development strategies that take into account the unique circumstances of the European market. The scientific sources cited in the table provide a solid foundation for further research and analysis in the area of e-commerce development in the European context.

3. Data and Methodology

The level of innovation of European countries was determined on the basis of a synthetic variable constructed by the authors of the article. A synthetic variable (also known as an aggregate variable) is a variable whose realisations are not directly observed but are estimated on the basis of observations of measurable diagnostic variables describing the objects under study. It can be used to determine the level of a complex phenomenon in the group of objects under analysis as well as to linearly order them [114]. Methods for the construction of synthetic variables are divided into reference point-based and reference point-free ones. The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method proposed by Hwang and Yoon [115] used in this article belongs to reference point-based methods. In this method, the values of each of the diagnostic variables, after normalisation, are compared to the positive and negative ideal solution.

The positive ideal solution is the abstract object for which all variables take the best values from the point of view of the composite phenomenon, whereas the negative ideal solution is the object with the worst values of the variables.

The relationship between the development of e-commerce and the level of innovation was examined using panel data models. A distinctive feature of models estimated from panel data is that constant-over-time and object-specific group effects are introduced [27,116–118] (Additionally, a third component, object-invariant and specific-to-time periods, can be distinguished. It is called the time effect (see, e.g., [119])). These group effects capture unobservable, individual specific effects that are not included in the regression. The model takes the following form:

$$y_{it} = \alpha_0 + \boldsymbol{\beta}^T \boldsymbol{x}_{it} + (\alpha_i + \varepsilon_{it}) \quad (1)$$

where $\boldsymbol{x}_{it}$ is the $(Kx1)$ vector of explanatory variables, α_0 and elements of vector $\boldsymbol{\beta}$ are parameters, α_i are the time-invariant group effects specific for the object i, and $\varepsilon_{it} \sim \mathrm{IID}(0, \sigma_\varepsilon^2)$ is an error term, $i = 1, \ldots, N$, $t = 1, \ldots, T$.

If the α_i effects are correlated with at least one of the explanatory variables (the elements of the $\boldsymbol{x}_{it}$, vector), they cannot remain part of the random component, as the LS estimator would lose consistency. They are then shifted to the intercept, and model (1) takes the form

$$y_{it} = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{x}_{it} + \varepsilon_{it} \quad (2)$$

where $\beta_0 = \alpha_0 + \alpha_i$. Model (2) is called a fixed effects model (FE). It meets the assumptions of OLS; however, some adaptation is sometimes used for its estimation. Due to the potentially large dimensions of the $\boldsymbol{X}$ matrix, which may be the case when there is a large number of N cross-sectional units, so-called within-transformation is applied, which consists of subtracting group averages from all variables (time averages of all the observations for unit i), leading to the form

$$y_{it} - \overline{y}_{i.} = \boldsymbol{\beta}^T (\boldsymbol{x}_{it} - \overline{\boldsymbol{x}}_{i.}) + (\varepsilon_{it} - \overline{\varepsilon}_{i.}) \quad (3)$$

In model (3), there is no intercept β_0 containing N group effects, hence no problems associated with the invertibility of the matrix $(\boldsymbol{X}^T \boldsymbol{X})$, the degree of which is reduced from $N + 1 + K$ in model (2) to K in model (3). The OLS estimator of model (3) is called the within estimator or the FE estimator. The estimation of group effects can be made based on the estimation of the vector $\boldsymbol{\beta}$ in the form (2).

Under the assumption that α_i effects are not correlated with any of the variables that are part of the vector $\boldsymbol{x}_{it}$, they can remain a component of the error term; therefore, the model remains in the form (1). Such a construction is called a random effects model (RE). The generalised least squares method is used for estimation, and it can be shown that the GLS estimator of the RE model is a matrix-weighted average of the within-group estimator and the so-called between-group estimator. The latter is an estimator of the model of the form (1), in which each variable is replaced by its group mean. The RE model estimator therefore uses information about the within-group variability and the between-group variability, while the FE model estimator is based only on information about the deviation of each individual from the group mean. If, therefore, the assumption of no correlation between group effects and explanatory variables is met, the RE estimator is more efficient than the FE one. The Hausman test, used to assess which estimator has better properties, is based on this property. More on the construction, estimation, and testing of panel data models can be found in in Baltagi [119], among others.

The following eight variables were initially selected as indicators of e-commerce development. Data were derived from the Eurostat website, https://ec.europa.eu/eurostat/data/database, accessed on 15 October 2022.

pur_all—percentage of people who made online purchases in the last three months;

pur_2554—percentage of people aged 25–54 who made online purchases in the last three months;

pur_1624—percentage of people aged 16–24 who made online purchases in the last three months;

fre_all—percentage of people who have made online purchases 3 to 5 times in the last 3 months;

fre_2554—percentage of people aged 25–54 who have made online purchases 3 to 5 times in the last 3 months;

fre_1624—percentage of people aged 16–24 who have made online purchases 3 to 5 times in the last 3 months;

sales—enterprises' turnover from e-commerce sales, as percentage of total turnover;

entpr—enterprises with e-commerce sales, percentage of enterprises (without the financial sector, 10 or more employees, and self-employed persons).

The first six variables, i.e., the percentages of people who have made online purchases, overall and by age group, describe consumer attitudes towards e-commerce, and thus the demand side. The two other variables reflect the situation of companies selling online, i.e., the supply side.

Data describing the innovation performance of national economies were taken from https://www.globalinnovationindex.org/home, accessed on 15 October 2022. The data comprise around 80 indicators, including measures on the political environment, education, infrastructure, and knowledge creation of the economies of 132 countries. These indicators are the basis for the determination of the Global Innovation Index (GII), which was envisioned to capture as complete a picture of innovation as possible. We decided not to use the GII values published on the website indicated in the study but instead to construct our own measure of the level of innovation, as a complete index was not needed for the purposes of this study. The idea behind the construction of the proposed measure was that it should reflect those aspects of innovation that are related to e-commerce. It was modelled on the construction of the GII, which aims to capture the multi-dimensional facets of innovation.

The survey covered 31 European countries for which complete data for the years 2019–2021 exist in the GII database. The construction of the innovation measure was preceded by a selection of sub-indicators for data completeness (the GII database has some gaps) and for their correlation with variables describing e-commerce. As a first step, Pearson's linear correlation coefficients were calculated for all available innovation indicators among themselves and with variables that are indicators of e-commerce development (*pur_all*, *pur_2554*, *pur_1624*, *fre_all*, *fre_2554*, *fre_1624*, *sales*, *entpr*). The percentage of innovation indicators that were significantly correlated with the others was then counted, and variables for which this percentage exceeded 96%, as well as those for which there were missing data, were discarded. The variables for which the correlation coefficient exceeded the critical value with a p-value of $p < 0.05$ were considered statistically significant. In the last step, using a similar procedure, the correlation coefficients between e-commerce development indicators and innovation indicators were analysed. The aim was to identify variables that are significantly correlated and therefore likely to influence the development of e-commerce development indicators. As a result of the procedure described above, three variables were selected: *pur_all*, *pur_2554*, and *sales* to serve as e-commerce development indicators in further analysis. They represent two of the factors in the development of e-commerce in European countries enumerated in Table 1: change in consumer preferences (variables *pur_all* and *pur_2554*) and availability of a wide range of products online (variable *sales*). The other factors indicated in Table 1 are either difficult to quantify (e.g., satisfying shopping experience) or reflect the driving forces behind e-commerce (e.g., technological innovations or education and digital awareness). The variables used in this research are meant to reflect the volume of e-commerce. One of the considerations that had to be taken into account in the selection of diagnostic variables for the synthetic measure was their availability in relation to the time horizon studied and the statistical units selected for analysis. At the same time, 22 variables representing each of the seven main pillars and most of their dozen sub-pillars were selected as innovation indicators. The diagnostic variables on

which the applied innovation measure was constructed are listed below, together with the names of the pillars and sub-pillars to which they belong:

1. Institutions;
1.1. Political environment;
1.1.1. Political, legal, operational, or security risk index;
1.2. Regulatory environment;
1.2.2. Rule of law index;
2. Human capital and research;
2.1. Education;
2.1.3. School life expectancy, primary to tertiary education, in years;
2.1.4. PISA scales in reading, maths, and science;
2.3. Research and development (R&D);
2.3.1. Researchers, full-time equivalent, per million population;
2.3.2. Gross expenditure on R&D, % of GDP;
2.3.4. Average score of the top three universities according to the QS world university ranking;
3. Infrastructure;
3.1. Information and communication technologies (ICTs);
3.1.2. ICT use index;
3.2. General infrastructure;
3.2.2. Logistics performance index;
3.3. Ecological sustainability;
3.3.2. Environmental performance index;
4. Market sophistication;
4.2. Investment;
4.2.3. Number of venture capital deals invested in (per billion PPP$ GDP, three-year average);
4.3. Trade, competition, and market scale;
4.3.2. Domestic industry diversification, based on manufacturing output;
5. Business sophistication;
5.1. Knowledge workers;
5.1.1. Employment in knowledge-intensive services, (% of workforce);
5.1.4. GERD financed by business enterprise (% of total GERD);
5.2. Innovation linkages;
5.2.1. University–industry R&D collaboration;
5.2.2. State of cluster development and depth;
6. Knowledge and technology outputs;
6.1. Knowledge creation;
6.1.1. Number of resident patent applications filed at a national or regional patent office (per billion GDP PPP as compared to the US dollar);
6.2. Knowledge impact;
6.2.4. Number of ISO 9001 quality certificates (per billion GDP PPP as compared to the US dollar);
6.3. Knowledge diffusion;
6.3.1. Charges for use of intellectual property (% total trade, three-year average);
7. Creative outputs;
7.1. Intangible assets;
7.1.4. Extent to which ICTs enable new organisational models;
7.3. Online creativity;
7.3.2. Country-code top-level domains (per thousand population, 15–69 years old);
7.3.3. Wikipedia yearly edits by country (per million population, 15–69 years old).

4. Results

The empirical results presented in this section are based on three e-commerce development indicators and the specially developed innovation measure constructed using the TOPSIS method on the basis of 22 diagnostic variables. The selection of variables is the

result of the procedure described in the Data and Methodology section. The e-commerce development indicators are as follows:

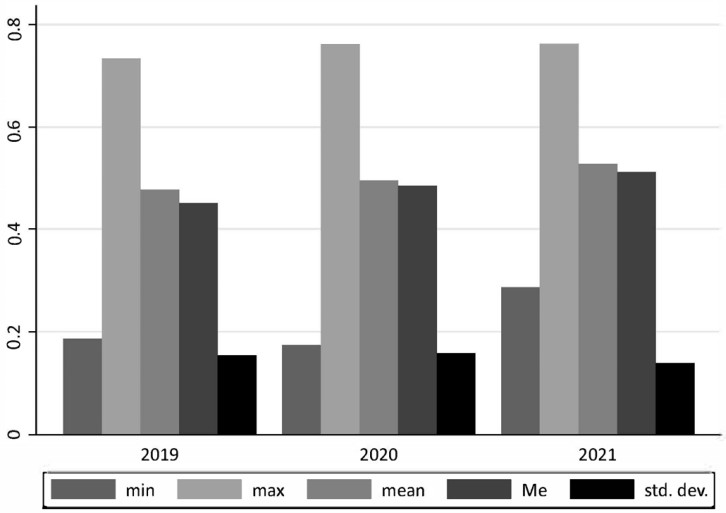
pur_all—percentage of people who have made an online purchase in the last three months;

pur_2554—percentage of people aged 25–54 who have made an online purchase in the last three months;

sales—enterprises' total turnover from e-commerce sales and percentage of turnover.

In determining the innovation measure, the Global Innovation Index was modelled on the construction of the Global Innovation Index, whose sub-indices are grouped into seven main pillars: institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs. The *MI* synthetic measure of innovation was determined for 31 European countries for which complete data were available for the years 2019–2021.

The basic statistical measures of the *MI* variable in the following years are provided in Figure 1.

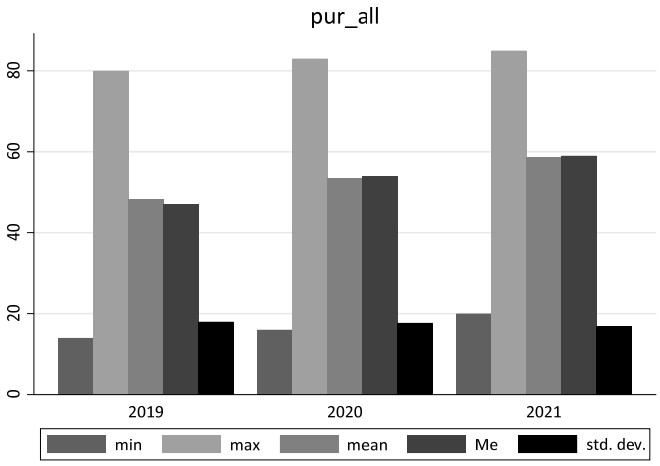


year	2019	2020	2021
min	0.186	0.174	0.288
max	0.732	0.761	0.762
mean	0.478	0.495	0.527
median	0.452	0.486	0. 511
std. dev.	0.155	0.159	0.140
V (%)	32.34	32.06	26.52

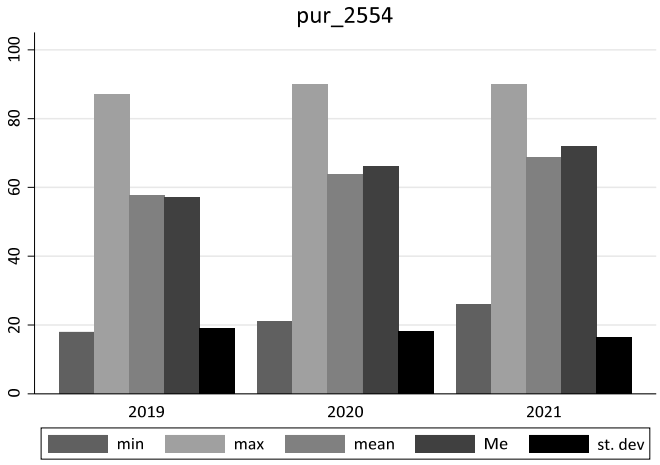
Figure 1. Basic statistics of MI measure. Source: own elaboration.

Figure 1 presents the basic statistical measures of the *MI* measure for the following years. In 2020, there was an increase in the spread of the innovation level measure compared to the previous year. The slight decrease in the minimum value with a slightly larger increase in the maximum may reflect the effect of the pandemic and lockdown, which increased demand for innovative technologies, mainly in the communications and IT industries. The countries with the lowest levels of innovation in each year were Serbia, Romania, Croatia, Bulgaria, and Greece, while the highest levels were observed in Switzerland, Sweden, Denmark, the Netherlands, Germany, and Finland. Both the average *MI* level and the median level increased over the period studied.

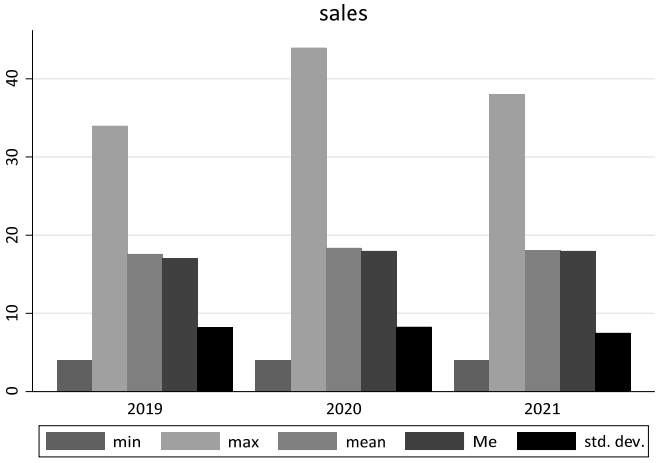
Figure 2 contains the basic statistical measures of the variables serving as indicators of e-commerce development in this study: *pur_all*, *pur_2554*, and sales in the following years. Year on year, there is an increase in the *pur_all* and *pur_2554* variables representing demand (this applies to all measures of location), with decreasing variation as measured by the coefficient of variation V. This means that consumers in all countries are increasingly willing to shop online. It is also worth noting that, in 2020 and 2021, the median of both variables exceeded the average; therefore, the number of countries with an above-average proportion of online shoppers is increasing. This thesis is confirmed by the decreasing negative skewness coefficients. A comparison of the range of values and measures of the central tendency of both variables confirms the regularity known from the literature that younger people, including those aged up to 55 years, are more open to ICT, thus being the most active online shoppers [120–124]; in each year, the mean and median of the *pur_2554* variable are approximately 20 pp higher than the *pur_all* variable.



year	2019	2020	2021
min	14	16	20
max	80	83	85
mean	48.29	53.42	58.55
median	47	54	59
std. dev.	17.97	17.71	16.85
V (%)	37.20	33.16	28.78
skewness	−0.05	−0.25	−0.39



year	2019	2020	2021
min	18	21	26
max	87	90	90
mean	57.74	63.77	68.77
median	57	66	72
std. dev.	18.93	18.13	16.27
V (%)	32.79	28.43	23.65
skewness	−0.32	−0.58	−0.89



year	2019	2020	2021
min	4	4	4
max	34	44	38
mean	17.61	18.39	18.03
median	17	18	18
std. dev.	8.17	8.28	7.50
V (%)	46.40	45.02	41.61
skewness	0.21	0.79	0.28

Figure 2. Basic statistics of e-commerce indicators. Source: own elaboration based on [125].

The impact of the COVID-19 pandemic is best seen on the business side (sales variable statistics in Figure 2). Year on year, the mean and median increased by around 4–5 pp in 2020, while in 2021, the mean decreased slightly, and the median did not change. The maximum percentage of turnover from e-commerce sales increased year on year in 2020 by as much as almost 30 pp, only to fall by 14 pp in 2021. Such an impact is also likely in the case of demand, but additional data on customer motivation would be needed to separate this from the systematic upward trend of the phenomenon.

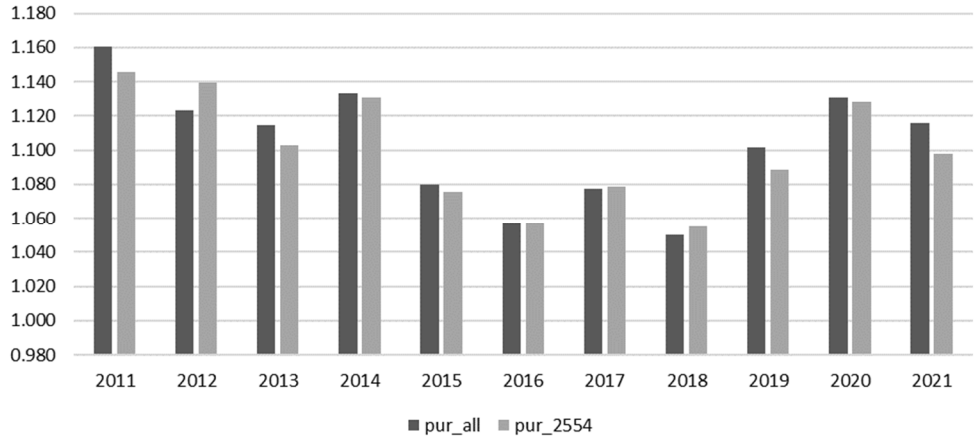
The countries with the highest proportions of online shoppers, regardless of age, are the United Kingdom, Denmark, the Netherlands, Switzerland, Germany, and Sweden,

while the lowest proportions are observed in Bulgaria, Romania, Serbia, Italy, and Portugal. The situation is different on the business side. Ireland, Belgium, and the Czech Republic have the highest percentages of turnover from e-commerce sales, followed by Switzerland, Denmark, and Sweden. At the opposite end of the spectrum are Bulgaria, Greece, Cyprus, Romania, and Latvia. E-commerce is global in nature; the location of the seller is irrelevant to the customer. Moreover, revenues can be reported in countries where the company is registered, and shipping warehouses can be located in different parts of the continent, allowing buyers to avoid overseas shipping costs; therefore, differences in the ranking of countries due to the demand and supply side are natural.

4.1. Long-Term Dynamics

In order to place the research in a broader context, data on e-commerce indicators since 2010 were used. Due to the availability of data, it was possible to analyse the dynamics of the percentage of people buying online (variables *pur_all* and *pur_2554*). Complete data on enterprises' total turnover from e-commerce sales (variable sales) was available over this long period for 12 of the 31 countries included in the analysis.

Chained dynamics indices were calculated for each country, and then the average rate of change was determined as the geometric mean of the country indices for the subsequent years. The results are shown in Figure 3.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
pur_all	1.161	1.123	1.114	1.133	1.080	1.057	1.077	1.050	1.102	1.131	1.116
put_2554	1.146	1.139	1.103	1.131	1.075	1.057	1.079	1.055	1.089	1.128	1.098

Figure 3. Average rate of change in the percentage of people making online purchases. Source: own elaboration based on [125].

Figure 3 shows a faster rate of change in the initial period, up to 2014, when the values of both variables increased by 10–16 pp. In the following years, until 2018, the average rate of change decreased and ranged from 5.5 pp to almost 9 pp.

The emergence of online commerce opportunities can be seen as the emergence of innovation. According to Rogers' [126] diffusion of innovations theory and Bass' [127] (pp. 215–227) sales model, diffusion is slow in the initial phases, then picks up speed, and finally reaches a certain degree of saturation or disappears. According to this theory, the period 2011–2014 can be considered a period in which e-commerce development accelerated, especially in countries lagging behind in terms of access to technology, including the Internet. The faster pace of change in these countries occurred later than in the more technologically advanced countries and raised the average. Since 2015, saturation has also occurred in these countries, and the rate of change, while still positive, has been slower. The years 2019–2021 are a

period of greater momentum, with a peak in 2020. The faster gains in online shopping, especially in 2020, are a result of the pandemic and the closure of stationary shops.

4.2. Econometric Models—Results

In order to verify the main research hypothesis that a higher level of innovation in a country is conducive to a higher propensity to buy online, econometric models were estimated in which the e-commerce indicators *pur_all*, *pur_2554*, and *sales* were explained, and the specially developed measure of the level of innovation *MI* was included as an explanatory variable. On the basis of the literature review presented in Section 1, other potential determinants of e-commerce were also selected: the income of households per person, the gross household saving rate, the GDP per capita, the final consumption expenditure of households per capita, the proportion of population aged 20–64 years, and the proportion of population aged 25–54 years. They reflect the material situation of the population and the proportion of the population in the age groups that are most likely to shop online. Alternative panel data model specifications were tested, with different combinations of explanatory variables. However, the *MI* measure of innovation is highly correlated with the aforementioned variables (Pearson's coefficient ranged from 0.65 for the saving rate to 0.83 for household income), resulting in a loss of statistical significance of the variables in the model. Given the purpose of this study, the intention was to leave the *MI* variable in the models. Therefore, the remaining potential determinants of e-commerce were removed one by one, ultimately obtaining models in which the level of innovation was the only factor shaping the level of the explanatory variable. Zero–one variables for individual years were also included in the models. The aim of such a procedure was to capture the impact of the COVID-19 pandemic on e-commerce development. Tables 2–4 contain the estimation results of the explanatory models for the variables *pur_all*, *pur_2554*, and *sales*. Fixed effects (FE) and random effects (RE) models were estimated. The results of the Hausman test for the models of the variables *pur_all* and *pur_2554* at the significance level of 0.05 indicate that there are no grounds to reject the null hypothesis, and, therefore, the RE estimator is consistent and more efficient than the RE estimator. For the *sales* variable model, a similar conclusion would be correct at the 0.1 significance level, and at the 0.05 level, the null hypothesis would have to be rejected. However, the *MI* variable was not significant in the FE model; therefore, further analysis was based on the RE model in this case as well.

Table 2. Estimation results for the panel data models of the e-commerce indicators—*pur_all*.

	Fixed Effects Model			**Random Effects Model**		
Variable	**Coefficient**	**Std.Error**	***p*-Value**	**Coefficient**	**Std.Error**	***p*-Value**
MI	8.412	27.534	0.761	89.154	10.056	0.000
d20	4.982	1.085	0.00	3.576	1.035	0.001
d21	9.843	1.670	0.00	5.861	1.134	0.000
constant	44.269	13.181	0.001	5.669	5.098	0.266
	fraction of variance due to αi: 0.947			fraction of variance due to αi: 0.819		
	Chow test: F(30.59) = 14.46; *p*-value = 0.000			Breusch—Pagan LM test: chi2 (1) = 51.24; *p*-value = 0.000		
	Hausman test: chi2 (3) = 4.46; *p*-value = 0.216					

Source: own calculations.

Table 3. Estimation results for the panel data models of the e-commerce indicators—*pur_2554*.

	Fixed Effects Model			Random Effects Model		
Variable	**Coefficient**	**Std.Error**	***p*-Value**	**Coefficient**	**Std.Error**	***p*-Value**
MI	39.986	31.595	0.211	93.084	10.513	0.000
d20	5.336	1.245	0.000	4.410	1.145	0.000
d21	9.060	1.917	0.000	6.442	1.243	0.000
constant	38.626	15.125	0.013	13.241	5.330	0.013
	fraction of variance due to αi: 0.892			fraction of variance due to αi: 0.797		
	Chow test: F(30.59) = 12.48; *p*-value = 0.000			Breusch—Pagan LM test: chi2 (1) = 49.57; *p*-value = 0.000		
	Hausman test: chi2 (3) = 3.18; *p*-value = 0.365					

Source: own calculations.

Table 4. Estimation results for the panel data models of the e-commerce indicators—*sales*.

	Fixed Effects Model			Random Effects Model		
Variable	**Coefficient**	**Std.Error**	***p*-Value**	**Coefficient**	**Std.Error**	***p*-Value**
MI	6.279	7.279	0.392	16.499	5.576	0.003
d20	0.819	0.386	0.038	0.894	0.392	0.023
constant	14.456	3.666	0.000	9.318	3.073	0.002
	fraction of variance due to αi: 0.950			fraction of variance due to αi: 0.938		
	Chow test: F(30.60) = 45.22; *p*-value = 0.000			Breusch—Pagan LM test: chi2 (1) = 62.55; *p*-value = 0.000		
	Hausman test: chi2 (3) = 5.55; *p*-value = 0.063					

Source: own calculations.

The influence of the *MI* variable is strong and statistically significant in all the models. A comparison of the results in Tables 2 and 3 shows a much stronger impact of a country's level of innovation on the proportion of online shoppers among those aged 25–54 than among the general population. Compared to the population as a whole, those aged 25–54 are characterised by a higher propensity to purchase online (Figure 2). In conjunction with the value of the parameter at the *MI* variable in the *pur_2554* model, it is possible to conclude that people in this age group are also more open to innovative solutions, including alternative forms of shopping.

A confirmation of the hypothesis that the outbreak of the pandemic significantly accelerated the development of this branch was obtained from the statistical significance of the zero–one variables *d20* and *d21* for the years 2020 and 2021 in the *pur_all* and *pur_2554* variable models (Tables 2 and 3) and the variable *d20* in the explanatory model percentage of enterprises' turnover from e-commerce sales (Table 4). The year 2020 was the time of the tightest COVID-19 restrictions, including very large restrictions on stationary trade, as reflected in the positive parameter scores with the variable *d20* in all models. Restrictions were partially maintained in 2021, to varying extents across countries. For the *pur_all* and *pur_2554* variables, the period-specific effect is even stronger than for the previous year, as evidenced by the comparison of parameter scores at both zero–one variables. This may be due, in addition to the impact of the pandemic, to the persistence of shopping habits, to the fact that consumers have 'taken a liking' to online shopping. It can also be interpreted as an indirect effect of the pandemic, reinforced by the phenomenon of habit spreading—some people who would not normally choose to shop online not only did so but also encouraged their friends to do so. By contrast, the impact of the pandemic on enterprises' turnover from e-commerce sales was limited to 2020—only variable *d20* proved significant in the *sales* variable model. In 2021, trade restrictions were much weaker than the year before, and stationary trade began to return to pre-pandemic levels. Businesses' revenue from

stationary trade therefore increased, which translated into a decrease in the share from e-commerce in overall revenue.

5. Discussion

There is a rapid increase in the global e-commerce index, which has a significant impact on the digital economy, especially in the microeconomic sphere. A systematic study of the impact of new information and communication technologies (ICTs) and innovation is necessary for companies to maintain and enhance their competitiveness. It is also important to understand the drivers of effective ICT use and innovation activities that promote national economic development.

According to Eurostat data [19,20], in the EU Member States, the share of enterprises that had e-sales was 22.8% in 2021 on average, more than 6 p.p. higher than in 2012. The share of e-commerce depends on the size of enterprises. In 2021, 44.1% of large enterprises conducted e-sales, corresponding to an e-sales value of 23.1% of total turnover in this size class. Of the medium-sized enterprises, 29.9% made e-sales generating 14.7% of total turnover in this size class. By contrast, 20.8% of small enterprises engaged in e-sales, generating 7.9% of the turnover of such enterprises [19,20]. An analysis of the differences between countries revealed significant discrepancies in the e-commerce indicators studied. E-commerce indicators differed more between countries than macroeconomic indicators. These differences may be due to differences in the level of innovative development, changes in the business environment, legal and organisational aspects, and government support for science and research [128–130]. However, there is a lack of studies that quantify the impact of technological and organisational innovation on firms' economic performance [131].

Literature studies and results from analyses of macroeconomic indicators [125] and summary innovation indicators for European economies—the Summary Innovation Index and the Global Innovation Index [132,133]—indicate that countries with higher levels of economic development also show higher levels of e-commerce and vice versa. For example, over the years, some of the highest e-commerce indicators—the value of e-commerce sales and enterprises' total turnover from e-commerce sales as a percentage of turnover—were achieved by Ireland (34–2019; 44–2020; 38–2021), Sweden (25–2019; 24–2020; 25), or Denmark (25–2019; 29–2020; 28–2021), while Bulgaria (5–2019; 6–2020; 4–2021) and Romania (7–2019; 12–2020; 9–2021) have the lowest indicators. In comparison, in the Global Innovation Index [133], Sweden (3–GII 2022) and Denmark (10–GII 2022) occupy the top positions, and Bulgaria (35–GII 2022) or Romania (49–GII 2022) are much further away from the top of the ranking.

When analysing the relationship between innovation and online sales performance, significant positive relationships were observed, suggesting that innovation has some impact on e-commerce performance. This impact is by far the strongest for purchases made by those under 55 years of age (model variable *pur_2554*, Table 2), although it is also significant for the other two variables. These results are also confirmed by studies conducted by Kabango and Asa [55], Akcali and Sismanoglu [134], Escursell et al. [6], Mohdhar and Shaalan [135], and others. Businesses that invest in products, services, and process innovation and use advanced technologies are more likely to succeed in online sales. Innovation can contribute to greater efficiency, competitiveness, and higher revenues in an e-commerce environment. This argumentation is relevant from the point of view of the variables included in the synthetic measure proposed by the authors. It is worth highlighting the strong positive correlation of the variable—knowledge-intensive employment (%)—with variables describing e-commerce, in particular with the percentage of total persons and persons aged 25–54 who have made online purchases in the last three months. Values of Pearson's linear correlation coefficients oscillated around 0.8 (in 2021) and exceeded 0.82 in 2020. A strong relationship was also observed with the variable describing R&D expenditure. According to the analyses presented in the article, gross expenditure on R&D (% of GDP) is strongly correlated with the percentage of online shoppers in all the years studied. According to Mohdhar and Shaalan [135], both product and process

innovations have a positive impact on online sales performance. Companies that introduce new trends, design patterns, and efficient processes can increase their competitiveness and achieve higher sales performance in an online channel. The study looked at online sales in the apparel sector in Malaysia.

The relationship between economic development outcomes and e-commerce appears to be positive. Attempts were made to include variables such as GDP per capita, gross household saving rate, gross disposable income of households per capita, and final consumption expenditure of households per capita in the models. However, these variables were not significant in the models together with the *MI* measure. They are strongly positively correlated with it, confirming the conjecture above. Consequently, faster economic development can be expected in countries with higher e-commerce rates. Overall, the results of the analysis suggest that countries with higher innovation activity show higher e-commerce rates, and that countries with higher levels of e-commerce show higher levels of economic development. These conclusions are also supported by studies conducted by Anvari and Norouzi [136], Belazreg and Mtar [137], Fernández-Portillo et al. [138], Xie et al. [139], and other authors [128]. In the context of e-commerce, the innovation index of an economy plays a crucial role in shaping consumer behaviours, particularly in terms of their propensity to engage in online shopping. A higher innovation index typically indicates a more advanced technological infrastructure, greater digital literacy among the population, and a more robust online market environment, all of which are conducive to increased online shopping. Economies with higher innovation indices often have better-developed e-commerce platforms, offering a wider range of products and services, enhanced user experiences, and more efficient delivery systems [140,141]. This, in turn, fosters consumer trust and confidence in online transactions. Furthermore, in economies with high innovation indices, there is typically greater investment in digital infrastructure, which not only improves accessibility but also ensures the security of online transactions, thereby encouraging more consumers to shop online [142]. Additionally, these economies often exhibit higher levels of consumer digital literacy, which further facilitates the adoption of e-commerce [143]. Therefore, a higher innovation index in an economy can significantly influence the inclination of its residents to make online purchases, not only by enhancing the technical capabilities and security of e-commerce platforms but also by fostering a digitally literate and confident consumer base.

Juxtaposing our own findings with those of other authors studying online shopping [122,144,145], it is worth noting that researchers pay a great deal of attention to demographics and the shopping experience of consumers. The most frequently studied factors according to the demographics are age [122,146–148] and gender [144,148,149]. On the other hand, some researchers have examined education [144,148], household income, and family composition [149] as the demographic factors affecting online shopping. In this article, we focus primarily on age as a factor that is relevant both from the point of view of consumers' online shopping behaviour (demand side), but also from the point of view of how a shop's offer is presented and how marketing strategies are aimed at specific audiences (supply side).

Fekete-Farkas et al. [146] conducted a study among Hungarian consumers that showed that there are significant differences in shopping behaviour (CPB) between the group of people under 22 and the group of people over 50. Also, the shopping behaviour of Hungarian consumers in the 23–37 and 38–50 age groups differed significantly from that of the over-50 group. All age groups showed significant differences in CPB compared to the over-50 group. Other studies have also found that younger consumers are more likely to shop online than older consumers [149–153]. The public statistics data in the Eurostat database, used in the article to build the panel data models, confirm this thesis. In each of the three consecutive years, 2019, 2020, and 2021, the percentage of online shoppers was higher in the 25–54 age group than in the total group. According to the comparison carried out between the two age groups of online shoppers, the largest differences of more than 11 p.p. were recorded in 2020 and 2021. In Poland, for example, in 2020, the percentage

of online shoppers in the total group was 70%, and in the 25–54 group it was 82%. For Portugal, in 2021, the difference between the percentages of people in the total group and in the 25–54 group was even greater, at 15 p.p. respectively. The percentage of online shoppers in the 25–54 age group, compared to the total group, was as much as 16 p.p. higher for Cyprus (2021) and France (2020). At the same time, this was the largest recorded difference in the last three years covered by the analysis. Another regularity emerges from the static data presented in the article. Looking at the longer horizon of the analysis, covering the years 2010–2021, it can be seen that the growth rate of the percentage of people buying online is higher in the total group than in the 25–54 age group. Therefore, it is possible to conclude that the importance of the youngest people, under the age of 25, is growing among the total number of people buying online. Thus, it is worth emphasising, as previous research has already shown, that different marketing strategies are needed for different age segments in e-commerce [154]. For example, older people should be encouraged to use the Internet by introducing them to this technology and helping them learn how to use it. Younger consumers, on the other hand, need an incentive to buy again. For younger consumers, additionally, the importance and impact of social networks as marketing channels influencing their purchasing behaviour is highlighted [147]. A study by Khanchanapong et al. [155] found that, in the case of online shopping, age significantly differentiates customers in terms of their need for information and their overall attitude towards online shopping. For example, as the authors showed in their study involving consumers of organic products, older consumers paid more attention to the appearance of sources of organic production when compared with younger consumers.

According to studies by Gu et al. [72], Jairoun et al. [156], and Fittler et al. [157], among others, the COVID-19 pandemic has had a significant impact on the development of the e-commerce market. Faced with the constraints of lockdown and social distancing, consumers turned to online shopping, leading to a rapid increase in online sales. This is also confirmed by the statistics used in the article. Enterprises' total turnover from e-commerce sales (percentage of turnover) in most of the countries analysed in the article increased in 2020 or 2021 compared to 2019. The largest differences in enterprises' total turnover from e-commerce sales were registered in Denmark, Germany, Greece, Ireland, the Netherlands, Romania, and Lithuania. The most spectacular increase occurred in Ireland, where the percentage of turnover from e-commerce sales in 2020 was 10 p.p. higher compared to 2019. According to the McKinsey & Company report, online sales rates in some product categories grew considerably. For example, online delivery's volume increased by the same amount in eight weeks as it had over the entire previous decade. Telemedicine experienced a ten-fold growth in subscribers in just 15 days [158].

The pandemic also caused changes in consumer preferences and behaviour. According to studies by Knecht-Tarczewska [159] and Amankwah-Amoah et al. [160], consumers began to value more the convenience, security, and speed of online shopping, which accelerated e-commerce adoption. In addition, studies have shown that the pandemic influenced increased sales in categories such as food/food products [161,162], supplements/pharmaceuticals [156,158], and hygiene items/cosmetics [163]. The values of the variables (*pur_all* and *pur_2554*) for which panel data models were developed in the article recorded increases between 2019 and 2020 or 2021 for most countries included in the econometric analysis. A comparison of the 2021 data with the 2019 data shows at least a 20% increase in the percentage of people who made an online purchase in the last three months for Hungary, Ireland, and Slovakia.

6. Conclusions

Over the past decade, the growth rate of the digital economy has significantly outpaced progress in traditional sectors. Over the years, the e-commerce sector has been gaining ground; the outbreak of the pandemic, however, has dynamised its growth, and the emergence of COVID-19 in particular has contributed to the multi-year growth trend seen in Figure 3.

Analysing the development of e-commerce, it can be seen that the number of factors that determine the growth of this sector is large, and the factors themselves are very diverse. The classification of factors is not disjointed, and individual factors can interact with each other. Literature studies prove that the primary determinant of e-commerce is the development of IT infrastructure. The authors point to the important role of investment in ICT infrastructure and activities carried out for consumer protection. Such a conclusion implies the rationale for weaker economies to align regulations related to purchasing security with leading economies. Educational factors certainly have a positive impact, as they narrow the gap between underdeveloped countries and countries with a more developed ICT structure, along with the demographic structure of Internet users characterised by a higher proportion of young people.

The authors of this paper claim that it is possible to identify the common features of the studies presented in the literature on the determinants of e-commerce development. And one of the key-common factors determining the development of the e-commerce market is broadly understood innovation relating to the economy, infrastructure, business activity, education, administration, and digital competence of society.

The analysis of differences between countries carried out in this paper indicates significant discrepancies in the e-commerce indicators studied. The highest values of these indicators were recorded in the Scandinavian countries as well as Germany and Switzerland, while the lowest values were recorded in the Balkan countries. At the same time, e-commerce indicators differed between countries more than macroeconomic indicators.

The empirical studies conducted have confirmed the main hypothesis that a higher level of innovation in a country promotes a higher propensity for online purchasing. This is demonstrated by the estimation results of both models explaining the percentage of online shoppers. The two specific hypotheses presented in the Introduction have also been confirmed. The analyses conducted indicate that the most active online customers are those aged 25 to 54. The average percentage of e-commerce customers in this age group is higher than in the population as a whole, with less variation (Figure 2). Moreover, in this group, the relationship between a country's level of innovation and the propensity for online purchasing is much stronger. It has also been confirmed that the COVID-19 pandemic accelerated the development of the e-commerce market in selected European countries. The impact of the pandemic is best seen on the business side, as evidenced by the statistics of the sales variable in Figure 2. However, this is a short-term impact, limited to 2020, as highlighted in the model explaining this variable. The situation is different for models explaining the percentage of e-commerce customers. The effect specific to 2021 was even stronger than in 2020, which could mean that the habit of online shopping is sustainable, and additionally, that this form is increasingly gaining followers.

A major limitation of the study conducted was the lack of some data on innovation subindices in the GII database, which meant that not all countries on the continent could be included in the survey.

The results of these analyses have yielded some interesting conclusions. First of all, innovation is positively related to e-commerce performance. This means that when innovation performance is low, e-commerce performance is also low. A higher innovation index can have a positive impact on e-commerce.

Despite attempts to fill the identified research gap, especially with regard to a quantitative assessment of the impact of innovation and the COVID-19 pandemic on the development of the e-commerce market in European countries, this relationship has not been fully explored yet. The authors of the presented paper plan to focus in the near future on assessing the relationship between innovation and e-commerce development in enterprises, that is, at a lower level of aggregation. They conclude that the desired development of e-commerce in individual European countries (macroeconomic level) is derived from the level of innovation and digital development of the business sector. It seems that a separate issue in future research should be to determine the strength of the impact of individual factors and to build a model that would allow for forecasting the speed of development

of the e-commerce market in Europe. The authors also plan to include environmental considerations in future research on e-commerce, thus linking it to the latest research trends in the field of green economies. Furthermore, the authors plan to delve into the issue of which online marketplaces are preferred by shoppers—for example, shopping platforms, company online shops, and shopping on social media.

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