

Spatial Pattern of the Association of E-commerce Adoption and Socio-digital Setting

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Abstract: This study applies the multiscale geographically weighted regression to investigate the spatial behaviour of e-commerce and the relationship with digital know-how level across provinces in Indonesia. The model was developed using e-commerce data from the Indonesian National Statistics Board and the Ministry of Information and Communication of 2022. The result shows that only two variables had a significant impact on e-commerce adoption, namely access to the Internet and Generation X population. Furthermore, each variable has a different direction of a strong effect on e-commerce adoption levels. These results show that the covariates comprise a spatial barrier to adopting e-commerce and enrich the current understanding of e-commerce at the local level. Based on the result, policymakers can develop strategies to increase e-commerce adoption through promotion and campaign initiatives and target these at geographically strategic locations.

Keywords: E-commerce adoption, Indonesia, socio-digital setting context, multiscale geographically weighted regression
JEL classification: C31, O10, R00

1. Introduction

In contemporary times, e-commerce is acknowledged as a highly dynamic and fundamental sector in the economy, playing a significant role in enhancing competitiveness (Bai & Li, 2022; Rodrigues et al., 2022). The rapid growth of e-commerce can be attributed to the widespread availability of the Internet, the increasing use of mobile devices, and the level of digital proficiency. The Internet has revolutionised trade, leading to more convenience, benefiting both businesses and consumers (Higuera-Castillo et al., 2023). Businesses can achieve cost savings in both fixed and variable expenses and also expand market reach both nationally and globally. Furthermore, consumers enjoy unrestricted access to information about products at any time. Consumers can easily find and compare offers, read user reviews and purchase products that were previously inaccessible due to geographical constraints, lack of time, or lifestyle differences.

In Indonesia, the widespread adoption of e-commerce has been evident over the past five years. The value of e-commerce transactions has increased significantly from IDR105.6 billion in 2018 to IDR453.75 billion in 2023 (Google, Temasek & Bain, 2023).

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The e-commerce market in Indonesia has witnessed substantial growth, surpassing a total market value of USD40 billion. This remarkable expansion is due to various factors, such as the pervasive penetration of smartphones and the Internet, enhanced logistics and payment infrastructure, and a developing middle-class enthusiast about online shopping. Government initiatives aimed at promoting digital literacy and facilitating online business transactions also play a significant role in fostering an enabling environment for e-commerce growth (Rahayu & Day, 2015). In the journey of digital transformation in Indonesia, the e-commerce landscape is ready for sustained expansion, presenting lucrative opportunities for businesses and significantly contributing to economic development.

E-commerce adoption refers to the process by which businesses use online platforms or other electronic methods in regular trading activities. This adoption includes various aspects, such as setting up an online store, implementing digital payment systems, and using online marketing strategies. Previous studies found that e-commerce adoption is influenced by various factors, such as technology infrastructures (e.g. Internet accessibility and device accessibility) (Cristobal-Fransi et al., 2020; Garín-Muñoz et al., 2019; Oliveri et al., 2023), socioeconomic advantages (Higuera-Castillo et al., 2023), and geographical characteristics. However, these studies typically model the relationship between e-commerce adoption and the influencing factors at the global or country level, neglecting local variability and the impact of key drivers. The interaction between e-commerce adoption and the key drivers within the local level or smaller areas is underexplored. Therefore, key questions arise regarding the spatial influencing factors affecting e-commerce adoption and the contributions to regional variations. An important question is “How do geographical factors influence e-commerce adoption across different regions?”. Moreover, what role does the accessibility of digital technologies play in shaping the spatial patterns of e-commerce adoption within the country?

In the context of government policy, the local differences in policy play a significant role in e-commerce adoption, as each area possesses distinct economic, infrastructural, social and regulatory conditions that influence its development. In Indonesia, the governance structure follows an autonomous administrative system, where policymaking is centralised, but the implementation, including supervision and the empowerment of local businesses, is carried out by local governments. Consequently, a uniform policy approach may not adequately address the diverse challenges or optimise the potential of e-commerce adoption across different regions, underscoring the importance of considering local differences.

The innovation shown in this study can be attributed to two aspects. First, the study applies spatial covariance analysis of digital-cultural factors relevant to e-commerce adoption, acknowledging a moderation by geographical context and digital-cultural settings. Furthermore, the digital-cultural method is applied innovatively to incorporate spatial dependence in e-commerce adoption. Second, the study applies multiscale geographical weighted regression (MGWR), allowing for the consideration of multiple scales by incorporating various neighbourhood sizes for each. This regression is used to estimate the local effects of digital-cultural factors on e-commerce adoption. No study has applied MGWR to capture the intricate spatial patterns and relationships

of e-commerce adoption and digital-cultural settings. Therefore, this study aims to identify key spatial factors driving e-commerce adoption in a regional context, with a particular focus on factors that hinder or facilitate spatial interaction within local areas, to estimate the effects on e-commerce adoption.

The remainder of this study is structured as follows. Section 2 presents a review of relevant literature, including strategies for e-commerce intervention. The study area and data used, along with the study methodology, are described in Section 3, followed by the results in Section 4. Finally, Section 5 presents the planning implications derived from the results, with the conclusions discussed in Section 6.

2. Literature Review

A significant portion of current economic and social science studies use various socioeconomic variables to examine the correlations with e-commerce behaviour (Joshi et al., 2024; Kurnia et al., 2015; Mamonov & Benbunan-Fich, 2017; Rahayu & Day, 2015). Building on the results of these studies, e-commerce adoption is frequently construed as an outcome of digital socioeconomic advantages, potentially impacting the adoption rate. This viewpoint shows that e-commerce adoption is digitally constructed to reflect societal stratification in a digital context, both socially and economically. However, a high level of digital literacy does not consistently correlate with low e-commerce adoption. It can also not be universally asserted that regions lacking digital literacy have lower levels of e-commerce adoption. Consequently, some additional factors may be associated with levels of e-commerce adoption. Figure 1 shows a summary of the framework illustrating the association between e-commerce adoption and the related external drivers. These drivers include socioeconomic disparities and advantages, Internet accessibility, device accessibility, and geographical factors. The

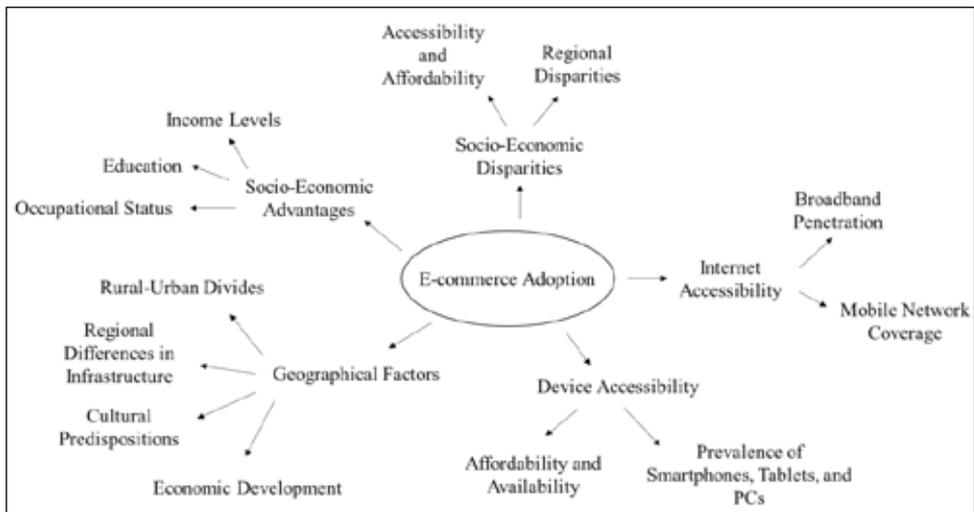


Figure 1. Framework of the association between e-commerce adoption and its socio-digital setting context

internal drivers include CEO innovation, organisational commitments, and others that might influence the level of e-commerce adoption (Ballerini et al., 2023).

E-commerce adoption is examined through the innovation diffusion theory by Everett M Rogers (1995), and this event has captured the interest of scholars. The innovation diffusion theory provides a structured method for understanding the adoption and dissemination of innovations, particularly e-commerce technologies in a population. Some of the factors influencing the adoption process include perceived attributes of the innovation, communication channels, the social system, the requisite extent of change for adoption and the temporal aspect of the adoption process (Rebecca, 2015; Rogers, 2003). The study by Dahnil et al. (2014) used the innovation diffusion theory to examine the significance of perceived attributes, such as relative advantage, compatibility, complexity, trialability and observability. This result is consistent with the report of previous studies that both businesses and consumers have a greater tendency to accept e-commerce technologies when perceived advantages are congruent with established practices, user-friendliness, facilitate trial periods and provide observable benefits.

Communication channels are also significant, with previous studies examining the impact of social media, word-of-mouth and marketing strategies on the diffusion process. The social system, consisting of cultural norms, social networks and organisational structures, is identified as a significant factor influencing e-commerce adoption (Dahnil et al., 2014; Hendricks & Mwapwele, 2024). Spatial variations, accounting for regional differences in infrastructure, cultural predispositions and economic development, contribute to the complexity of the adoption process. Furthermore, studies related to the e-commerce and innovation diffusion theory investigate temporal aspects, providing explicit explanation on the dynamics of technological diffusion and factors influencing the rate of adoption. The studies show the usefulness of the innovation diffusion theory for examining e-commerce adoption and mentioned the various factors that influence the spread across different areas.

Majority of studies aiming to comprehend the dynamics influencing e-commerce adoption examine the correlation between e-commerce adoption and accessibility to digital technology factors (Garín-Muñoz et al., 2019; Kurnia et al., 2015). Various models are used to explore the relationship between accessibility to digital technology and the inclination to engage in e-commerce activities (Cuellar-Fernández et al., 2021; Payal et al., 2024). In this context, digital infrastructure and Internet accessibility are important determinants in the models. Communities and regions with robust digital infrastructure, comprising high-speed Internet and reliable connectivity, tend to experience an increased rate of e-commerce adoption (Al-Qirim, 2007; Corbitt et al., 2003). The majority of studies frequently integrate measures of digital infrastructure (Kurnia et al., 2015), such as broadband penetration and mobile network coverage, into econometric models to determine the impact on e-commerce engagement.

The role of device accessibility in shaping patterns of e-commerce adoption is investigated by various studies. The models consider the prevalence of smartphones, tablets and personal computers within a population. This is because the availability and affordability of the devices significantly influence the capability of an individual to engage in online transactions (Rahman et al., 2022; Suryani et al., 2021). Device

accessibility is often correlated with socioeconomic factors, thereby causing a complex relationship that models aim to dissect.

Geographical factors play a significant role in understanding accessibility in digital technology. The differences in infrastructure between regions, such as rural versus urban areas, affect the adoption of e-commerce. The modelling of these spatial dimensions provides valuable insights into the variability of digital accessibility and the impact on e-commerce adoption. Moreover, the study shows the importance of digital literacy in e-commerce adoption. Individuals with higher digital literacy are more capable of navigating online platforms, conducting secure transactions, and making the most of e-commerce services. Models that incorporate measures of digital literacy determine the relationship influence of knowledge and skills on access to digital technology and e-commerce adoption. Table 1 provides a summary of recent studies on the relationship between e-commerce adoption and the driving factors.

In summary, many studies show the complexity of the relationship between e-commerce adoption and access to digital technology. Several models that incorporate factors of digital infrastructure, device accessibility, geographical disparities and digital literacy are adopted to understand the diverse influences on e-commerce adoption. With digital technology constantly evolving, ongoing studies in this area are crucial for developing strategies to improve digital accessibility and encourage widespread e-commerce adoption.

3. Methodology

3.1 Study Area

The area of this study is Indonesia, which is the most densely populated country with a populace of approximately 275 million individuals (Badan Pusat Statistik [BPS], 2023). Approximately 206 million individuals are connected to the Internet, with 64 million categorised as micro small enterprises (MSEs). Given the substantial number of Internet users and MSEs, Indonesia presents an ideal setting for investigating the adoption of e-commerce. Moreover, the country has a culturally diverse populace spanning across provinces and regions, necessitating prioritised development in economic strategy to improve both local and national economic growth. The unique characteristics of the Indonesian populace and the geographical landscape have consequently engendered diverse patterns of economic activities. Consequently, delineating the localised impacts of spatial factors on e-commerce adoption at a regional level through mapping outputs will facilitate targeted resource allocation, interventions, and digital transformation initiatives within the e-commerce sector.

3.2 Data

The data used in this study pertains to e-commerce adoption sources from the Indonesian National Statistics Board of 2022 which includes 34 provinces across Indonesia. This choice is primarily driven by data availability and consistency. The data for 2022 is the most recent for which comprehensive, province-level datasets across all relevant variables are accessible at the time of analysis. As shown in Figure 2, all

Table 1. Novel studies on the association of e-commerce adoption and its related drivers

Study	Socio-economy factor			Digital factor				Businesses				Environ-ment	Modelling		Country	
	Social	Economy	Demography	Technology	Literacy	Digital skill	Commitment	Innovative	Business model	Performance	Policy		Outbreak	Technique		Global effect
Garín-Muñoz et al. (2019)	x	x	x		x								Logistic regression	x		Spain
Kurnia et al. (2015)				x												Malaysia
Al-Qirim (2007)								x								New Zealand
Dakduk et al. (2020)		x														Ecuador
Zeng et al. (2023)		x														China
Ballerini et al. (2023)									x				EFA and CFA	x		
Ghezzi (2019)					x											
Oliveri et al. (2023)					x				x							Italy
Wang & Ahmed (2009)	x		x		x								Logistics regression	x		UK
Dahnil et al. (2014)					x											
Dahbi & Benmoussa (2019)																
Luo et al. (2023)		x											K-mean cluster	x		US
Mamonov & Benbunan-Fich (2017)	x	x			x								EFA and CFA	x		
Rahayu & Day (2015)					x											
Higueras-Castillo et al. (2023)	x	x	x		x								Hierarchical tree-bases regression	x		
Frasquet et al. (2021)													Latent class analysis	x		Spain
Lee (2009)													CFA	x		Taiwan
El Said (2017)																Egypt
Ahmed & Hasan (2016)																Syria
Mthembu et al. (2018)		x														Africa
Makame et al. (2014)		x	x													Tanzania
Cristobal-Fransi et al. (2020)													Principal component analysis			Spain

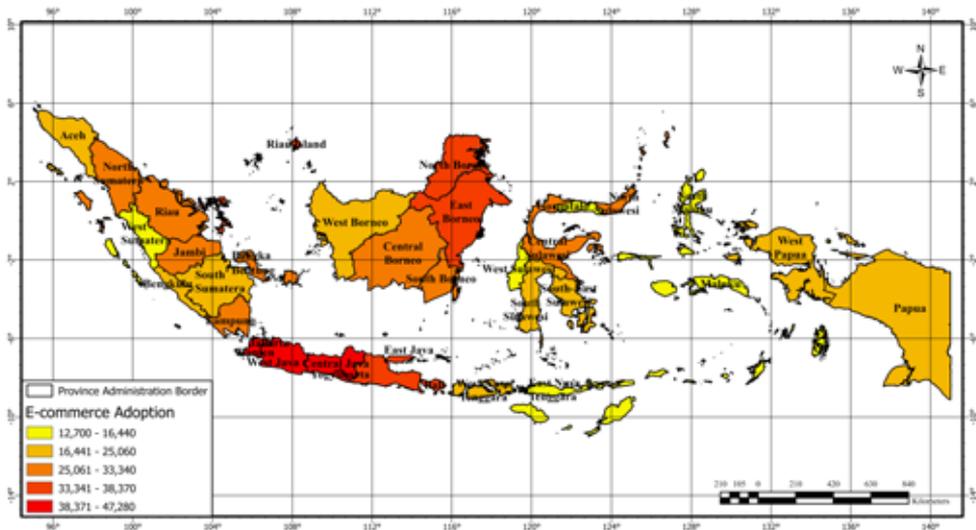


Figure 2. Map of e-commerce adoption of 34 provinces across Indonesia in 2022

provinces within Java Island exhibit a high level of e-commerce adoption, ranging from 38.38% to 47.28%. The provinces with the highest levels of e-commerce adoption include Jakarta, Banten, Yogyakarta, West Java and Central Java, accounting for 47.28%, 47.19%, 44.64%, 44.27% and 41.4%, respectively. West Sulawesi, Maluku and East Nusa Tenggara are characterised by the lowest levels of e-commerce adoption, registering 12.7%, 13.1% and 14.76%, respectively.

Various spatial factors are examined as potential influential variables in order to accomplish the aim of this study. These factors include the digital literacy index, access to Internet, Internet signal coverage, and demographics by generation, such as Pre-Boomer, Boomer, Gen X, Millennial, Gen Z, and Post-Gen Z populations. The data is taken from Ministry of Information and Communication of 2022. Table 2 shows the representation of the socio-digital environment of these factors.

3.3 Multiscale Geographical Weighted Regression

Multiscale geographical weighted regression (MGWR) is an advanced spatial modelling method that extends beyond the traditional geographically weighted regression (GWR). The focus of GWR is on exploring spatial variations in variable relationships across regions (Ardianto et al., 2023; Ardianto & Yulianti, 2021). However, MGWR recognises that these variations may not be consistent across all scales within a study area. To address this limitation, MGWR incorporates multiple scales by allowing different bandwidths or neighbourhood sizes for each spatial unit. This flexibility enables studies to capture intricate spatial patterns and relationships at various resolutions, providing a more nuanced understanding of spatial heterogeneity in the data (Mansour et al., 2021; Shi et al., 2023).

Table 2. Variables used in the study

Variable	Description	
<i>A. Digital setting</i>		
Digital literacy index	Digital literacy index	A ₁
Access to Internet	Percentage of people who have been accessing the Internet in the last 3 years	A ₂
Internet signal coverage	Percentage of area with Internet signal of 4G/LTE	A ₃
	Percentage of area with Internet signal of 3G/H/H+/EVDO	A ₄
	Percentage of area with an Internet signal of 2.5G/E/GPRS	A ₅
<i>B. Population demographics</i>		
Pre-Boomer population	Percentage of people within an area who are born before 1945	B ₁
Boomer population	Percentage of people within an area who are born between 1946 – 1964	B ₂
Gen X population	Percentage of people within the area who are born between 1965 – 1980	B ₃
Millennial population	Percentage of people within an area who are born between 1981 – 1996	B ₄
Gen Z population	Percentage of people within an area who are born between 1997 – 2012	B ₅
Post Gen Z population	Percentage of people within the area who are born after 2013	B ₆

A key strength of MGWR is the capacity to account for the hierarchical structure of spatial processes. This capacity enables the simultaneous examination of both local and global influences, providing a comprehensive perspective on the spatial dynamics within an area. The method evaluates the changes in the impact of explanatory variables across different scales, showing patterns that might be overlooked by traditional regression models. In this study, the basic equation for MGWR can be represented as follows:

$$y_i = \alpha_{0_i} + \sum_{k=1}^5 \alpha_{k_i} A_{k_i} + \sum_{k=1}^6 \alpha_{k_i} B_{k_i} + \varepsilon_i \tag{1}$$

where:

- y_i represents the dependent variable for province i , for $i = 1, \dots, 34$
- α_{0_i} represents the intercept for province i , for $i = 1, \dots, 34$
- α_{k_i} represents the coefficient for the explanatory variable for province i , for $i = 1, \dots, 34$
- ε_i represents the error term for province i , for $i = 1, \dots, n$
- A_{k_i} represents the explanatory variable for digital setting for province i , for $i = 1, \dots, 34$ and $k = 1, \dots, 5$
- B_{k_i} represents the explanatory variable for population demographics for province i , for $i = 1, \dots, 34$ and $k = 1, \dots, 6$

The MGWR model integrates multiple bandwidths for each spatial unit, thereby accommodating spatial heterogeneity. The bandwidths are denoted as h_{k_i} , showing the scale or neighbourhood size for each explanatory variable x_{k_i} in province i . The kernel function $K(\cdot)$ is used to allocate weights to neighbouring observations based on the distance from the focal point, expressed as follows:

$$\hat{\alpha}_{k_i} = (X'W(i, h_{k_i})X)^{-1}(X'W(i, h_{k_i})y) \tag{2}$$

where:

$\hat{\alpha}_{k_i}$ represents the estimated coefficient for the k -th variable in the MGWR model at province i , for $i = 1, \dots, n$

X represents the matrix of explanatory variables

$W(i, h_{k_i})$ represents the spatial kernel function that assigns weights to neighbouring observations based on their distance from the focal point i and the bandwidth, h_{k_i} , for $i = 1, \dots, n$

The MGWR model estimates coefficients at each spatial location, accommodating various scales for each explanatory variable. This method allows studies to capture spatial heterogeneity and investigate the fluctuation in the relationships between variables across different scales within the study area.

4. Empirical Results

The analysis is initially started by employing the ordinary least squares (OLS) model and the GWR model to selected variables such as the digital literacy index, access to the Internet, Internet signal coverage and demography by generation, such as Pre-Boomer, Boomer, Gen X, Millennial, Gen Z and Post-Gen Z populations. The result of fitting the model shown in Table 3 indicates the MGWR consistently yielded markedly improved results. The Akaike information criterion (AIC) values indicate the enhanced performance of the MGWR model over the OLS model and the GWR model with the lower AIC. The R-squared (R²) value between the OLS model and the GWR models and the R² value between the OLS model and the MGWR model are different by approximately 71.6% and 76%, respectively, indicating the explained variance being not accounted for by the global model. Both the GWR model and the MGWR model address the local effect of the selected variables. However, the MGWR model explains better the local effect than the GWR model with a difference of 4.4%.

Prior to running MGWR, the collinearity diagnostic is conducted by using the variance inflation factor (VIF) to assess the degree of multicollinearity among the explanatory variables. The VIF values for demography and digital setting variables,

Table 3. Summary of fitting characteristics for the regression models analysed in the study

Model	AIC	R ²
OLS	74.853	0.114
GWR	72.558	0.830
MGWR	65.852	0.874

including digital literacy index, access to the Internet, and Internet signal coverage, are below the commonly accepted threshold ($VIF < 5$). However, exceptions are noted for the variables of 4G/LTE and 2.5G/E/GPRS, which exhibit VIF values of 17.922 and 10.964, respectively. While these values exceed the threshold of 5, indicating a higher degree of multicollinearity, the variables are retained due to their theoretical importance in capturing distinct aspects of Internet infrastructure and connectivity. The high VIF values for 4G/LTE and 2.5G/E/GPRS are acknowledged, but these variables represent crucial indicators of network quality and availability, which are distinct from the broader access to the Internet. However, these variables are then executed by MGWR which by estimating local coefficients potentially mitigates some of the adverse effects of collinearity on coefficient stability and interpretability.

Furthermore, some conceptual overlap may still exist, particularly between access to the Internet and Internet signal coverage. These variables are retained in the initial specification to capture different dimensions of digital infrastructure; access refers to actual usage, while signal coverage reflects physical availability. The significance of only one (Internet access) suggests that it may serve as a more direct proxy for digital engagement. Similarly, while generational percentages are mutually exclusive and collectively exhaustive, they are included to capture nuanced demographic influences and explore which population will be a dominant variable.

The MGWR model is then fitted to selected variables, including the digital literacy index, access to the Internet, and Internet signal coverage, such as 4G/LTE, 3G/H/H+/EVDO and 2.5G/E/GPRS. Other variables examined include population by generation, such as Pre-Boomer, Boomer, Generation X, Millennial, Generation Z and Post-Generation Z. The local variable estimates for the MGWR model exhibited variability in magnitude and direction. Golden search is used as a default method in MGWR software. This method searches multiple combinations of each explanatory variable value and select values with the smallest AIC or AICc. Table 4 summarises the descriptive statistics for the variable estimates of selected covariates. Most variables show minimal standard deviation with all having negative correlation except A_2 . The A variables representing digital setting (e.g. A_1, A_2, A_3, A_4, A_5) exhibit minimal spatial variation, suggesting their effects are relatively homogeneous across the study region. This implies that their influence on the dependent variable does not significantly change from one location to another. Conversely, the B variables representing population (e.g. $B_1, B_2, B_3, B_4, B_5, B_6$) show very large absolute magnitudes in means, implying they exert a consistently strong negative influence across the study area.

Interestingly, all variables except A_2 have a negative correlation with e-commerce adoption. This means that the lower the value of these variables, the higher the level of e-commerce adoption. Meanwhile, for variable A_2 – representing access to the Internet – the higher the level of Internet accessibility, the greater the level of e-commerce adoption. This is reasonable as Internet infrastructure is one of the key enablers of e-commerce. Table 4 also shows that only two variables are significant in the model, namely access to the Internet (A_2) and the Generation X population (B_3). These variables are significant in 34 areas, accounting for 100% of the total. For spatial illustration, Figure 3 maps the significance of coefficient of each variable across the 34 areas, which in this case is the 34 provinces of Indonesia.

Table 4. Descriptive statistics for the variable estimates

Variable	No. of significant area	% of significant area	Mean deviation	Standard	Min	Median	Max
Intercept	0	0	-0.007	0.009	-0.032	-0.005	0.006
A ₁	0	0	-0.015	0.006	-0.032	-0.014	-0.006
A ₂	34	100	0.550	0.007	0.532	0.551	0.558
A ₃	0	0	-0.714	0.008	-0.735	-0.714	-0.703
A ₄	0	0	-0.043	0.005	-0.047	-0.045	-0.018
A ₅	0	0	-0.543	0.014	-0.567	-0.544	-0.506
B ₁	0	0	-203639.853	0.011	-203639.875	-203639.854	-203639.822
B ₂	0	0	-666530.244	0.012	-666530.270	-666530.244	-666530.214
B ₃	34	100	-457199.824	0.003	-457199.834	-457199.824	-457199.821
B ₄	0	0	-385756.432	0.024	-385756.492	-385756.432	-385756.389
B ₅	0	0	-612137.486	0.012	-612137.513	-612137.487	-612137.459
B ₆	0	0	-448306.297	0.008	-448306.305	-448306.299	-448306.269



Significance of scaled digital literacy index

Figure 3. Map of significance of coefficient variables in multiscale geographical weighted regression



Significance of scaled access to the Internet

Figure 3. Continued



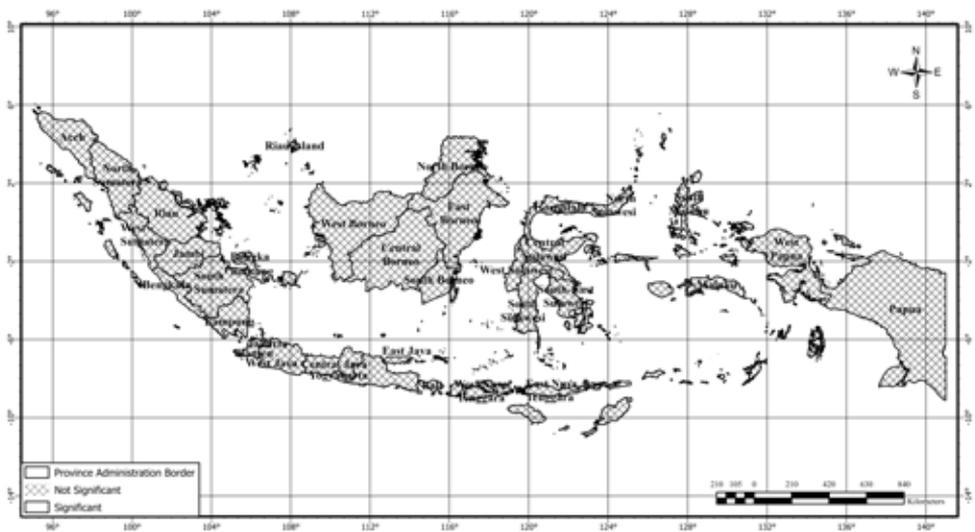
Significance of scaled Internet signal coverage of 4G/LTE

Figure 3. Continued



Significance of scaled Internet signal coverage of 3G/H/H+/EVDO

Figure 3. Continued



Significance of scaled Internet signal coverage of 2.5G/E/GPRS

Figure 3. Continued



Significance of scaled Pre-Boomer Generation population

Figure 3. Continued



Significance of scaled Boomer Generation population

Figure 3. Continued

Spatial Pattern of the Association of E-commerce Adoption and Socio-digital Setting



Significance of scaled Generation X population

Figure 3. Continued



Significance of scaled Millennial Generation population

Figure 3. Continued



Significance of scaled Generation Z population

Figure 3. Continued



Significance of scaled Post-Generation Z population

Figure 3. Continued

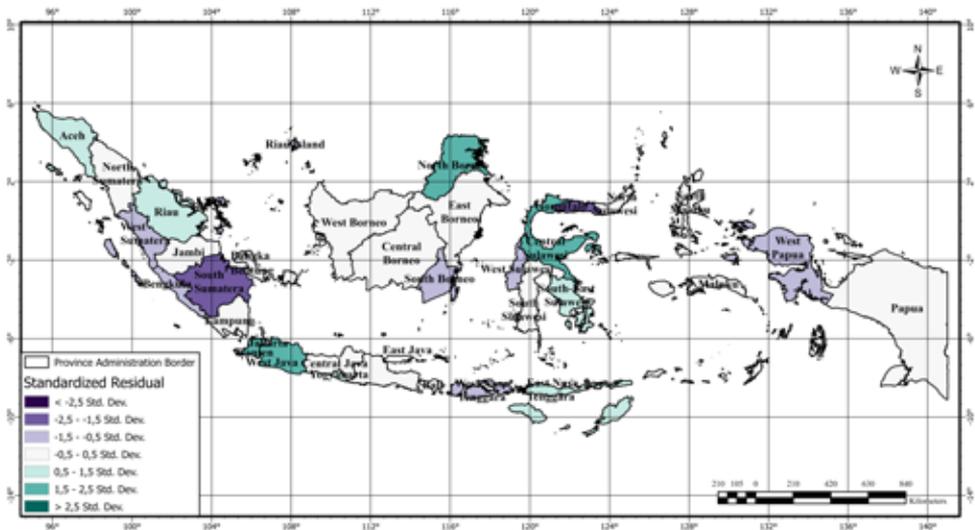


Figure 4. Map of the standardised residual of multiscale geographical weighted regression

Figure 4 shows the standardised residual values, with a mean of zero and a standard deviation of one. These standardised residuals are essential for evaluating the predictive accuracy of a model, showing either accurately predicted, under-predicted, or over-predicted values. Statistically significant clusters where values exceed 0.5 times the standard deviation or fall below 2.5 times the standard deviation, suggest missing explanatory variables in the model. Upon examination, Figure 4 shows that the standard residuals derived from the MGWR model generally fall within the range of 2.5 standard deviations of the mean. However, there is an exception where values were under-predicted, namely for the Provinces of Gorontalo and South Sumatera.

MGWR enables the presentation and visualisation of estimates for each explanatory variable on a raster surface, providing a more accessible comprehension of the spatially varying complex relationships. The raster surface for predictors shows the spatial variations in the correlation between e-commerce adoption and the associated variables across the area. The result of MGWR shows both positive and negative relationships. A positive correlation suggests that as specific explanatory variables increase, e-commerce adoption also increases. Similarly, a negative relationship suggests that an increase in a particular explanatory variable corresponds to a decrease in e-commerce adoption. Figures 5 and 6 show local coefficient estimates for significant explanatory variables, such as access to the Internet and the Generation X population. The colour gradient ranges from light to dark, with darker shades representing a strong influence of that particular variable on e-commerce adoption. Lighter shades represent areas where the variable exerts weak or low influence on e-commerce adoption.

Figure 5 shows the influence of access to the Internet, which is predominantly concentrated in western Indonesia, particularly Sumatra and Java islands. The result

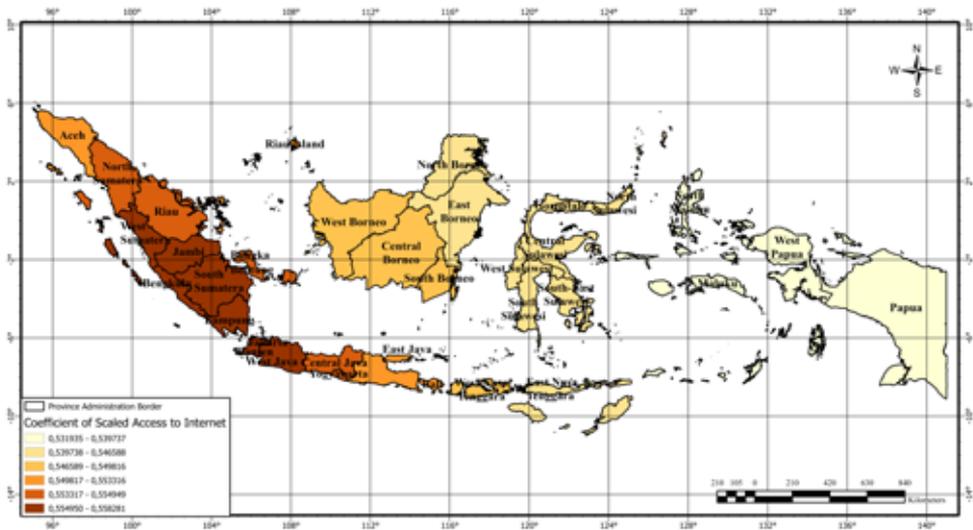


Figure 5. Map of the magnitude of the coefficient of scaled access to the Internet

shows a significant positive impact of the access to Internet variable on e-commerce adoption in the western regions. This suggests a direct correlation, where increased access to the Internet corresponds to higher levels of e-commerce adoption.

The cartographic representation shows the relationship between access to the Internet and e-commerce adoption across Indonesia. In western Indonesia, areas characterised by higher Internet access exhibit a significantly stronger influence on e-commerce adoption, highlighting the critical role of sociocultural factors in facilitating digital transformation. It is reasonable that accessibility to information especially through the Internet foster greater receptivity to technology innovation, stimulate heterogeneous consumer preferences, and generate a dynamic market conducive to the diffusion of e-commerce platforms.

However, the spatial pattern diminishes markedly toward the eastern region of Indonesia, particularly across Papua and West Papua provinces, where the marginal effect of Internet access on e-commerce adoption substantially weakens. This weakening rationally reflects a confluence of infrastructural deficits, socioeconomic inequalities, and traditional economic practices. Moreover, digital setting embeddedness may further mediate the efficacy of Internet penetration in translating into active e-commerce adoption. These findings, as illustrated in Figure 5, underscore the importance of developing a region-specific understanding of the relationship between Internet access and e-commerce adoption, considering a more context-sensitive framework that explicitly integrates sociocultural and geographic specificities into the design of e-commerce adoption strategies. Without such a differentiated approach, initiatives risk reproducing regional disparities and failing to unlock the full potential of e-commerce across Indonesia's heterogeneous socio-spatial landscape.

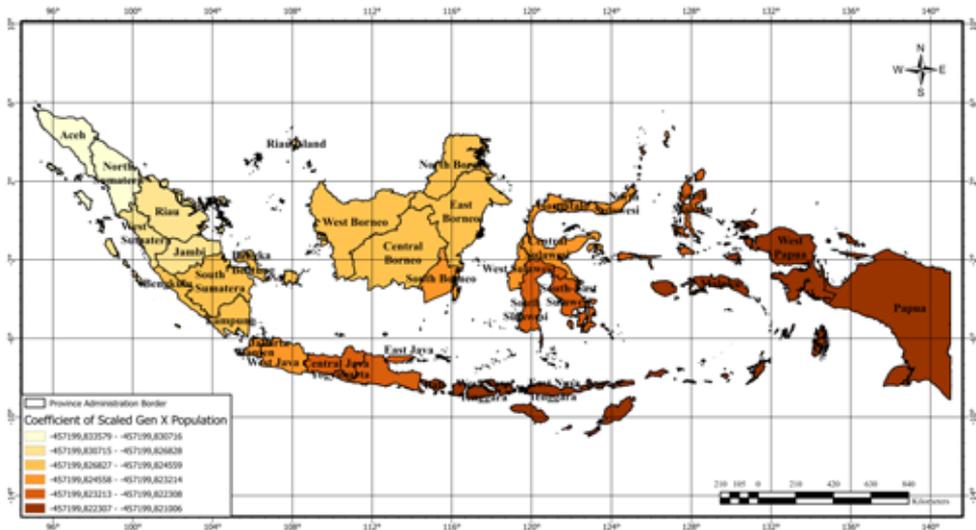


Figure 6. Map of the magnitude of the coefficient of scaled Generation X population

Figure 6 shows the spatial manifestation of the impact of Generation X population on e-commerce adoption, primarily observed in eastern Indonesia, including Papua, Sulawesi and Nusa Tenggara islands. The resulting variable estimate, characterised by a negative orientation, suggests a strong adverse effect of the Generation X population variable on the adoption of e-commerce within these eastern areas. This result shows that a higher proportion of individuals belonging to Generation X correlates with reduced levels of e-commerce adoption. The pronounced influence of the Generation X population on e-commerce adoption is particularly noticeable in eastern Indonesia. However, this influence steadily declines in strength towards the west, from Papua to Sumatra island in western Indonesia.

The concentration of this negative effect in eastern Indonesia likely reflects the intersection of generational preferences with broader regional disparities, including variations in digital literacy, economic structures and exposure to technology-driven market transformations. Generation X individuals, shaped by pre-digital economic systems and traditional consumption patterns, may demonstrate lower responsiveness to e-commerce opportunities, thereby inhibiting the broader diffusion of digital platforms in these areas. Moreover, the observed attenuation of this effect as one moves westward – from Papua towards Sumatra – signals a gradual shift in generational engagement with e-commerce, potentially influenced by higher urbanisation rates, better infrastructural support and greater integration into the national digital economy.

In summary, the diagnostic assessment of the MGWR model shows specific geographical areas requiring further scholarly inquiry. The MGWR outputs provide valuable insights, showing that the spatial dimension plays a crucial role in determining e-commerce adoption. Additionally, among the various variables considered, only access to the Internet and the Generation X population are statistically significant contributors

to the e-commerce adoption paradigm. The study observes that e-commerce adoption depends on local spatial intricacies, where each variable has a unique impact. The variable either enhances or reduces the level of e-commerce adoption across different provinces in Indonesia. For example, in the eastern regions, access to the Internet shows a strong positive association with e-commerce adoption in provinces, such as Sumatera Selatan, Lampung, Jakarta and West Java. On the contrary, the Generation X population has an adverse impact in Papua, Sulawesi and Nusa Tenggara islands. This result suggests that higher proportions of the Generation X population are associated with decreased levels of e-commerce adoption.

The third observation highlights the distinct directional influences exerted by each variable. Internet access demonstrates a strong east-to-west effect, while the Generation X population exerts influence in the opposite direction, moving from west to east. These contrasting spatial dynamics reveal the complexities underlying e-commerce adoption patterns in the Indonesian context. The observed east-west gradients underscore the importance of accounting for both generational and regional factors in the development of policies aimed at promoting inclusive digital participation. Overall, the findings suggest that e-commerce adoption is not only determined by technological access but is also critically mediated by demographic structures and their interaction with localised socioeconomic conditions.

5. Discussion

The MGWR model does not only identify where e-commerce is thriving or struggling, but it also offers a spatial lens to understand and respond to local digital disparities across Indonesia. In practical terms, the e-commerce adoption in Indonesia is not uniform across the country. Instead, it varies significantly depending on locality thus emphasising the importance of geography in digital development. This means that what drives or hinders e-commerce adoption in one province might not have the same effect in another. For instance, one of the clearest findings is the positive role that the accessibility of digital technologies, such as Internet connectivity and mobile networks plays in shaping the spatial patterns of e-commerce adoption. This aligns with common-sense expectations that without reliable Internet, people simply cannot engage in online shopping or digital transactions. Areas with strong digital infrastructure, characterised by high-speed Internet access and reliable mobile networks, tend to experience higher rates of e-commerce adoption. On the other hand, areas with limited digital accessibility may encounter challenges in fully embracing online commerce.

The model also identifies that not all demographic factors support e-commerce growth in the same way across regions. For instance, a higher proportion of the Generation X population who roughly aged 40 to 55, has a negative correlation with e-commerce adoption in places like Papua, Sulawesi and the Nusa Tenggara islands. This suggests that in these provinces, people in this age group may be less inclined or slower to adopt online shopping, possibly due to lower digital literacy or simply habits formed before the digital era took root. These areas also tend to be more rural or less digitally connected, which could reinforce generational resistance to digital commerce. Interestingly, the digital literacy index do not exhibit a significant impact on e-commerce

adoption. This may be attributed to the index's potential limitations in capturing the practical skills necessary for online shopping. If the index primarily emphasises technical proficiency or cybersecurity awareness rather than transactional familiarity, its correlation with e-commerce adoption may be weak. Another contributing factor is the accessibility of user-friendly e-commerce platforms. Major e-commerce platforms in Indonesia feature intuitive and localised interfaces, enabling individuals with limited digital literacy to engage in online transactions with relative ease.

Hence, the factors influencing the adoption of e-commerce in Indonesia are complex and include various dynamics. Geographical factors, such as the distribution of urban and rural areas, regional infrastructure and economic development disparities, play a significant role in improving e-commerce adoption patterns. Economic factors also contribute significantly to regional variations in e-commerce adoption. Furthermore, disparities in income levels and economic development between different areas affect purchasing power and consumer behaviour. Areas with higher income levels and stronger economic activities often witness more extensive e-commerce adoption. This is because consumers tend to have more disposable income and access to digital technologies.

Therefore, e-commerce policy and strategy cannot be one-size-fits-all. The examination of local disparities in e-commerce adoption has provided valuable insights for shaping operational and strategic responses to significant policy inquiries. A significant observation is the lack of a comprehensive strategy for fostering e-commerce enterprises which serves as a crucial factor impacting results against objectives. The specific focus of this study on digital social-spatial barriers and economic strategies is important. In this context, the contribution and development of e-commerce is an important element influencing economic strategies. This shows the need for the formulation of effective strategies for businesses encountering digital social-spatial barriers during the development of educational programs.

In this context, several policy considerations are proposed:

- *Digital infrastructure*: Substantial investments should be directed toward enhancing digital infrastructure, particularly in areas characterised by limited access. This means improving high-speed Internet availability and ensuring reliable mobile networks.
- *Geographically targeted campaigns*: Using spatial analysis to identify areas with high potential for e-commerce growth was recommended. Furthermore, implementing marketing campaigns directed to the distinct needs and preferences of identified regions is important.
- *Localised promotions*: Using spatial analysis to customise for specific areas can effectively attract and retain customers in those particular geographic areas.
- *Digital literacy programs*: Initiatives aimed at boosting digital literacy and fostering e-commerce skills are essential, particularly in areas characterised by lower digital literacy rates. In considering older entrepreneurs and consumers, specific programs and initiatives can also be developed so that people in specific demographic groups (e.g. age, regions, etc.) become comfortable with e-commerce.

- **Community engagement:** Advocating for the participation of local businesses in decision-making processes related to e-commerce initiatives is important. This will facilitate community engagement and ensure that strategies are consistent with the unique characteristics of each locality.

The geographical factors influencing e-commerce adoption across different regions in Indonesia show the importance of adopting detailed and area-specific methods. An integrated strategy, incorporating a diverse set of customised methods to meet the specific needs of distinct groups, holds promise for effectiveness. Consequently, addressing challenges related to e-commerce adoption requires a significant advocacy role to champion effective interventions and enhance Internet infrastructure within targeted areas. Adapting strategies to the unique characteristics of each area, considering economic, cultural and technological factors, are essential for fostering widespread e-commerce adoption. Moreover, the significance of digital technology accessibility cannot be overstated. This is because digital technology plays an important role in determining the extent to which e-commerce can penetrate different regions and contribute to the digital economy. Policymakers, businesses and stakeholders need to collaborate strategically to address these spatial influencing factors, promoting an inclusive and resilient e-commerce landscape across the diverse geography of Indonesia.

6. Conclusion

In conclusion, this study develops an innovative methodological framework to examine the relationship between e-commerce adoption and socio-digital setting variables across space. Key assumptions and constraints are derived using data provided by the Indonesian National Statistics Board of 2022, which covered 34 provinces. The MGWR is formulated with e-commerce adoption as a dependent variable. The influencing factors comprised a range of spatial factors, such as the digital literacy index, access to the Internet and signal coverage. Another factor was demographics by generation, which included Pre-Boomer, Boomer, Gen X, Millennial, Gen Z and Post-Gen Z populations.

The key results of the study show that access to the Internet and Generation X population significantly influence e-commerce adoption. Furthermore, different areas show varying contextual situations that impact e-commerce adoption. The spatial characteristics effect of access to the Internet and Generation X population on e-commerce adoption tend to vary across urban areas. Increased Internet access has a robust positive effect on e-commerce adoption in western Indonesia. However, a higher number of Generation X population in eastern Indonesia has a marked negative effect on e-commerce adoption. Each variable shows a distinct direction of influence on e-commerce adoption levels. Specifically, Internet access has a directional impact from eastern to western Indonesia. The Generation X population has an opposite directional impact from western to eastern Indonesia.

The results show that certain factors acted as spatial barriers to e-commerce adoption at the provincial level. Some unique local characteristics enhance e-commerce adoption in certain provinces while having the opposite effect in others. In general, the variability in e-commerce adoption is context-specific and influenced the levels of

e-commerce adoption. These results address the study question by showing that the socio-digital setting characteristics influencing e-commerce adoption varied across urban areas. However, because the case study focussed on Indonesia, while the methods are generalisable, the results showing the relationship between e-commerce adoption and various spatial characteristics cannot be applied universally. Different socio-digital settings and geographical characteristics should be taken into account. Perhaps, there will be space for further research applying similar MGWR studies in other countries with more various characteristics either in geographical setting or socio-digital setting. Future studies should also consider a sensitivity check and increase the sample size and spatial detail by refining geographic units (e.g. district).

References

- Ahmed, J.U., & Hasan, H. (2016). A study on identification of key barriers to e-commerce in Syria. *Journal of Supply Chain Management Systems*, 5(1), 14. <https://doi.org/10.21863/jscms/2016.5.1.023>
- Al-Qirim, N. (2007). The adoption of eCommerce communications and applications technologies in small businesses in New Zealand. *Electronic Commerce Research and Applications*, 6(4), 462–473. <https://doi.org/10.1016/j.elerap.2007.02.012>
- Ardianto, R., Chhetri, P., Oktriana, B., Lee, P.T.-W., & Lee, J.Y. (2023). Modelling spatio-temporal patterns of Chinese foreign direct investment under the Belt and Road Initiative. *Journal of International Logistics and Trade*, 21(4), 220–254. <https://doi.org/10.1108/JILT-03-2023-0019>
- Ardianto, R., & Yulianti, Y. (2021). The spatial pattern of fraudulence risk in legal metrology and its socio-economic drivers: A case study of Bandung. *The Indonesian Journal of Development Planning*, 5(2), 269–282. <https://doi.org/10.36574/jpp.v5i2.209>
- Bai, Y., & Li, H. (2022). Mapping the evolution of e-commerce research through co-word analysis: 2001–2020. *Electronic Commerce Research and Applications*, 55, Article 101190. <https://doi.org/10.1016/j.elerap.2022.101190>
- Ballerini, J., Herhausen, D., & Ferraris, A. (2023). How commitment and platform adoption drive the e-commerce performance of SMEs: A mixed-method inquiry into e-commerce affordances. *International Journal of Information Management*, 72, Article 102649. <https://doi.org/10.1016/j.ijinfomgt.2023.102649>
- Badan Pusat Statistik. (2023). *Statistical yearbook of Indonesia 2023*. <https://www.bps.go.id/en/publication/2023/02/28/18018f9896f09f03580a614b/statistik-indonesia-2023.html>
- Corbitt, B.J., Thanasankit, T., & Yi, H. (2003). Trust and e-commerce: A study of consumer perceptions. *Electronic Commerce Research and Applications*, 2(3), 203–215. [https://doi.org/10.1016/S1567-4223\(03\)00024-3](https://doi.org/10.1016/S1567-4223(03)00024-3)
- Cristobal-Fransi, E., Montegut-Salla, Y., Ferrer-Rosell, B., & Daries, N. (2020). Rural cooperatives in the digital age: An analysis of the Internet presence and degree of maturity of agri-food cooperatives' e-commerce. *Journal of Rural Studies*, 74, 55–66. <https://doi.org/10.1016/j.jrurstud.2019.11.011>
- Cuellar-Fernández, B., Fuertes-Callén, Y., & Serrano-Cinca, C. (2021). Survival of e-commerce entrepreneurs: The importance of brick-and-click and internationalization strategies. *Electronic Commerce Research and Applications*, 46, Article 101035. <https://doi.org/10.1016/j.elerap.2021.101035>
- Dahbi, S., & Benmoussa, C. (2019). What hinder SMEs from adopting E-commerce? A multiple case analysis. *Procedia Computer Science*, 158, 811–818. <https://doi.org/10.1016/j.procs.2019.09.118>

- Dahnil, M.I., Marzuki, K.M., Langgat, J., & Fabeil, N.F. (2014). Factors influencing SMEs adoption of social media marketing. *Procedia - Social and Behavioral Sciences*, 148, 119–126. <https://doi.org/10.1016/j.sbspro.2014.07.025>
- Dakduk, S., Santalla-Banderali, Z., & Siqueira, J.R. (2020). Acceptance of mobile commerce in low-income consumers: Evidence from an emerging economy. *Heliyon*, 6(11), Article e05451. <https://doi.org/10.1016/j.heliyon.2020.e05451>
- El Said, G.R. (2017). A cloud computing-based model of e-commerce adoption for developing countries. *Journal of Electronic Commerce in Organizations*, 15(3), 64–82. <https://doi.org/10.4018/JECO.2017070104>
- Frasquet, M., Ieva, M., & Ziliani, C. (2021). Online channel adoption in supermarket retailing. *Journal of Retailing and Consumer Services*, 59, Article 102374. <https://doi.org/10.1016/j.jretconser.2020.102374>
- Garin-Muñoz, T., López, R., Pérez-Amaral, T., Herguera, I., & Valarezo, A. (2019). Models for individual adoption of eCommerce, eBanking and eGovernment in Spain. *Telecommunications Policy*, 43(1), 100–111. <https://doi.org/10.1016/j.telpol.2018.01.002>
- Ghezzi, A. (2019). Digital startups and the adoption and implementation of lean startup approaches: Effectuation, bricolage and opportunity creation in practice. *Technological Forecasting and Social Change*, 146, 945–960. <https://doi.org/10.1016/j.techfore.2018.09.017>
- Google, Temasek & Bain. (2023). *e-Conomy SEA 2023*. https://services.google.com/fh/files/misc/e_economy_sea_2023_report.pdf
- Hendricks, S., & Mwapwele, S.D. (2024). A systematic literature review on the factors influencing e-commerce adoption in developing countries. *Data and Information Management*, 8(1), Article 100045. <https://doi.org/10.1016/j.dim.2023.100045>
- Higueras-Castillo, E., Liébana-Cabanillas, F.J., & Villarejo-Ramos, Á.F. (2023). Intention to use e-commerce vs physical shopping. Difference between consumers in the post-COVID era. *Journal of Business Research*, 157, Article 113622. <https://doi.org/10.1016/j.jbusres.2022.113622>
- Joshi, A., Pani, A., Sahu, P.K., Majumdar, B.B., & Tavasszy, L. (2024). Gender and generational differences in omnichannel shopping travel decisions: What drives consumer choices to pick up in-store or ship direct? *Research in Transportation Economics*, 103, Article 101403. <https://doi.org/10.1016/j.retrec.2023.101403>
- Kurnia, S., Choudrie, J., Mahbubur, R.M., & Alzougool, B. (2015). E-commerce technology adoption: A Malaysian grocery SME retail sector study. *Journal of Business Research*, 68(9), 1906–1918. <https://doi.org/10.1016/j.jbusres.2014.12.010>
- Lee, M.-C. (2009). Predicting and explaining the adoption of online trading: An empirical study in Taiwan. *Decision Support Systems*, 47(2), 133–142. <https://doi.org/10.1016/j.dss.2009.02.003>
- Luo, Q., Forscher, T., Shaheen, S., Deakin, E., & Walker, J.L. (2023). Impact of the COVID-19 pandemic and generational heterogeneity on e-commerce shopping styles – A case study of Sacramento, California. *Communications in Transportation Research*, 3, Article 100091. <https://doi.org/10.1016/j.commtr.2023.100091>
- Makame, W.H., Kang, J., & Park, S. (2014). Factors influencing electronic commerce adoption in developing countries: The case of Tanzania. *South African Journal of Business Management*, 45(2), 83–96. <https://doi.org/10.4102/sajbm.v45i2.126>
- Mamonov, S., & Benbunan-Fich, R. (2017). Exploring factors affecting social e-commerce service adoption: The case of Facebook Gifts. *International Journal of Information Management*, 37(6), 590–600. <https://doi.org/10.1016/j.ijinfomgt.2017.05.005>
- Mansour, S., Al Kindi, A., Al-Said, A., Al-Said, A., & Atkinson, P. (2021). Sociodemographic determinants of COVID-19 incidence rates in Oman: Geospatial modelling using multiscale geographically weighted regression (MGWR). *Sustainable Cities and Society*, 65, Article 102627. <https://doi.org/10.1016/j.scs.2020.102627>

- Mthembu, P., Kunene, L.N., & Mbhele, T.P. (2018). Barriers to E-commerce adoption in African countries. A qualitative insight from Company Z. *Journal of Contemporary Management*, 15(1), 265–304.
- Oliveri, L.M., Chiacchio, F., D’Urso, D., Munnia, A., & Russo, F. (2023). Successful digital transformations enabled by technologies or by open mind? Italian case studies. *Procedia Computer Science*, 217, 1066–1075. <https://doi.org/10.1016/j.procs.2022.12.305>
- Payal, R., Sharma, N., & Dwivedi, Y.K. (2024). Unlocking the impact of brand engagement in the metaverse on real-world purchase intentions: Analyzing pre-adoption behaviour in a futuristic technology platform. *Electronic Commerce Research and Applications*, 65, Article 101381. <https://doi.org/10.1016/j.elerap.2024.101381>
- Rahayu, R., & Day, J. (2015). Determinant factors of e-commerce adoption by SMEs in developing country: Evidence from Indonesia. *Procedia - Social and Behavioral Sciences*, 195, 142–150. <https://doi.org/10.1016/j.sbspro.2015.06.423>
- Rahman, S., Fadrul, F., Yusrizal, Y., Marlyna, R., & Momin, M.M. (2022). Improving the satisfaction and loyalty of online shopping customers based on e-commerce innovation and e-service quality. *Gadjah Mada International Journal of Business*, 24(1), 56–81. <https://search.informit.org/doi/10.3316/informit.289848833328877>
- Rebecca, L.M. (2015). Rogers’ innovation diffusion theory (1962, 1995). In M.N. Al-Suqri & A.S. Al-Aufi (Eds.), *Information seeking behavior and technology adoption: Theories and trends* (pp. 261–274), IGI Global. <https://doi.org/10.4018/978-1-4666-8156-9.ch016>
- Rodrigues, V.F., Policarpo, L.M., da Silveira, D.E., da Rosa Righi, R., da Costa, C.A., Barbosa, J.L. V., Antunes, R.S., Scorsatto, R., & Arcot, T. (2022). Fraud detection and prevention in e-commerce: A systematic literature review. *Electronic Commerce Research and Applications*, 56, Article 101207. <https://doi.org/10.1016/j.elerap.2022.101207>
- Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Shi, X., Ling, G.H.T., Leng, P.C., Rusli, N., & Ak Matusin, A.M.R. (2023). Associations between institutional-social-ecological factors and COVID-19 case-fatality: Evidence from 134 countries using multiscale geographically weighted regression (MGWR). *One Health*, 16, Article 100551. <https://doi.org/10.1016/j.onehlt.2023.100551>
- Suryani, T., Fauzi, A.A., & Nurhadi, M. (2021). Enhancing brand image in the digital era: Evidence from small and medium-sized enterprises (SMEs) in Indonesia. *Gadjah Mada International Journal of Business*, 23(3), 314–340. <https://search.informit.org/doi/10.3316/informit.147548831830004>
- Wang, Y., & Ahmed, P.K. (2009). The moderating effect of the business strategic orientation on eCommerce adoption: Evidence from UK family run SMEs. *The Journal of Strategic Information Systems*, 18(1), 16–30. <https://doi.org/10.1016/j.jsis.2008.11.001>
- Zeng, S., Fu, Q., Haleem, F., Han, Y., & Zhou, L. (2023). Logistics density, E-commerce and high-quality economic development: An empirical analysis based on provincial panel data in China. *Journal of Cleaner Production*, 426, Article 138871. <https://doi.org/10.1016/j.jclepro.2023.138871>

