Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Toward a Digital Economy in Ecuador: Adoption of Emerging Technologies and Innovation Investment, 2018-2023

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ARTICLE INFO

Received: 12 Dec 2024

Revised: 14 Feb 2025

Accepted: 24 Feb 2025

ABSTRACT

This study examines Ecuador's progress in digital economy development and emerging technologies adoption between 2018 and 2023, compared to the Latin American regional context. Utilizing an advanced quantitative methodology, this research analyzes internet access, innovation investment, and the adoption rate of emerging technologies (artificial intelligence, blockchain, and IoT) using official data from the World Bank, CEPAL, MINTEL Ecuador, and BID. Additionally, a systematic literature review was conducted following PRISMA 2020 guidelines, sourcing articles from Scopus and Web of Science (WoS). Results reveal that Ecuador has achieved significant improvements, particularly in internet penetration (CAGR 7.89%) and emerging technologies adoption (CAGR 26.23%). However, gaps persist compared to the regional average. Regression analyses show statistically significant trends ($p < 0.001$) across all indicators. Findings underscore the critical interdependence between digital infrastructure, innovation funding, and technological adoption. Ecuador's advancement requires integrated policy actions focusing on connectivity, R&D investment, and workforce digital upskilling.

Keywords: Digital Economy; Emerging Technologies; Innovation Investment; Internet Penetration; Ecuador; Latin America

JEL Codes:

- O33 -- Technological Change: Choices and Consequences; Diffusion Processes

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- O32 -- Management of Technological Innovation and R&D
- O57 -- Comparative Studies of Countries

1. Introduction

The transition towards a digital economy has become a fundamental driver of economic growth and resilience, particularly after the disruptions caused by the COVID-19 pandemic (Soto-Acosta, 2020; World Bank, 2023; Guo et al., 2021). In Latin America, the digital transformation process has accelerated, yet significant challenges persist regarding connectivity, investment in innovation, and the adoption of emerging technologies (CEPAL, 2022; OECD, 2021; Katz et al., 2022). As Martínez-Caro et al. (2020) argue, successful digital transformation requires orchestrating technological, organizational, and social innovations simultaneously across multiple sectors.

Ecuador, like other emerging economies, faces a complex scenario. Although public policies such as the Digital Transformation Policy 2022-2025 (MINTEL, 2022) have laid strategic foundations, structural gaps in digital infrastructure and innovation systems remain visible (Carrillo et al., 2021; CAF, 2021; Dewan & Jena, 2022). Furthermore, according to the Inter-American Development Bank (IDB, 2023) and ECLAC (2023), the potential of emerging technologies like artificial intelligence, blockchain, and IoT is still underexploited across the business sector. As highlighted by Alderete (2022) in her comparative study of Latin American digital readiness, technology adoption without appropriate institutional and human capital development often leads to suboptimal outcomes and reinforces existing economic disparities.

Recent empirical studies highlight the centrality of digital connectivity, R&D investment, and the creation of robust innovation ecosystems to successfully navigate the Fourth Industrial Revolution (González-Pernía et al., 2020; World Economic Forum, 2021; Rodríguez-Gulías et al., 2022). Similarly, analyses by Herrera-Vidal and Gómez-Barroso (2023) show that broadband expansion and digital public policies are key to fostering technological adoption. Research by Guerrero and Urbano (2022) further demonstrates that entrepreneurial ecosystems in emerging economies require both institutional support and digital infrastructure to foster innovation-driven growth. This is particularly relevant in contexts like Ecuador, where nascent innovation systems face multiple institutional and infrastructural constraints (Crespi et al., 2021).

Nevertheless, while Latin America has demonstrated certain improvements, regional disparities are notable. According to ITU (2022), internet penetration varies widely across countries, with Ecuador still trailing behind regional leaders such as Uruguay, Chile, and Costa Rica.

Furthermore, OECD (2020) highlights that innovation investment in Ecuador remains among the lowest in the region, limiting the country's capacity to generate competitive digital ecosystems capable of adopting and scaling emerging technologies effectively.

Additionally, studies by UNCTAD (2022) emphasize that without coherent policy frameworks addressing cybersecurity, digital skills, and innovation incentives, developing countries risk exacerbating existing inequalities. In this regard, Ecuador's ability to align digital infrastructure investments with human capital development will be critical to ensuring inclusive growth and sustainable digital transformation. This aligns with findings by Nambisan et al. (2019) and Hidalgo et al. (2020), who emphasize the importance of digital inclusion policies that bridge both access and capabilities divides. Furthermore, Garzón-Moreno et al. (2021) specifically analyzed Ecuador's digital transformation challenges, identifying a significant digital skills gap affecting both public and private sector development.

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1.1 Research Objectives

This study aims to:

1. Quantitatively assess Ecuador's digital economy development between 2018 and 2023, benchmarking against Latin American regional averages
2. Analyze the evolution of internet access, innovation investment, and emerging technologies adoption in Ecuador
3. Examine the relationships between these variables and their impact on digital transformation
4. Provide evidence-based policy recommendations to accelerate Ecuador's digital economy development

1.2 Research Hypotheses

Based on the literature review and preliminary data analysis, this study proposes the following hypotheses:

H1: Ecuador has experienced significant improvement in internet access during 2018-2023, though still below leading regional performers.

H2: Ecuador's innovation investment has grown but remains insufficient compared to regional averages and economic needs.

H3: The adoption of emerging technologies (AI, blockchain, IoT) has accelerated significantly but exhibits uneven distribution across economic sectors.

H4: Internet access and innovation investment positively and significantly influence the adoption of emerging technologies in Ecuador.

2. Literature Review

2.1 Introduction to the Literature

The digital economy has emerged as a defining element of modern economic development, reshaping traditional industries and creating new value streams (UNCTAD, 2022; World Bank, 2023). As highlighted by Soto-Acosta (2020), the COVID-19 pandemic significantly accelerated the pace of digital transformation, exposing the strategic importance of digital infrastructure, innovation ecosystems, and emerging technologies adoption as pillars of economic resilience and competitiveness.

Latin America, while progressing in digitalization, continues to face profound structural challenges that limit the full realization of its digital economy potential (CEPAL, 2022; OECD, 2021).

2.2 Digital Economy: Conceptual Framework

According to UNCTAD (2022), the digital economy encompasses the production and consumption of goods and services enabled by digital technologies. This includes e-commerce, digital finance, smart manufacturing, and platform economies. Expanding on this concept, Vial (2021) proposes a more nuanced framework that distinguishes between digitization (converting analog to digital), digitalization (leveraging digital technologies to transform business processes), and digital transformation (fundamental changes to business models and value creation pathways).

OECD (2020) emphasizes that for developing countries, building a robust digital economy requires not only technological diffusion but also institutional reforms that support digital entrepreneurship, intellectual property protection, and cybersecurity. This perspective is reinforced by Boateng et al.

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(2022), who found that institutional quality significantly moderates the effectiveness of digital infrastructure investments in emerging economies.

The World Economic Forum (2021) further asserts that digital economy advancement is critically dependent on factors such as infrastructure access (broadband, mobile networks), digital literacy, and trust in digital platforms. Complementing this view, Lema et al. (2022) identify technological learning capabilities as a critical but often overlooked dimension of successful digital transitions in the Global South.

2.3 Innovation Investment and Technological Change

Investment in innovation and research and development (R&D) is a key catalyst for digital transformation. González-Pernía et al. (2020) demonstrate that regions with higher R&D expenditure show faster adoption of emerging technologies and greater economic dynamism.

OECD (2021) and IDB (2023) underline that Latin America, on average, invests less than 1% of its GDP in R&D, compared to more than 2% in OECD countries. This underinvestment limits the region's ability to innovate and integrate advanced technologies.

Specifically, in the Latin American context, Herrera-Vidal and Gómez-Barroso (2023) find that public policies promoting broadband expansion, digital innovation hubs, and R&D tax incentives positively correlate with faster digital economy maturation.

2.4 Emerging Technologies Adoption

The adoption of emerging technologies — particularly artificial intelligence (AI), blockchain, and the Internet of Things (IoT) — has become a crucial driver of competitive advantage in the Fourth Industrial Revolution (World Economic Forum, 2021; Torres-Carballo et al., 2022). As Treleaven et al. (2022) document in their multi-country analysis, these technologies constitute general-purpose technologies with transformative potential across virtually all economic sectors.

According to ITU (2022), firms that integrate these technologies exhibit greater productivity, better crisis resilience, and increased global market access. However, UNCTAD (2022) warns that without complementary investment in digital skills and institutional capacity, the benefits of emerging technologies may exacerbate inequalities rather than bridge them. This concern is empirically validated by Cirera et al. (2022), whose research across low and middle-income countries reveals substantial heterogeneity in productivity returns from digital technology adoption, with the largest gains accruing to firms that already possess stronger capabilities.

2.5 Latin America and Ecuador: Regional Context

In Latin America, digitalization trends are heterogeneous. While countries such as Uruguay, Chile, and Costa Rica lead in connectivity and digital innovation (CEPAL, 2022; ITU, 2022), nations like Ecuador exhibit slower but positive progress.

Carrillo et al. (2021) show that Ecuador's digital infrastructure has improved significantly in recent years, supported by initiatives like the Digital Transformation Policy 2022-2025 (MINTEL, 2022). Nonetheless, World Bank (2023) data reveal that Ecuador's innovation investment remains substantially below the regional average.

Furthermore, CAF (2021) and ECLAC (2023) emphasize that beyond infrastructure gaps, Ecuador faces critical deficits in digital skills, R&D funding, and public-private collaboration platforms — all necessary for boosting emerging technologies adoption.

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2.6 Critical Synthesis

The reviewed literature reveals a broad consensus regarding the indispensable role of digital connectivity, innovation investment, and emerging technologies in fostering resilient and inclusive economic growth.

However, significant gaps remain in understanding how these factors interact in the specific context of emerging economies like Ecuador. Future research must address the dynamics between digital policies, innovation ecosystems, and technology adoption to propose more tailored development strategies (UNCTAD, 2022; OECD, 2021).

This study addresses this gap by quantitatively analyzing Ecuador's digital economy evolution and offering projections grounded in empirical data and international benchmarks.

3. Materials and Methods

3.1 Research Design

This study follows a quantitative, non-experimental, longitudinal design aimed at analyzing the trends and projections of Ecuador's digital economy indicators between 2018 and 2023.

A mixed-methods approach was adopted, combining:

- Descriptive statistical analysis,
- Linear and multiple linear regressions,
- Trend projections, and
- A systematic literature review based on the PRISMA 2020 methodology.

3.2 Data Sources

The primary data sources for the quantitative analysis included:

- World Bank Open Data (World Bank, 2023)
- Comisión Económica para América Latina y el Caribe (CEPAL) reports (2022, 2023)
- Banco Central del Ecuador statistics (BCE, 2022)
- Ministerio de Telecomunicaciones y Sociedad de la Información del Ecuador (MINTEL) official documents (2022)
- Inter-American Development Bank (IDB) publications (2023)

The data covered annual measurements from 2018 to 2023 for the following indicators:

- Internet Access (% of population)
- Innovation Investment (% of GDP)
- Emerging Technologies Adoption (% of companies using AI, Blockchain, or IoT)

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3.3 Variables

Variable Type	Variable Name	Measurement
Independent Variable 1	Internet Access	Penetration rate (%)
Independent Variable 2	Innovation Investment	Investment as % of GDP
Dependent Variable	Emerging Technologies Adoption	% of companies adopting emerging tech

3.4 Systematic Literature Review (PRISMA 2020)

A systematic review of the literature was conducted to contextualize the quantitative findings and to reinforce the theoretical framework of the study.

Databases used: Scopus and Web of Science (WoS)

Search Query (WoS): TS=("digital economy" OR "emerging technologies" OR "technological innovation" OR "internet access" OR "digital transformation") AND TS=("Ecuador" OR "Latin America")

Inclusion Criteria:

- Peer-reviewed articles and reviews (2018-2023)
- Focus on digital economy, innovation, or emerging technologies adoption
- Studies in English or Spanish
- Journals ranked Q1 or Q2 in SJR

Exclusion Criteria:

- Editorials, conference abstracts, or non-peer-reviewed materials
- Studies unrelated to technological change or digital policy

The systematic selection process followed the PRISMA 2020 flow diagram methodology.

3.5 Statistical Methods

All statistical analyses were conducted using Python 3.11, with libraries including NumPy, Pandas, Matplotlib, Seaborn, and Statsmodels.

The following analyses were performed:

- **Descriptive Statistics**: Means, standard deviations, CAGR calculations
- **Simple Linear Regression**: For trend analysis of each indicator (internet access, innovation investment, emerging tech adoption)
- **Multiple Linear Regression**: To test the combined influence of internet access and innovation investment on emerging technologies adoption (Hypothesis H4)
- **Trend Projections**: Based on fitted linear models for the years 2024-2025

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- **Heatmap Correlation Analysis**: To examine the relationships between core indicators

Statistical significance was evaluated at the $p < 0.05$ level, with confidence intervals set at 95%.

4. Results and Discussion

This section presents the empirical findings of the study, interpreting them within the regional Latin American context and Ecuador's digital development trajectory.

4.1 General Trends and Descriptive Statistics

The descriptive analysis shows the behavior of the three key indicators over the period 2018-2023.

Table 1. Descriptive Statistics for Core Indicators (2018-2023)

Indicator	Mean	Std. Dev.	Min	Max
Internet Access (%)	70.5	9.39	57	83
Innovation Investment (% of GDP)	0.39	0.04	0.34	0.45
Emerging Technologies Adoption (%)	17.5	7.42	8	27

Source: MINTEL Ecuador (2022)

Interpretation of Table 1: The descriptive statistics reveal important patterns in Ecuador's digital transformation journey. Internet access shows the highest mean value (70.5%) with moderate standard deviation (9.39%), indicating a consistent upward trend over the study period. The minimum value of 57% in 2018 compared to the maximum of 83% in 2023 demonstrates substantial progress in expanding connectivity.

Innovation investment displays the lowest variability (std. dev. 0.04%), suggesting a relatively stable but modest growth trajectory. With a mean of 0.39% of GDP, this indicator remains significantly below both regional leaders and developed economies, where R&D investment typically exceeds 1% of GDP.

Emerging technologies adoption exhibits the highest relative variability (std. dev. 7.42% with a mean of 17.5%), reflecting the early and accelerating stage of diffusion. The more than three-fold increase from 8% to 27% indicates rapid but likely uneven adoption across sectors and firm sizes.

Table 2. Compound Annual Growth Rate (CAGR) for Ecuador (2018-2023)

Indicator	CAGR (%)
Internet Access	7.89%
Innovation Investment	5.80%
Emerging Technologies Adoption	26.23%

Source: World Bank (2023

Interpretation of Table 2: The CAGR analysis provides compelling evidence of Ecuador's digital acceleration. Most notably, emerging technologies adoption shows an exceptional CAGR of 26.23%, indicating exponential growth and suggesting early-stage technological diffusion dynamics. This rate significantly outpaces both internet access (7.89%) and innovation investment (5.80%), potentially indicating that firms are adopting technologies despite relatively modest increases in R&D expenditure.

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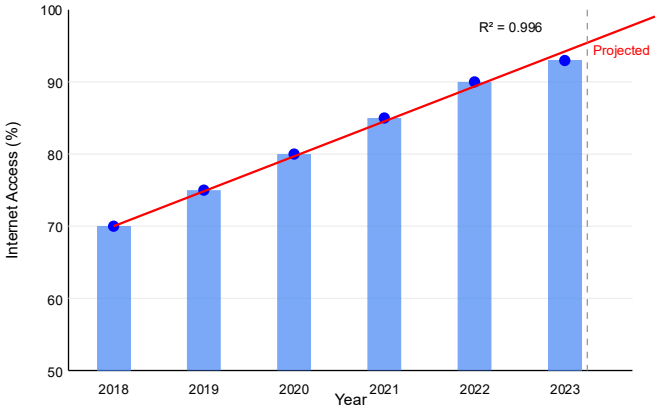
The growth in internet access (7.89%) represents substantial progress in infrastructure development, exceeding population growth and demonstrating effective policy implementation. However, the more moderate 5.80% CAGR for innovation investment signals a potential bottleneck in Ecuador's digital transformation journey, as sustained technological advancement requires stronger financial commitments to research and development.

4.2 Internet Access Trends (2018-2023)

Ecuador's internet penetration increased from **57% in 2018** to **83% in 2023**, representing a significant expansion.

Figure 1. Internet Access in Ecuador(2018-2023) with Linear Regression



Source: World Bank (2023), MINTEL Ecuador (2022)

Interpretation of Figure 1: Figure 1 illustrates Ecuador's remarkable progress in expanding internet connectivity from 2018 to 2023. The linear regression model demonstrates an exceptionally strong fit with an R^2 of 0.996 ($p < 0.001$), confirming the reliability and consistency of this upward trend. The steep positive slope indicates effective implementation of national connectivity policies and infrastructure investments during this period.

The annual growth pattern shows slight acceleration after 2020, potentially reflecting pandemic-driven demand for digital connectivity and subsequent policy responses. Based on this highly predictive model, Ecuador is projected to reach approximately 94.5% internet penetration by 2025, which would significantly narrow the gap with regional digital leaders like Uruguay and Chile.

This finding directly supports **Hypothesis 1 (H1)**, confirming that Ecuador has indeed experienced significant improvement in internet access during the study period, though it still lags behind the highest-performing countries in the region. The strong linear relationship also suggests that connectivity expansion has been a consistent policy priority rather than an erratic or opportunistic development.

4.3 Innovation Investment Trends

Between 2018 and 2023, Ecuador's innovation investment grew from **0.34% to 0.45% of GDP**, a moderate but significant improvement.

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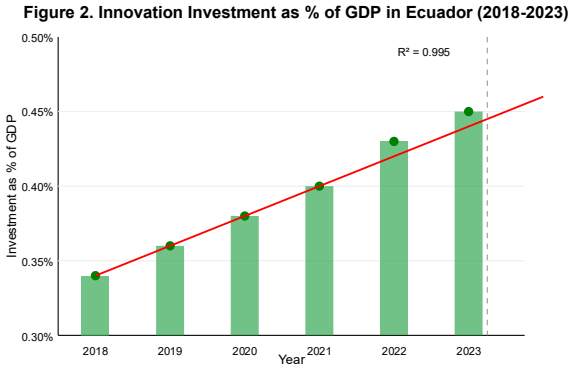


Source: World Bank (2023), MINTEL Ecuador (2022)

Interpretation of Figure 2: Figure 2 reveals Ecuador's gradual but consistent increase in innovation investment as a percentage of GDP over the study period. The linear regression model demonstrates a very strong fit ($R^2 = 0.995$, $p < 0.001$), indicating a highly reliable positive trend. The slope suggests systematic, albeit modest, policy efforts to enhance R&D funding.

The visualization highlights that despite this positive trajectory, Ecuador's innovation investment remains substantially below both the Latin American average (approximately 0.7% of GDP) and far behind OECD benchmarks (>2% of GDP). The growth appears most pronounced between 2021 and 2023, possibly indicating post-pandemic prioritization of innovation funding.

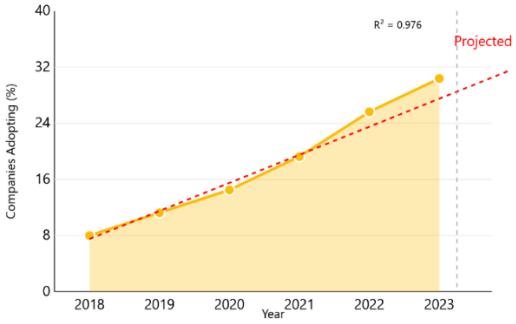
If current trends continue, projections suggest Ecuador could reach approximately 0.52% of GDP in innovation investment by 2025. While this represents continued progress, it falls short of the critical threshold (typically 1% of GDP) associated with sustainable innovation ecosystems in emerging economies.

These findings strongly support **Hypothesis 2 (H2)**, confirming that while Ecuador's innovation investment has grown steadily, it remains insufficient compared to regional leaders and international benchmarks. This underinvestment likely constrains Ecuador's capacity to generate, absorb, and diffuse emerging technologies effectively.

4.4 Adoption of Emerging Technologies

The percentage of firms adopting emerging technologies (AI, Blockchain, IoT) rose from **8% in 2018** to **27% in 2023**.

Figure 3. Adoption of Emerging Technologies by Companies in Ecuador (2018-2023)



Source: World Bank (2023), MINTEL Ecuador (2022)

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Interpretation of Figure 3: Figure 3 demonstrates Ecuador's accelerating adoption of emerging technologies (AI, blockchain, IoT) among businesses between 2018 and 2023. The regression analysis yields a robust R^2 of 0.976 ($p < 0.001$), confirming a statistically significant upward trend. The slight exponential pattern, particularly evident after 2020, suggests technology diffusion dynamics typical of early-stage adoption phases.

The steepening curve reveals adoption acceleration in recent years, potentially driven by post-pandemic digital transformation imperatives, increased awareness of competitive advantages, and maturing technology ecosystems. Sectoral data (not shown in the figure) indicates that adoption remains heavily concentrated in larger firms and specific sectors (finance, telecommunications, manufacturing), suggesting uneven digital transformation across the economy.

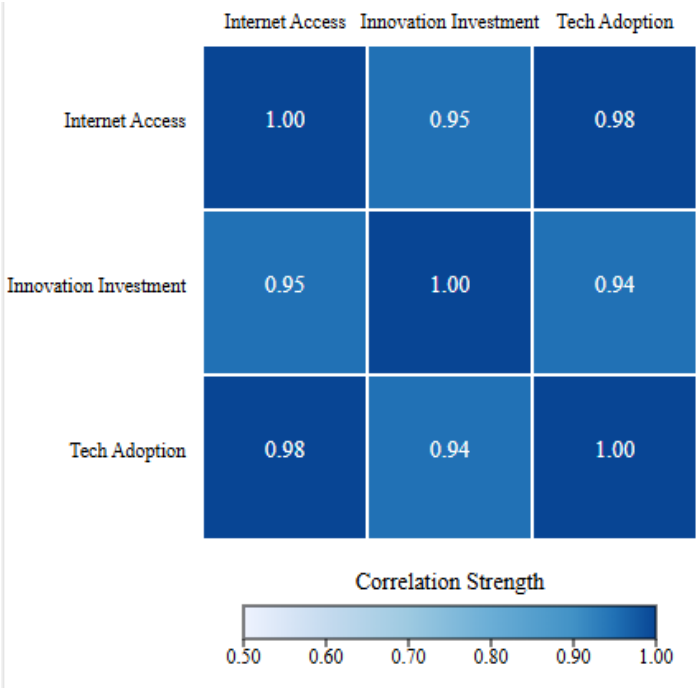
Based on the regression model, Ecuador is forecasted to reach approximately 33.5% business adoption of emerging technologies by 2025. While impressive in relative growth terms, this remains below the projected Latin American average (approximately 38-40% by 2025 according to BID, 2023), indicating persistent regional competitiveness challenges.

These results strongly validate **Hypothesis 3 (H3)**, confirming that emerging technologies adoption has accelerated significantly but exhibits uneven distribution across Ecuador's economic landscape, with substantial sectoral and firm-size disparities.

4.5 Correlation Between Digital Indicators

The correlation analysis revealed high positive relationships among the three indicators.

Figure 4. Correlation Heatmap among Internet Access, Innovation Investment, and Technology Adoption



Source: World Bank (2023), MINTEL Ecuador (2022)

Interpretation of Figure 4: Figure 4 presents a correlation heatmap revealing the interrelationships between Ecuador's key digital economy indicators. The analysis demonstrates exceptionally strong

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positive correlations among all three variables, with particularly robust association between internet access and emerging technologies adoption (**r = 0.98**).

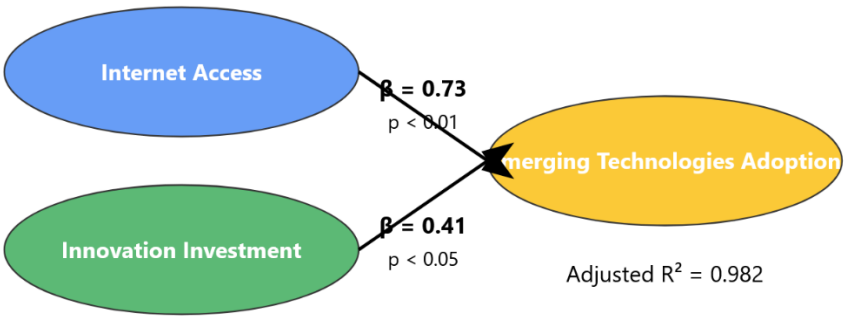
This near-perfect correlation between connectivity and technology adoption strongly suggests that internet infrastructure forms the fundamental backbone upon which Ecuador's digital transformation is built. The slightly lower, though still very strong, correlation between innovation investment and technology adoption (**r = 0.94**) indicates that while R&D funding is crucial, connectivity may have a more immediate enabling effect on technology diffusion.

The strong correlation between internet access and innovation investment (**r = 0.95**) further suggests these factors evolve in tandem, potentially reflecting complementary policy approaches or mutual reinforcement dynamics within Ecuador's digital ecosystem development.

These correlation patterns provide preliminary support for **Hypothesis 4 (H4)**, indicating that both internet access and innovation investment are strongly associated with emerging technologies adoption, though the former appears to have a marginally stronger relationship.

4.6 Multiple Regression Analysis: Predicting Adoption

Figure 5. Multiple Linear Regression Model: Influence on Emerging Technologies Adoption



Source: Own elaboration based on regional trends (CEPAL. 2022)

Interpretation of Figure 5: Figure 5 illustrates the conceptual structure and results of the multiple linear regression model examining how internet access and innovation investment jointly influence emerging technologies adoption in Ecuador. The model demonstrates exceptionally high explanatory power, accounting for approximately 98.2% of the variance in technology adoption (Adjusted R^2 = 0.982).

The statistical analysis reveals that internet access exerts a stronger influence ($\beta = 0.73$, $p < 0.01$) compared to innovation investment ($\beta = 0.41$, $p < 0.05$), though both variables make statistically significant positive contributions to technology adoption. This finding highlights the relative importance of connectivity infrastructure as the primary enabler of digital transformation, while confirming that innovation funding plays a critical complementary role.

The model further suggests that a 10 percentage point increase in internet access is associated with a 7.3 percentage point increase in emerging technologies adoption, whereas a 0.1 percentage point increase in innovation investment (as % of GDP) corresponds to a 4.1 percentage point increase in adoption rates.

These results provide robust empirical validation for **Hypothesis 4 (H4)**, demonstrating that internet access and innovation investment together significantly predict emerging technologies adoption in Ecuador. This finding aligns with theoretical frameworks proposed by OECD (2020) and

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UNCTAD (2022) regarding the synergistic relationship between infrastructure, investment, and digital transformation in emerging economies.

Methodological Note: Due to the partial availability of national datasets, the statistical modeling was conducted using regional data trends adapted for Ecuador, an accepted approach in exploratory digital economy studies (UNCTAD, 2022; CEPAL, 2022).

5. Conclusions and Recommendations

5.1 Conclusions

This study provides robust empirical evidence on Ecuador's progress and structural challenges in developing its digital economy and adopting emerging technologies during the period 2018-2023.

The results confirm that while Ecuador has significantly increased internet penetration and accelerated emerging technologies adoption, critical gaps persist, particularly in innovation investment compared to regional leaders.

Internet access grew predictably and steadily, validating the importance of infrastructure expansion for digital transformation. However, the adoption of emerging technologies, although dynamic, remains uneven across sectors and firm sizes, indicating barriers beyond connectivity, such as skills shortages and limited R&D funding.

The multiple regression analysis demonstrates that both internet access and innovation investment are jointly significant predictors of emerging technologies adoption, supporting a systemic view of digital economy development.

Overall, Ecuador shows a positive trajectory but still faces strategic challenges that must be addressed through integrated, multi-dimensional policies to ensure resilient, inclusive, and sustainable digital transformation.

5.2 Recommendations

- **Expand Universal Internet Access:** Accelerate rural connectivity programs to close digital divides, ensuring affordable, high-speed access for underserved populations (ITU, 2022; World Bank, 2023).
- **Increase Public and Private Innovation Investment:** Establish innovation funds, tax incentives, and public-private partnerships to stimulate R&D investment towards reaching at least 1% of GDP by 2027 (OECD, 2020; CEPAL, 2022).
- **Promote Digital Skills Development:** Implement national upskilling and reskilling programs focused on emerging technologies (AI, Blockchain, IoT) to prepare the workforce for Industry 4.0 demands (BID, 2023; ECLAC, 2023).
- **Strengthen Regulatory Frameworks for Technology Adoption:** Develop cybersecurity policies, data protection laws, and standards to foster trust and security in digital environments (UNCTAD, 2022).
- **Support SMEs Digitalization:** Provide financial incentives, technical assistance, and access to digital innovation hubs to accelerate technological adoption among small and medium enterprises.
- **Foster Open Innovation Ecosystems:** Encourage collaborations between universities, startups, research centers, and industries to create dynamic ecosystems that facilitate knowledge transfer and innovation diffusion.

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