

UNDERSTANDING E-COMMERCE ADOPTION ACROSS COUNTRIES WITH PLS-SEM AND FSQCA: THE INTERPLAY OF INTERNET USAGE, EDUCATION, AND ELECTRONIC SECURITY

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Abstract:

This study aims to investigate the influence of internet usage (IU), e-security (ESEC), and education (ED) on e-commerce adoption (ECOM) across 49 countries by utilizing common index data. The dataset was obtained from secondary data collected through research carried out by prominent international organizations for the year 2024. The data were analyzed using the PLS-SEM (Partial Least Squares Structural Equation Modeling) method. To corroborate the outcomes of the PLS-SEM analysis, the study used fuzzy-set Qualitative Comparative Analysis (fsQCA) as a configurational approach. Results show that ESEC negatively affects ECOM, while IU does not have a significant direct effect. ESEC has a negative, significant indirect effect on the relationship between IU and ECOM. Rigorous ESEC standards lead to increased multi-stage encryption and verification procedures. This makes e-commerce transactions more complex and difficult to use. Rising security protocols can increase consumers' risk perception, decreasing in ECOM. Additionally, IU has a positive impact on ESEC, and ED positively affects IU. This study employs a unique combination of PLS-SEM and fsQCA to examine the impact of IU, ESEC, and ED on ECOM and provides a robust, cross-national perspective that is rarely addressed in prior research.

Key words: *E-commerce Adoption, Internet Usage, E-Security, PLS-SEM, fsQCA*

1. Introduction

Rapid increases in global internet adoption have led to over five billion users worldwide, and the number of people utilizing e-commerce is constantly growing. E-commerce transactions are expected to exceed 4.3 trillion U.S. \$ worldwide by 2025 (Statista, 2025). The growth of e-commerce is strongly correlated with the development of internet technologies and the global increase in IU (Thompson et al., 2019: 239). Therefore, the most crucial requirement for e-commerce is an internet connection and its usage. The progress of internet-related technologies and the rapid growth in IU led to a fundamental shift in traditional commerce, driving a transformation from physical stores to

e-commerce. Notably, COVID-19 has been one of the key factors driving social and economic change worldwide. Because of the COVID-19 outbreak, many activities have moved online, and customers who are avoiding physical contact are increasingly shopping by using e-commerce (Jula et al., 2024: 3; Nacar and Özdemir, 2021: 206). Increased IU, particularly the ECOM, has provided businesses with numerous benefits, including increased sales, reduced costs, improved insight into customer preferences, product availability and market dynamics (Jula et al., 2024: 2). Additionally, internet and e-commerce usage establish more efficient connections with suppliers and customers and allow customers to access products and services with ease and immediacy, regardless of their location (Nacar and Özdemir, 2021: 207).

As the use of the internet and e-commerce has increased, security issues have emerged as a crucial factor in both academic literature and practical applications. Security threats have a negative impact on individuals' use of e-commerce. Therefore, increased IU and e-commerce depend on ESEC applications and measures (Matbouli and Gao, 2012; Khan, 2019). The usage of ESEC measures is significant in protecting personal data and mitigating customers' privacy concerns. Therefore, focusing on ESEC becomes crucial for loyal customers and enhancing reputation in a highly competitive market (Karim, 2024: 52). ESEC has the potential to influence the relationship between IU and e-commerce. Since individuals who use the internet tend to engage in more online shopping if ESEC measures are in place. However, in the absence of any indications of ESEC measures, and in cases where individuals perceive a threat, they may refrain from making purchases on e-commerce platforms or websites. In this regard, the strength or direction of the relationship between IU and ECOM may differ according to ESEC.

ED is another significant factor that affects IU and the ECOM. Households with higher ED tend to exhibit higher IU and ECOM (Quaglione et al., 2018). Indeed, according to Tekin et al. (2018), there is a positive link between higher levels of ED and innovation. As Jula et al. (2024) indicated, one of the most critical factors in the success and increased ECOM is the presence of highly educated individuals. The level of ED influences consumer behaviors, such as online shopping and digital transactions. Individuals who have higher ED tend to have a more positive attitude towards e-commerce, viewing it as an efficient and useful shopping channel (MacGregor and Vrazalic, 2007). Additionally, the ED of individuals increases the tendency towards online shopping (Ünver and Alkan, 2021). Also, ED level affects e-commerce satisfaction and security preferences for individuals (Lightner, 2003). This phenomenon is explained by the positive correlation between higher levels of ED and greater digital literacy, which enables individuals to conduct more effectively in ECOM (Jula et al., 2024: 4). Also, a poor ED system is one of the most essential barriers to ECOM, especially in developing countries (Lawrence and Tar, 2010). In this context, the relationship between IU and ECOM may also differ depending on the level of ED. The direction or strength of the relationship between IU and ECOM may be affected by the level of ED.

The effects mentioned above are largely indicative of the findings from studies in the extant literature on surveys collected from consumers, individuals, or firms at the micro level (Lightner, 2003; Chien-Ta Ho and Oh, 2009; Chiu et al., 2014; Tekin et al., 2018; Ünver and Alkan, 2021; D'adamo et al., 2021; Karim, 2024). There are also studies based

on macro-level index data for countries, but they examine different research questions or do not cover many countries (Jula et al., 2024; Weng and Wu, 2024; Paun et al., 2024). In this context, the objective was to reveal the relationship and interaction between the variables of IU, ECOM, ESEC, and ED by using the index data of the countries at the macro level. We also aimed to verify and test whether studies conducted on consumers and individuals in countries at the micro level yield similar results at the macro level.

This study aims to examine the impact of IU, ESEC, and ED on ECOM across countries by using index data. Moreover, the study analyzed the indirect effect of ESEC on the impact of IU on ECOM. Also, we investigated the influence of ED on IU and the subsequent effect of IU on ESEC. The final purpose of the study is to assess the moderating effects of ESEC and ED on the impact of IU on ECOM. ESEC was measured with two sub-dimensions: the National Cyber Security Index and the Data Protection Index. IU was measured with two sub-dimensions: the IU Index and Mobile Social Media Penetration. ECOM was measured with two sub-dimensions: Weekly Online Purchase and Weekly Online Grocery Purchase. The Education Index was divided into two sub-dimensions: Tertiary Education and Research and Development. Despite the study's global orientation, it utilizes data commonly available across countries. The study was conducted within a country context using index data. In this context, the study's findings will likely contribute to the extant literature. The usage of index data is important for the findings to be reliable. The analysis encompassed 49 countries, all of which were observed to have common index data. The dataset utilized in the present study was derived from secondary data collected through research carried out by prominent international organizations for the year 2024. The data obtained were analyzed utilizing the PLS-SEM method. To confirm the results of the PLS-SEM analysis and explore causal complexity further, the study used fsQCA as a configurational approach. This dual method strengthens the robustness of the results by combining variance-based and set-theoretic perspectives.

The internet and e-commerce are being adopted rapidly and widely on a global scale. Nevertheless, despite the existence of studies that have demonstrated the significance of security concerns and ED levels, the absence of adequate precautions and the implementation of effective strategies presents a significant research opportunity in this area. This opportunity can be explored through studies that adopt different perspectives. In this context, we analyzed our research data and interpreted our findings in our cross-country study. The results are then discussed in the conclusion and discussion section, offering both theoretical and practical implications. Finally, the limitations are addressed, and several recommendations for future research are provided.

2. Literature review and hypothesis

In this study, as in many scientific studies, a literature review was conducted to build the link between the variables in the research model. E-commerce, defined as the exchange of products, services, and information between customers, businesses, and suppliers utilizing internet technologies (Taher, 2021: 156), has significantly transformed the carried out of businesses and the economies of countries (Alamro and Trawneh, 2011:

497). E-commerce offers various advantages to both businesses and customers (Al Tamer, 2021: 2). While it enables businesses to establish more efficient connections with suppliers and customers through the Internet, it also allows customers to access products and services with ease and immediacy, regardless of their location (Nacar and Özdemir, 2021: 207). With the advent of e-commerce, businesses can offer their products to customers in international markets, in addition to the domestic market. Moreover, customers could purchase products from any location in the world (Al Tamer, 2021: 2).

The development and increasing use of e-commerce have been strongly correlated with the evolution of internet technologies and the rise in internet usage on a global scale (Thompson et al., 2019: 239). It is therefore essential to note that the most fundamental requirement for e-commerce is the existence of an internet connection and its subsequent utilization. As Eastin (2002) emphasized, the Internet has become a direct business environment (e-commerce). In the context of the digital economy, the advent of internet access and its utilization have engendered a paradigm shift in business models, profoundly influenced consumer behavior, and assumed a critical role in the accelerated growth of e-commerce. This phenomenon can be ascribed to the widespread availability of the internet, which enables individuals to access e-commerce at any time and from any location. Especially, mobile internet access is identified as a crucial factor in increasing individuals' willingness to adopt e-commerce (Jula et al., 2024: 4). Indeed, Deng and Zhang (2014) emphasized that the degree of internet use by individuals in a country is one of the most critical determinants of ECOM. A study utilizing a six-year panel dataset covering 31 countries found that Internet use significantly and positively affects B2C e-commerce in these countries. Given that internet connectivity is a prerequisite for e-commerce, the percentage of the population with internet access appears to have a strong correlation with the prevalence of e-commerce across a country. Indeed, early studies such as Eastin (2002) have identified internet use as a key antecedent of overall ECOM. Similarly, Beilock and Dimitrova (2003) posit that the rising number of Internet users facilitates the openness of a society. Consequently, both businesses and individuals are more likely to use e-commerce. In recent studies, for instance, Ma et al. (2020) found that internet use increased farmers' ECOM. Similarly, Jula et al. (2024) utilized Eurostat data. They conducted a study across EU countries, finding that both long-term and short-term internet access and individual IU rates positively impact e-commerce sales. In their study of ten European countries, Xie et al. (2023) found that countries' adaptation to e-commerce was positively affected by internet access. Hence, we proposed H1.

H1: IU affects ECOM.

Internet and e-commerce usage are also related to the security problem. Users are increasingly subjected to security threats (Furnell et al., 2007: 410). Tirumala et al. (2016) emphasized that the rise in internet use increases cybersecurity attacks, and in this context, it is essential to take necessary precautions and raise awareness about cybersecurity. Especially due to the internet, the corporate data of businesses is at risk and threatened with being stolen and used for malicious purposes (Hawkins et al., 2000). In this respect, countries need to take the necessary measures for ESEC and protect both individual users and businesses from security problems that may arise from internet use. According to Kolat and Ünver (2025), a study conducted on 171 countries, the advent

technological infrastructure can increase investments in cybersecurity to enhance ESEC. ESEC is defined as a subjective form of trust in which individuals perceive that their personal information is protected from potential manipulation and misuse. This trust is critically important, since it directly affects customers' willingness to shop via e-commerce. Because ESEC not only ensures the protection of personal data and customers' privacy concerns but also strengthens their trust. Thus, prioritizing ESEC is critical for attracting loyal customers and building a reputation in an increasingly competitive marketplace (Karim, 2024: 52). In this regard, according to information security theory, individuals, must protect information against potential risks and threats by ensuring necessary controls and taking precautions (Liu et al., 2022: 3). Asymmetric information in e-commerce transactions creates concerns for consumers because e-commerce inherently involves uncertainty and risk (Chiu et al., 2014). Considering the prospect theory, customers desire to avoid uncertainty, risk, and loss (Tversky and Kahneman, 1992). In this context, security measures and risk reduction appear to be factors that increase individuals' e-commerce usage rates (Chiu et al., 2014). Signal theory also emphasizes the critical importance of security signals on a website or e-commerce platform in enhancing ECOM. It has been posited that consumers will continue shopping if they perceive the e-commerce platform as trustworthy (Mavlanova et al., 2012). In this respect, the direction or strength of the Link between IU and ECOM may differ according to ESEC. Indeed, Shah et al. (2014) stated in their study that technical protection and security features on e-commerce platforms are key indicators for mitigating individuals' concerns. In this respect, Sanayei and Rajabion (2008) highlighted in their study examining ESEC governance in developing countries that e-commerce without ensuring security will not be beneficial and will not be adopted by individuals. Furthermore, as Matbouli and Gao (2012) interpret, ESEC threats have a detrimental effect on e-commerce usage. Individuals who perceive threats tend to avoid e-commerce. Also, a significant obstacle to the adoption of ECOM, particularly in developing countries, is the absence of security measures. Similarly, Khan (2019) posits that addressing security measures and providing confidence are essential for the success of ECOM. As also underlined by Hepfer (2021) and Liu et al. (2022), enhancing and investing in ESEC is vital for attaining a competitive advantage and ensuring the success of e-commerce. However, ESEC enhanced with multi-stage encryption, verification processes, and numerous security and safety procedures can make e-commerce more complex. Increasing security measures with extra procedures and precautions reduces ECOM. Indeed, according to Davis et al. (1989) (Technology Acceptance Model), individuals avoid utilizing complex and difficult-to-use technological products. Consequently, ease of use helps individuals develop more positive attitudes (Smith, 2008). Ease of use is the belief that people don't need to exert much effort when using a technological product. It is a significant determinant for ECOM. In this respect, increased ease of use is boosting ECOM (Liu and Wei, 2003). In other words, ESEC measures can reduce ease of use, thus negatively influence ECOM. Thus, we suggest H2, H3, H4, and H5.

H2: IU affects ESEC.

H3: ESEC affects ECOM.

H4: ESEC moderates the relationship between IU and ECOM.

H5: ESEC mediates the relationship between IU and ECOM.

Another significant factor in the adoption of e-commerce and IU is ED. Younger and more educated individuals tend to adopt and utilize novel technologies. As posited by Tekin et al. (2018: 633), there is a positive link between ED and innovation. Consequently, the utilization of the internet and e-commerce is increasing. Indeed, as Jula et al. (2024) emphasize, one of the most fundamental factors in the success and increased ECOM is the presence of highly educated individuals between the ages of 25 and 34 who have completed higher ED. As Quaglione et al. (2018: 312) demonstrate, households with higher levels of ED tend to display higher levels of IU and ECOM. Similarly, Manlove and Whitacre (2019) indicated that more educated individuals are likely to use the internet. This is considered a factor that increases e-commerce usage and adoption. Recent research also reveals a strong correlation between ED level and ECOM (Jula et al., 2024: 4). However, it is asserted that the level of ED affects consumer behaviors such as online shopping, and that individuals who have higher ED level tend to have a more positive attitude towards e-commerce and see it as an efficient and useful shopping channel (MacGregor and Vrazalic, 2007). Ünver and Alkan (2021) posit that the education of individuals raises the tendency towards online shopping. Looking also at former studies, Lightner (2003) noted that ED level affects e-commerce satisfaction and security preferences for individuals. This phenomenon is explained by the positive correlation between higher levels of ED and greater digital literacy, which enables individuals to perform more effectively in online settings (Jula et al., 2024: 4). Similarly, Lawrence and Tar (2010) highlighted that the poor ED system is a significant barrier to ECOM. Within a robust ED system, individuals are expected to receive comprehensive and systematic training in computer skills and information technology. This has a direct impact on e-commerce and IU. Indeed, comprehensive ED enables individuals to grasp the advantages offered by the internet and e-commerce and to desire to take advantage of them. In another study conducted in countries, Paun et al. (2024) posit that ED positively affects e-commerce, utilizing panel data analysis on 133 countries. However, a similar situation also arises in the context of employees. As suggested by Tekin et al. (2018), employees with a higher level of ED appear to utilize e-commerce technologies more proficiently than their colleagues with a lower level of ED. Therefore, we proposed H6, H7, and H8.

H6: ED affects IU.

H7: ED affects ECOM.

H8: ED moderates the relationship between IU and ECOM.

In this context, the theoretical and conceptual model of the study is presented in

Figure 1.

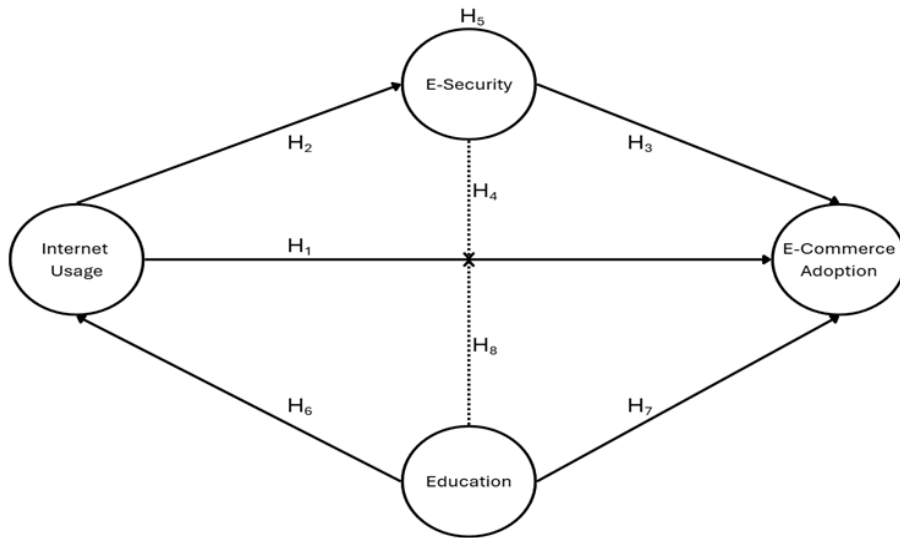


Figure 1. Conceptual model

3. Methodology

The study employed two methods to obtain more robust results. The first of these is the PLS-SEM method, while the second is the fsQCA method. Initially, hypotheses were tested using the PLS-SEM approach. Subsequently, the fsQCA was applied to examine the robustness of the PLS-SEM results.

3.1. Sample

This study utilizes index data to examine the impact of IU on ECOM across countries, and to investigate whether educational attainment acts as a moderator and ESEC functions both as a moderator and a mediator in this relationship. Although the study was designed from a global perspective, it was conducted using commonly available data across countries. The countries included in the analysis are presented in Table 1 below.

Table 1. Sample countries of study

Americas	Oceania	Europe	Asia	Africa
Argentina	Australia	Austria	China	Egypt
Brazil	New Zealand	Belgium	India	Ghana
Canada		Bulgaria	Israel	Kenya
Chile		Croatia	Japan	Morocco
Colombia		Czechia	Malaysia	Nigeria
Mexico		Denmark	Philippines	South Africa
		France	Saudi Arabia	
		Germany	Singapore	

Greece	South Korea
Hungary	Thailand
Ireland	Türkiye
Italy	United Arab Emirates
Netherlands	Vietnam
Norway	
Poland	
Portugal	
Romania	
Russia	
Spain	
Sweden	
Switzerland	
United Kingdom	

Source: Authors' own work

As shown in Table 1, the research was conducted across forty-nine countries on five continents. The data used in this study were not merely extracted from automated databases; rather, they were manually collected from official reports of reputable institutions. To ensure a zero-error process, a cross-check mechanism was implemented among the authors, thereby guaranteeing the integrity of the data mining process. Upon completing these rigorous checks, it was observed that not all indices were available for every country. Consequently, the final sample was refined to 49 countries where complete data for all indices could be obtained.

The dataset was derived from secondary data collected through research conducted by reputable international organizations for the year 2024. Table 2 below provides detailed information regarding the dataset.

Table 2. Information about the data used

Data	Abbreviation	Variable	Variable Abbreviation	Source
National Cyber Security Index	CSI	Electronic Security	ESEC	Surfshark (2024) Digital Quality of Life Index
Data Protection Index	DPI			
Internet Usage Index	IUI	Internet Usage	IU	
Mobile Social Media Penetration	MSMP			Similarweb (2024)
Weekly Online Purchase	WOP	Electronic Commerce	ECOM	
Weekly Online Grocery Purchase	WOGP			
Tertiary Education	TED	Education	ED	WIPO (2024), Global Innovation Index
Research and Development	RD			

Source: Authors' own work

Table 2 presents the variables used in the study along with their respective data sources. The data were obtained through field studies conducted by internationally reputable organizations. In this way, the micro-level findings of these studies were utilized

in the creation of novel macro-level variables. Regarding the credibility of the databases utilized in this study, the World Intellectual Property Organization (WIPO) stands as a primary authority. As a specialized agency of the United Nations (UN), WIPO plays a pivotal role in establishing global standards and monitoring innovation-related statistics across nations. Its regularly published reports serve as a foundational resource for major international organizations, such as the World Economic Forum (WEF). For digital traffic and cybersecurity metrics, data were obtained from Surfshark and Similarweb. The reliability of Similarweb has been empirically validated by Jansen et al. (2022), demonstrating a high correlation with Google Analytics data. Furthermore, Similarweb's datasets are frequently referenced by the WEF, mirroring the institutional trust placed in WIPO reports. Surfshark is recognized not only as a data provider but also as a research center specializing in cybersecurity and digital rights. Its reporting standards, which align with UN protocols, have been acknowledged by the FBI and are utilized as a benchmark by international auditing firms such as Deloitte. To ensure the timeliness of the research, the 2024 editions of the relevant reports were employed.

3.2. PLS-SEM methodology and results

Since the study employs single-year cross-sectional data for each country and each variable, it is not possible to conduct a time series or panel data analysis. Furthermore, the available literature does not offer sufficiently long-term data series to justify such approaches. Therefore, the most appropriate analytical technique for assessing the valuable findings of this study is considered to be PLS-SEM. A similar and recent application of this methodology can be seen in Sarihan and Yildiz (2025). As noted by Develi and Yildiz (2021), PLS-SEM is a suitable alternative for studies with relatively small sample sizes. Hair et al. (2022) suggest that 10 observations per variable may be sufficient, implying that 40 observations would be adequate for a model with four constructs. Nevertheless, to assess the statistical power of the sample, the G*Power software was utilized (Faul et al., 2009). With an effect size of $f^2 = 0.25$, $\alpha = 0.05$, and a desired power of 0.80, the required minimum sample size was calculated to be 48 ($u = 3$, $v = 44$). Since the study draws upon data from 49 countries, this threshold is exceeded, and the statistical power requirements are sufficiently met.

All variables in the model were constructed as formative constructs in accordance with the perspective of Rigdon et al. (2010). In this context, one of the most critical requirements—the Variance Inflation Factor (VIF) values—was evaluated first. The analyses then proceeded with the examination of the outer weights. In the final stage, the hypotheses were tested using the structural equation modeling approach based on the partial least squares method (Hair et al., 2011; Ramayah et al., 2018). A similar methodological approach was also followed in a study employing formative constructs derived from different indices (Sarihan and Yildiz, 2025). The findings of the current research are presented in Table 3 below.

Table 3. Results of significance testing for outer weights/loadings of formative constructs and indicators

Formative constructs and indicators	VIF	Outer weights	t-statistics	p values	PCI	Factor Loadings (FL)	p values for FL
<i>E-commerce Adaptation (ECOM) (RA=1.000)</i>							
Weekly Online Purchase (WOP)	2.154	-0.129	0.231	0.817	[-1.076 - 1.325]	0.669	0.013
Weekly Online Grocery Purchase (WOGP)	2.154	1.090	2.150	0.032	[-0.805 - 1.476]	0.996	0.000
<i>Electronic Security (ESEC) (RA=1.000)</i>							
National Cyber Security Index (CSI)	1.817	0.494	7.648	0.000	[0.418 - 0.681]	0.896	0.000
Data Protection Index (DPI)	1.817	0.599	9.245	0.000	[0.424 - 0.690]	0.930	0.000
<i>Internet Usage (IU) (RA=1.000)</i>							
Internet Usage Index (IUI)	3.664	0.517	20.684	0.000	[0.465 - 0.568]	0.962	0.000
Mobile Social Media Penetration (MSMP)	3.664	0.522	18.784	0.000	[0.482 - 0.592]	0.963	0.000
<i>Education (ED) (RA=1.000)</i>							
Tertiary Education (TED)	1.453	0.767	9.072	0.000	[0.582 - 0.921]	0.959	0.000
Research and Development (RD)	1.453	0.343	3.100	0.002	[0.122 - 0.562]	0.771	0.000

Source: Authors' own work

One of the most critical aspects presented in Table 3 is the redundancy analysis results. Based on the procedure outlined by Sarstedt et al. (2016), this analysis revealed that the single-item measured variables—ECOM_G, ESEC_G, IU_G, and ED_G—corresponding to the constructs ECOM, ESEC, IU, and ED, respectively, each had a value of 1.000. These values exceed the recommended threshold of 0.70, as indicated by Hair et al. (2022), thereby confirming the convergent validity of the endogenous variables. Regarding the VIF values reported in Table 3, it is observed that most values fall below the conservative threshold of 3.3 (Kock and Lynn, 2012), while the indicators for Internet Usage (IU) exhibit a VIF of 3.664, which remains well within the acceptable limit of 5.0 commonly cited in PLS-SEM literature (Hair et al., 2022).

The outer weights of the indicators were subsequently calculated using 10,000 bootstrap samples. At the 5% significance level, it was determined that the indicator Weekly Online Purchase (WOP) was not a significant contributor to its respective construct ($p = 0.817$). However, all other indicators were found to be significantly associated with their latent variables ($p < 0.05$). Given the insignificance of the WOP indicator weight, its factor loading was further examined. The respective loading of 0.669 ($p = 0.013$) was significantly above the conventional threshold of 0.50. Therefore, both theoretical and methodological considerations support the validity of the formative constructs (Hair et al., 2022). At this stage of model development, it can be concluded that none of the indicators were eliminated, and all index structures were retained. The next step involves testing the research hypotheses, the results of which are presented in Table 4.

Table 4. The results of the path coefficients, mean, standard deviation, t-statistics, and p-values of the structural model

Paths	Beta	Mean	STDEV	t values	p values	PCI
Internet Usage --> E-Commerce Adoption	0.177	0.218	0.448	0.394	0.693	[-0.539 - 1.302]
Internet Usage --> Electronic Security	0.420	0.425	0.111	3.773	0.000	[0.179 - 0.608]
Internet Usage --> Electronic Security --> E-Commerce Adoption	-0.305	-0.301	0.138	2.207	0.027	[-0.572 - 0.017]
Education --> Internet Usage	0.792	0.795	0.057	13.987	0.000	[0.664 - 0.884]
Education --> E-Commerce Adoption	0.232	0.205	0.372	0.623	0.533	[-0.624 - 0.846]
Education x Internet Usage --> E-Commerce Adoption	-0.076	-0.071	0.255	0.297	0.766	[-0.612 - 0.459]
Electronic Security --> E-Commerce Adoption	-0.727	-0.704	0.225	3.232	0.001	[-1.050 - -0.083]
Electronic Security x Internet Usage --> E-Commerce Adoption	0.116	0.108	0.295	0.392	0.695	[-0.452 - 0.772]

Source: Authors' own work

An examination of the structural model reveals that ED has the strongest and most significant positive effect on IU ($\beta = 0.792$, $p = 0.000$). While Internet Usage and Education do not have a statistically significant direct effect on ECOM at the 5% significance level ($\beta = 0.177$, $p = 0.693$ and $\beta = 0.232$, $p = 0.533$, respectively), ESEC emerges as a critical variable with a significant negative effect on ECOM ($\beta = -0.727$, $p = 0.001$). The results of the model indicate that no significant moderating effect was identified for either ED x IU ($\beta = -0.076$, $p = 0.766$) or ESEC x IU ($\beta = 0.116$, $p = 0.695$). However, a significant mediating effect was found in the relationship between IU and ECOM through ESEC ($\beta = -0.305$, $p = 0.027$). The percentile confidence interval (PCI) for this indirect effect $[-0.572, -0.017]$ does not include zero, confirming the statistical significance of the mediation. This indicates that ESEC plays a "full" mediating role, as the direct path from IU to ECOM remains non-significant. To evaluate the explanatory power of the model, it is necessary to examine the R^2 value.

In the analysis of the R^2 values concerning the model's explanatory power, the R^2 value for IU is 0.628 (adjusted $R^2 = 0.620$), indicating a substantial level of explanatory power. The R^2 value for ECOM is 0.359 (adjusted $R^2 = 0.284$), which represents a moderate level of explanation, while ESEC yielded an R^2 of 0.176 (adjusted $R^2 = 0.159$), reflecting a weaker but still relevant predictive relevance in the structural model. Regarding the f^2 effect sizes, the most prominent result is the effect of ED on IU, which reached an exceptionally high value of f^2 , indicating a very large effect size. Furthermore, the f^2 effect size for ESEC on ECOM is calculated to be 0.431, reflecting a large effect, while IU on ESEC shows a medium effect size of 0.214. In contrast, the direct effects of ED ($f^2 = 0.023$) and IU ($f^2 = 0.007$) on ECOM resulted in small to negligible effect sizes. Additionally, the f^2 effect sizes for the interaction terms of the moderation effects are considered negligible, confirming that the moderation effects do not contribute significantly to the model's explanatory power. Consequently, while the primary causal paths exhibit strong to moderate predictive power, the structural stability of the model is

This approach is consistent with guidelines proposed by Ragin (2008) and Schneider and Wagemann (2012), who recommend anchoring fuzzy-set calibration in both empirical observations and conceptual clarity.

Table 5. Data calibration breakpoints of each construct

Breakpoints	IU	ESEC	ECOM	ED
Full membership	≥ 98.91	≥ 90.39	≥ 70.19	≥ 58.05
Crossover point	89.54	70.13	34.51	38.03
Full non-membership	≤ 53.98	≤ 38.70	≤ 2.66	≤ 13.14

Source: Authors' own work

Following the calibration process, a truth table was constructed to identify configurations of causal conditions that are consistently associated with the outcome. The truth table lists all logically possible combinations of the calibrated conditions and aligns them with empirical cases from the dataset. In this study, 49 countries were analyzed using three causal conditions (IU_fz, ESEC_fz, and ED_fz) and one outcome condition (ECOM_fz). Each row in the table represents a unique configuration of presence or absence of conditions, along with the number of empirical instances and consistency scores. A consistency threshold of 0.8 was applied to determine sufficient configurations, in line with established methodological standards (Ragin, 2008; Schneider and Wagemann, 2012). Configurations below this threshold were excluded from further minimization. This step allowed for the identification of alternative causal pathways—known as causal recipes—that may lead to the outcome, thus capturing the complexity and equifinality inherent in social phenomena. Table 6 shows the fsQCA results of the model.

Table 6. Configuration of conditions for high e-commerce adoption

Configuration	1	2	3	4	5	6	7	8
IU	⊗	⊗	⊗	⊗	•	•	•	•
ESEC	⊗	⊗	•	•	⊗	⊗	•	•
ED	⊗	•	⊗	•	⊗	•	⊗	•
Consistency	0.495	0.795	0.723	0.757	0.764	0.832	0.816	0.852
Raw Coverage	0.288	0.238	0.292	0.321	0.307	0.382	0.380	0.619
Unique Coverage	0.026	0.000	0.007	0.010	0.006	0.043	0.005	0.157
Overall Solution Consistency	0.657							
Overall Solution Coverage	0.799							

Source: Authors' own work

Note: Black dot (•) demonstrates the presence of the condition, and circle-crossing (⊗) shows the absence of the condition. All conditions have been found as core.

Examining the eighth configuration, it is concluded that the simultaneous presence of internet usage, electronic security, and education strongly influences e-commerce adaptation, with a consistency score of 0.852. The unique coverage value of 0.157 further elucidates that the digital ecosystem functions as an integrated whole. Additionally,

configurations 6 and 7 also exceeded the 0.8 threshold, empirically demonstrating the robust sufficiency of the proposed model.

The sufficiency analysis identified three primary configurations that meet the consistency threshold. The most dominant pathway, Configuration 8, represents the simultaneous presence of high IU, ESEC, and ED ($IU \cdot ESEC \cdot ED$), exhibiting the highest consistency of 0.852 and a broad raw coverage of 0.619. Additionally, Configuration 6 ($IU \sim ESEC \cdot ED$) and Configuration 7 ($IU \cdot ESEC \sim ED$) emerged as alternative pathways with consistency scores of 0.832 and 0.816, respectively. These results illustrate the principle of equifinality, as multiple distinct combinations of factors lead to the same high level of e-commerce adoption. The overall solution consistency of 0.657 and overall solution coverage of 0.799 further confirm the robust explanatory power of the configurational model.

A key finding of this analysis is the central role of Internet Usage (IU), which appears as a core component across all sufficient configurations. To further investigate this, a necessity analysis was performed. Table 7 shows the necessity analysis results.

Table 7. Necessity analysis results based on fsQCA method

Condition	High E-Commerce Adoption		Low E-Commerce Adoption	
	Consistency	Coverage	Consistency	Coverage
ESEC_fz	0.750	0.724	0.553	0.491
~ESEC_fz	0.473	0.535	0.690	0.718
ED_fz	0.781	0.787	0.538	0.498
~ED_fz	0.502	0.541	0.770	0.764
IU_fz	0.856	0.780	0.558	0.467
~IU_fz	0.415	0.505	0.738	0.825

Source: Authors' own work

As shown in Table 7, IU_fz emerged as the most critical condition for high ECOM, with a consistency score of 0.856 and a coverage of 0.780. While ED_fz and ESEC_fz also showed relatively high consistency scores (0.781 and 0.750, respectively), they did not reach the same level of indispensability as internet infrastructure. This suggests that while IU is not a strictly necessary condition in the absolute sense (threshold > 0.90), it functions as a quasi-necessary prerequisite for the outcome.

The results underscore the value of adopting a dual-methodological approach. While the PLS-SEM analysis indicated that internet usage does not exert a direct, linear "net effect" on adoption ($\beta = 0.177$, $p = 0.693$), the fsQCA results reveal that it is the most potent and necessary component within a broader causal system. This discrepancy highlights that internet usage establishes the vital infrastructure required for e-commerce, but its potential is only fully realized when combined with other systemic factors or when security-related mediation effects, as observed in the SEM results ($\beta = -0.305$, $p = 0.027$), are accounted for.

4. Conclusion

This study examined the relationship between internet usage, e-security, and education in explaining e-commerce adoption across 49 countries. Table 8 below presents the results of the hypothesis testing. The findings are clearly outlined in this section to serve as a foundational basis for the subsequent discussion stage.

Table 8: Evaluation of hypothesis

No	Hypothesis	Result
H ₁	Internet Usage --> E-Commerce Adoption	Partially Supported (fsQCA)
H ₂	Internet Usage --> E-Security	Supported
H ₃	E-Security --> E-Commerce Adoption	Supported
H ₄	E-Security Moderates Internet Usage --> E-Commerce Adoption	Rejected
H ₅	E-Security Mediates Internet Usage --> E-Commerce Adoption	Supported
H ₆	Education --> Internet Usage	Supported
H ₇	Education --> E-Commerce Adoption	Partially Supported (fsQCA)
H ₈	Education Moderates Internet Usage --> E-Commerce Adoption	Rejected

Source: Authors' own work

The findings obtained through the formative PLS-SEM and fsQCA structures have yielded original contributions to the marketing and economics literature. Various analyses conducted within this study reveal that explaining e-commerce adoption at the national level requires a complex modeling approach. In today's conditions of ever-increasing digitalization, this study identifies the factors that influence and determine e-commerce as a critical component of the economic system. It is particularly important to emphasize that the dual perspective of this study aligns with the inherent nature of the economic context. Just as solving economic problems depends on understanding both the necessity of human behavior and the impact of monetary mechanisms, comprehending the inclination toward e-commerce requires a similar dual approach. While the fsQCA method provides an asymmetric and appropriate perspective to understand these necessities, PLS-SEM offers a symmetric presentation of the influencing factors. This methodological synergy not only enhances the value of the findings but also establishes a scientifically logical narrative timeline.

Firstly, regarding the PLS-SEM results, it is observed that neither internet usage nor education levels directly increases a country's inclination toward e-commerce. Furthermore, as electronic security measures increase, countries appear to distance themselves from e-commerce. On the other hand, although internet usage alone does not increase e-commerce effectiveness, the inclusion of electronic security into this relational network leads countries even further away from electronic commerce. Another significant finding is that higher education levels lead to increased internet usage. However, the impact of internet usage on e-commerce remains unchanged regardless of increases in education or electronic security. A final critical output of the PLS-SEM analysis is that as

internet usage grows, electronic security measures within countries also increase. These results facilitate a clear, symmetric understanding of the net effects within the model.

Conversely, the fsQCA results reveal whether these variables are truly necessary to explain the inclination toward e-commerce from an asymmetric standpoint. Despite the non-significant results in the PLS-SEM analysis, the fsQCA findings demonstrate that e-commerce inclination cannot be explained without internet usage; in other words, the model is inconceivable without this variable. Furthermore, models that combine internet usage, electronic security, and education are shown to be more comprehensive in predicting national e-commerce demand. Precisely for this reason, although internet usage does not directly "affect" e-commerce in the symmetric model. Similarly, fsQCA findings show that while education does not directly influence e-commerce in the symmetric model, e-commerce adoption is directly related to education. Therefore, hypotheses H_1 and H_7 are noted as "partially supported" in Table 1.

In the global economic system, where e-commerce is increasingly prominent in foreign trade policy, a comprehensive and scientific understanding of this phenomenon is of paramount importance. Therefore, the findings of this research are believed to possess a high potential for widespread impact. Naturally, a more descriptive and detailed discussion of these results from marketing and economic perspectives, supported by scientific evidence, will be presented in the subsequent section.

5. Discussion

The results of the PLS-SEM revealed that internet usage and education do not directly increase a country's e-commerce adoption. However, the fsQCA results show that internet usage and education are critical issues for e-commerce inclination. A research model that integrates these variables yields more comprehensive results in predicting countries' e-commerce adoption. When internet usage and education are considered holistically, along with electronic security, they contribute to explaining the inclination of e-commerce. Therefore, the second method, fsQCA, helped uncover how diverse combinations of these factors lead to higher levels of e-commerce adoption. While the statistical model highlighted the influence of each factor on its own, the configurational analysis showed that e-commerce is not driven by individual factors in isolation, but rather by specific combinations. The results emphasize the importance of looking beyond linear relationships when studying complex phenomena like digital transformation.

In addition, internet usage positively affects electronic security. As internet usage increases in countries, they are investing more in electronic security measures. Naturally, as the internet-using population increases, the electronic security issue becomes more important for countries. Because the rise in internet usage makes e-security measures a necessity for governments. In this context, as Kolat and Ünver (2025) emphasize, the advancement of technological infrastructure like the internet has the potential to increase investment in cybersecurity, thereby fortifying defenses against security threats. Similarly, Khan et al. (2023) stated that e-security requires digital knowledge obtained through repeated actions and applications, and this is achieved through internet usage. However, electronic security is negatively associated with e-commerce adoption. Indeed, Matbouli

and Gao (2012) emphasized that electronic security threats have a negative effect on e-commerce adoption. Individuals who perceive threats tend to avoid e-commerce. Also, an important barrier to e-commerce adoption is the absence of security measures. Similarly, Sanayei and Rajabion (2008), Shah et al. (2014), and Khan (2019) stated that security measures on e-commerce are key elements for mitigating individuals' concerns. E-commerce without ensuring security will not be beneficial and will not be adopted by individuals. According to Chien-Ta Ho and Oh (2009), electronic security measures can decrease risk perception of individuals and potentially increase online purchases. However, increasing electronic security measures can make it more difficult and complicated for individuals to utilize e-commerce systems because it requires them to go through many security procedures, multi-stage encryption, and verification processes. Indeed, according to the Technology Acceptance Model (Davis, 1989), consumers' adoption or usage of technological products is diminished when ease of use is inadequate. Ease of use is defined as the belief that people do not need to exert effort when using a technological product. Therefore, it is a key determinant for e-commerce adoption. In this regard, Liu and Wei (2003) stated in their study that ease of use affects e-commerce adoption. According to the study, as ease of use increases, consumers use e-commerce more. Smith (2008) similarly emphasized that ease of use significantly influences attitudes toward using e-commerce websites and that websites that are easy to use are more likely to be utilized. In a recent study, Nuralam et al. (2024) also posit that ease of use affects customer satisfaction and repurchase intention in e-commerce. Concurrently, individuals might become suspicious of potential risks when they encounter extra security measures, thus raising their risk perception. As stated by Matbouli and Gao (2012), risk perception increases, e-commerce adoption is likely to decrease. Additionally, our results demonstrate that education positively influences internet usage. This result is consistent with the existing literature. Indeed, Tekin et al. (2018) emphasized the positive link between education and innovation, as expected, causing an increase in internet usage. Similarly, Quaglione et al. (2018) posit that households with higher education levels had higher internet usage. Increases in individuals' education levels lead to a boost in internet usage (Manlove and Whitacre, 2019). Because educated individuals can learn digital interfaces faster and more easily. Furthermore, individuals with higher levels of education are more inclined to utilise the opportunities offered by the internet and databases for accessing information, rather than traditional methods. Also, educated individuals tend to have more favorable and encouraging work and social environments for internet usage. Most of the highly educated individuals work in white-collar jobs. This is critical because we measured education with tertiary education and research and development sub-dimension.

It is of equal significance to discuss the obtained findings from the perspectives of business, economics, and policymakers. According to the results, it cannot be argued that an increase in education levels directly leads to a rise in individual e-commerce purchases. However, a critical nuance emerges: the fact that education drives internet usage ensures the functionalization of digital infrastructure, which is a structural necessity for e-commerce. Therefore, while education acts as a foundational resource for infrastructure, the actual growth of e-commerce remains contingent upon broader market dynamics.

Furthermore, it is plausible to suggest that higher education levels better prepare individuals to navigate cyber risks. Although this relationship was not directly measured, it is reasonable to anticipate that educated individuals exhibit more informed and conscious behaviors. This prudence ensures that users interact with digital platforms more cautiously. Education should be viewed not only as an individual competency but also as an institutional output for nations. Consequently, while an educated populace renders e-commerce technically viable, it does not guarantee an absolute economic impact on e-commerce adoption. In today's world, where digital transformation is paramount and economies are increasingly structured upon this transformation, the necessity for nations to prioritize education becomes evident to ensure efficient and effective market management while leveraging the cost-effective opportunities of e-commerce. Finally, the "Security Paradox"—where increased electronic security, intended to protect users at various education levels, actually dampens the inclination toward e-commerce—stands out as a striking observation. Nevertheless, it is expected that as awareness levels grow over time, individuals will acclimate to these security systems, eventually neutralizing the current effect of hesitation.

Considering that the impacts of a skilled workforce and technological advancement on economic growth and exports have been extensively documented in the literature, it is appropriate to assert that the intensive participation of educated and internet-proficient countries in e-commerce will further contribute to the digital transformation of economic growth. In this manner, significant thresholds on the path toward achieving more effective and efficient market management can be crossed within the evolving dynamics of the global landscape.

6. Implications

The findings have several significant implications for policymakers, practitioners, and scholars interested in digital transformation and e-commerce development. First, the fact that high e-commerce adoption can be achieved in countries with lower levels of electronic security, if internet usage is high, highlights the critical role of digital accessibility and information infrastructure. Even if internet usage doesn't directly influence e-commerce adoption, it actually plays a significant role in the overall research model and contributes to explaining a country's e-commerce inclination. This suggests that investments aimed at expanding internet access and encouraging digital literacy may yield substantial returns, even in environments where traditional institutional resources are limited. The expansion and development of internet infrastructure in underdeveloped regions, along with strategic investment in these areas, is critical for ensuring equitable e-commerce opportunities. Policymakers need to provide financial support in this context to accelerate infrastructure projects that will increase internet usage. Additionally, e-commerce platforms and businesses should enhance security measures and advance strategies to promote internet usage. The e-commerce adoption is influenced by the perception of electronic security. Thus, improving the perception of security in e-commerce platforms can lead to a subsequent increase in adoption. In this context, businesses are advised to utilize HTTPS protocol, secure payment systems, data protection protocols, and

third-party certificates on their platforms or websites, while ensuring that such measures are indicated. However, when businesses implement e-security measures, they should avoid measures that negatively impact the ease of use of e-commerce platforms or websites, making them difficult and complex. Because the extra effort involved in utilizing technology negatively affects adoption. Individuals prefer user-friendly and easy-to-use e-commerce websites or platforms. Therefore, taking security measures without confusing individuals or complicating the shopping process is critically significant for businesses. Another crucial consideration when implementing security measures is managing individuals' risk perceptions. The deployment of additional security measures, such as multi-stage encryption and authentication, can cause individuals to perceive more risk and negatively affect their shopping behavior. Accordingly, businesses should both implement the requisite security measures and avoid making the shopping process difficult, and manage individuals' risk perceptions effectively. Furthermore, businesses need to maintain open communication channels and foster customer trust through various channels such as customer service, live support, or prompt response options. Businesses should also focus on enhancing the user experience, designing secure and transparent payment systems, and creating user-friendly interfaces.

Moreover, policymakers should prioritize robust cybersecurity framework deployment and enhancement and allocate resources appropriately. Businesses, customers, and civil society organizations should take responsibility for sustaining a secure digital ecosystem and participate in capacity-building activities. Also, policymakers should encourage the implementation of educational programs that are designed to reduce users' security concerns and enable them to develop conscious digital behaviors. They should also offer incentives that make it easier for businesses to take security measures and regularly monitor e-commerce businesses. Also, since increased education levels lead to increased internet usage, businesses should consider this when determining their segmentation and targeting strategies. In particular, promotion activities can be conducted more effectively online for countries or individuals with higher education levels. Marketing budgets can be adjusted accordingly. Conversely, for countries with lower education levels, businesses should carry out marketing activities utilizing more traditional methods. Moreover, businesses are able to conduct marketing research online, particularly in countries with a high level of education. Especially, consumers' needs and wants can be identified by utilizing their digital footprints. This allows businesses to determine consumers' product and service preferences.

Second, the configurational perspective offered by the fsQCA analysis reveals that one-size-fits-all strategies are ineffective in supporting e-commerce development. Instead, policies should be tailored to the specific socio-economic and technological profiles of countries. For instance, in contexts where institutional factors are weak, fostering active and broad-based internet usage can serve as a compensatory mechanism to drive digital adoption. Finally, for academic researchers, this study demonstrates the value of using complementary methodological approaches. Combining variance-based and set-theoretic methods enables a more nuanced understanding of complex socio-technical phenomena, such as e-commerce adoption. Future studies may benefit from adopting similar multi-

method strategies to explore other domains of digital transformation, particularly in cross-national or comparative contexts.

7. Limitations and Future Research

As in many studies, this study has some limitations. The first limitation of the study is the number of countries analyzed. In this study, 49 countries were analyzed because common index data were available. Including more countries in future studies could strengthen the results. However, as the number of countries increases, they can be classified and analyzed according to their level of development or region. This approach will also provide novel and valuable insights in terms of regional and economic development. Secondly, cultural and technological differences between countries have not been addressed. Future studies could conduct new analyses considering culture and countries' levels of technology. Furthermore, the study examined internet usage, electronic security, and education variables. A variety of factors, including income level, age, gender, access to technology, and digital service diversity, have been identified as potentially influencing e-commerce adoption. However, these factors were not incorporated into the model. In future studies, the model may be expanded to include different demographic variables. Additionally, the data set employed in this study is derived from 2024, which may not fully capture the rapid pace of technological advancement and contemporary trends in user behavior. Consequently, in future studies, if common index data is available, data from different years can be collected and analyzed using panel data analysis. Finally, another limitation of the study is that internet usage, education, electronic security, and e-commerce adoption were measured with a limited number of sub-dimensions. Utilizing diverse sub-dimensions in future studies could contribute to the literature.

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