Digitalization and economic growth in Mexico: an analysis using dynamic panel models (2015-2023)

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Abstract

This study aims to investigate the causal relationship between digitalization and economic growth in Mexico by constructing a Digital Economy and Society Index (DESI) at the state level from 2015 to 2023. The results suggest that a 1% increase in the DESI boosts total GDP by 0.058%. This effect is double in states with greater economic progress, reaching 0.134%. The results also suggest that greater technological infrastructure, closing the digital divide and developing digital skills are imperative for Mexico to be among the world's top ten economies. Additionally, these factors influence the reduction of heterogeneous state patterns of digitalization through the implementation of public policies on digital matters.

Keywords: panel models; economic growth; digitalization index; digital divide; Mexico.

1. INTRODUCTION

Today's digital world permeates societies and economies around the world to varying degrees. Its economic importance is undeniable. In Mexico, the gross censal added value of e-commerce contributed 5.9% to GDP in 2022 (INEGI, 2023a), while the telecommunications subsector grew at an average annual rate of 9% between 2015 and 2023 (INEGI, 2023e), well above the average annual growth rate, close to 1%. Developed countries perform better globally, with e-commerce value growing at average annual rates of between 8% and 10% in countries such as Germany, South Korea and the United States (OECD, 2024).

In recent decades, specialized literature on the relationship between digitalization variables and economic growth has grown. One World Bank (WB) study (Qiang *et al.*, 2009) found that telecommunications variables positively impact on economic growth. Katz's (2009) analysis validated its positive transversal effect on developed and Latin American (LA) countries through employment, investment, innovation, productivity and economic development. Other studies for Latin American countries have also validated the multiplier effects of technological infrastructure on economic performance (Alderete, 2017; Katz *et al.*, 2023; Zaballos and López-Rivas, 2012). For example, Rabanal (2024) affirms that there is evidence of the technology productivity paradox (Solow, 1987) in his analysis of 12 Latin American countries.

Regarding Mexico, the literature measuring the causal relationship between telecommunications variables and economic growth is scarce. Some studies have been identified, such as that by Jiménez *et al.* (2014) with data from 1991 to 2010, which found a positive effect of the variables of mobile phone users and the number of computers on GDP using the Global Innovation Index (GII).[1] A subsector study by Díaz *et al.* (2018) revealed that level of education, information and communication technology (ICT) skills and the availability of ICT infrastructure in companies are important determinants of labor productivity in Mexico. Meanwhile, González (2020) estimated that the effect of broadband internet increased GDP by 0.13% for the period from 2013 to 2018.

It is important to note the context of this research: *i)* there is a positive relationship between digitalization variables and economic growth; *ii)* a greater effect is observed in countries with high levels of economic progress, linked to variables such as human capital, exports, foreign direct investment and public investment (Pradhan *et al.*, 2018); *iii)* the use of individual telecommunications variables or composite digitalization indices has become popular (CMD, 2024; ITU, 2024a; Milošević *et al.*, 2018); and *iv)* the analyses are intended for countries. This paper goes a step further by constructing a robust digitalization index for the 32 states of Mexico for the period 2015-2023. This index includes socioeconomic variables, ICT assets in homes and ICT skills, in line with international digital development indices (EC, 2024; ITU, 2024b; Jyoti and Singh, 2023; Katz, 2009).

The main objective of the research is to measure the impact of a Digital Economy and Society Index (DESI) on Mexico's economic growth. Dynamic panel regression models are employed, and the impact of digitalization is differentiated according to the states' economic levels.

The paper is structured as follows: the second section details the conceptual aspects of the relationship between economic growth and technical progress related to digitalization. It then discusses the use of digitalization variables and indices in relation to economic growth. The fourth section details methodological aspects of the DESI and the econometric model specifications. The fifth section presents the econometric modeling and results. This is followed by a discussion and implications. The final section contains the conclusions and annexes.

2. ECONOMIC GROWTH AND THE DIGITAL ECONOMY: CONCEPTUAL ASPECTS

Schumpeter (1942) was one of the first to recognize innovation and investment in knowledge and technical progress as sources of economic growth and industrial transformation, capable of maintaining and reproducing the capitalist system. Meanwhile, neoclassical economic theory (Solow, 1956; Swan, 1956) assumes that economic growth is explained by improvements in productivity and technology rather than directly by the accumulation of physical or human capital. Endogenous growth theorists (Aghion and Howitt, 1998 and 2008) argue that technical progress can boost economic growth through innovation and knowledge, thus overcoming diminishing returns on capital.

The works of Katz and Koutroumpis (2013)[2] and Pradhan *et al.* (2014) posit that technological or telecommunications infrastructure variables embody technical progress and generate increasing returns to scale. Technological progress, digitalization, and the Internet are embodied in countless commercial activities, streamlining government services and connecting suppliers with consumers of goods and services. Tapscott (1996) defines the digital economy as a combination of networks, knowledge, intelligence and creativity for creating wealth and social development. In the opinion of Kling and Lamb (2000, p. 17), “it focuses on goods and services whose development, production, sale or provision depend critically on digital technologies […]". The OECD (2020), meanwhile, defines it as involving technologies, digital infrastructure, digital services and data used by three main agents: producers, consumers and the government. Meanwhile, Bukht and Heeks (2017) speak of a digital economy ecosystem that connects individuals, businesses, devices and society as a whole.

Therefore, the concept of the digital economy encompasses aspects of technological infrastructure, the market and organization. However, it is worth mentioning that it was difficult to measure for many years. Solow (1987, p. 2) coined the phrase, “The computer age is visible everywhere, except in the productivity statistics," as investments in computers, telephones and technological devices were not reflected in productivity and income statistics.

Therefore, most of the existing literature measures causal relationships between telecommunications variables or digitalization indices to relate them to economic performance, relying largely on official statistics from the World Bank, the World Economic Forum, the International Telecommunication Union (ITU) and the European Commission (EC). In fewer cases, national data is used (Chen and Kimura, 2019; Hanafizadeh *et al.*, 2009; Jyoti and Singh, 2023). Based on this premise, studies analyzing the relationship between digitalization variables and economic growth were reviewed.

3. REVIEW OF THE LITERATURE ON THE RELATIONSHIP BETWEEN DIGITALIZATION AND ECONOMIC GROWTH

Globally, models have been documented using individual variables of digitalization and economic growth: *i)* the number of fixed telephone lines or teledensity (Datta and Agarwal, 2004; Norton, 1992); *ii)* Jacobsen (2003) and Minges (2000) considered the number of personal computers and the number of telephones, highlighting income, level of education, employment and geographic location as key factors in society and the economy; *iii)* the WB (Qiang *et al.*, 2009) used broadband internet connection, mobile phone use and mobile internet connectivity, respectively; *iv)* Fernández-Portillo *et al.* (2020) used internet use and ICT-mediated activity variables (reading digital newspapers, e-commerce and use of e-government).

Digitalization indices are created to measure inequalities or gaps, with a view to transitioning toward the construction of information societies (Tello, 2008). The ITU's Digital Development Index (2024b) shows Mexico above the global average (80.7 versus 74.8). The European Digital Economy and Society Index (EC, 2022)[3] highlights the leadership of the Nordic countries and the United Kingdom.

Similarly, some studies validate the positive effect of digitalization on economic growth in Latin American countries. Alderete (2017) found that a 1% increase in the number of broadband internet connections would increase average GDP by 0.184%; Zaballos and López-Rivas (2012) found that a 1% increase in fixed broadband penetration increased GDP by 0.32% in countries in Latin America and the Caribbean (LAC) between 2003 and 2009. Brenes-González (2023) found that a 1% increase in households connected to the internet increased productivity by 0.04% in Nicaragua from 2000 to 2020. Only Quiroga-Parra *et al.* (2017) validated the negative association between low technological penetration and economic backwardness.

The study by Farhadi *et al.* (2013), covering the period 1995 to 2009, used a digitalization index composed of ICTs in developed countries. The results showed that GDP increased by 0.15% for every 1% increase in the index. Using a digitalization index, Katz and Koutroumpis (2013) found a 0.06% increase in GDP for each percentage point of the index in a sample of 184 countries for the period 2004-2010. Hanafizadeh *et al.* (2009) used a composite ICT digitalization index for 150 countries, grouped by level of ICT development and validated the leadership of Nordic countries and the lagging of African countries. Meanwhile, the index developed by Gerpott and Ahmadi (2015) found a greater effect of broadband and mobile telephony variables on aggregate output and development.

Regarding Mexico, cross-sectional studies and studies on the digital divide predominate (Escobar and Sámano, 2018; Martínez-Domínguez and Mora-Rivera, 2020; Rodríguez, 2019; Rodríguez *et al.*, 2024) within a heterogeneous regional context (CMD, 2024). There has been persistent progress in states in the center and north of the country, such as Mexico City, Nuevo León and Baja California, while states in the south and southeast, such as Chiapas, Guerrero and Oaxaca, have fallen behind. This is evident in the DESI calculated for Mexico (see annexes 1, 2 and 3), which shows a structural digital lag in southeastern Mexico.

These studies are linked to this paper through the selected units of analysis (households or ICT users), the sample and the relationship between economic growth and digitalization variables.

In view of the above, the proposal of this paper is based on the following: *i)* the DESI developed by the EC (2022), which focuses on measuring the digital progress of its member countries and guiding policies and strategies for digital transformation and economic growth; *ii)* the Digital Development Index of the ITU (2024b); and the index developed by Farhadi *et al.* (2013), who use this index as a proxy for ICT development in econometric modeling. For Mexico, the DESI proposal reveals the digital evolution of its 32 states and highlights the importance of addressing the level of digitalization (economic and social) at the state level and in public policy on digital matters.

Here, digitalization will be defined as the level of ICT development, estimated by the socioeconomic status of households, the availability of ICT assets and digital skills for specialized internet use. The inclusion of socioeconomic variables is justified by the existence of economic and social inequalities between states, such as poverty, informal employment and low levels of education, among others. The methodological aspects for constructing the DESI are described below.

4. METHODOLOGICAL ASPECTS AND DATA USED

In methodological terms, using ICT variables to construct indices is a useful tool when considering a larger amount of information and robustness. The main input for this paper was the processing of microdata from the National Survey on the Availability and Use of Telecommunications in Households (ENDUTIH by its Spanish initials) from 2015 to 2023[4] (INEGI, 2015 to 2023), from questionnaires on dwellings, households and users. With the exception of 2019,[5] the sample is representative at the national and state levels and is comparable for both households and users.[6] Additionally, there is no significant variation between the statistics of some telecommunications variables published by the OECD at the country level and the ENDUTIH statistics.[7]

Unlike the methodologies tested in other studies, such as those of Farhadi *et al.* (2013) (eight indicators in three categories: access, use and education and skills indicators), ITU (2024b) (14 indicators in three categories: access, use and skills), Katz and Koutroumpis (2013) (16 indicators in six components related to affordability, ICT infrastructure, use and human capital) or the aforementioned DESI for European countries, the selection of socioeconomic and ICT variables (access, use and skills) reflects the use of ENDUTIH microdata and its units of analysis (dwellings, households and users). This allows the index to be constructed over time for the 32 states.

Twenty variables were used to construct the DESI, divided into three categories: *1)* housing conditions (measuring minimum conditions for basic needs); *2)* availability of ICT assets and services (approximating minimum conditions for digital inclusion); and *3)* digital skills (reflecting human capital for interacting in society and the economy). The index was calculated using a simple average, with weightings of 0.20, 0.40, and 0.40, respectively. It is important to take into account the socioeconomic aspects of households, as the index is based on the persistent unaffordability of internet service.

Table 1 lists the variables used to construct the DESI, definitions and weightings. All variables are dichotomous and take the value 1 when the answer is affirmative, at the household or individual level.

The data panel is supplemented by state-level added variables that influence the behavior of the interaction between ICT variables and economic growth behavior, namely public investment, exports and foreign direct investment (Datta and Agarwal, 2004; Katz and Koutroumpis, 2013; Pradhan *et al.*, 2018) (see Figure 1). The result was the creation of a data panel with 288 observations (32 states and nine years) and a programming code in the Stata version 17 package.

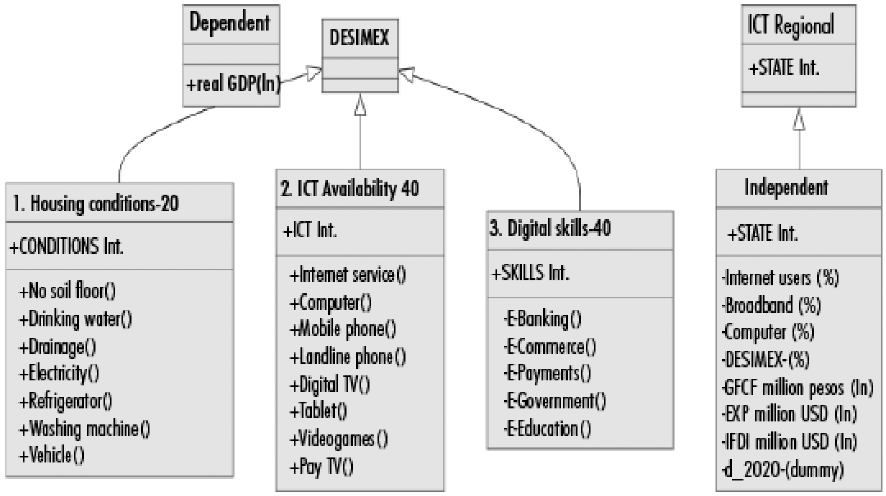
Table 1. Socioeconomic, ICT and digital skills variables

Variable (indicator)		*Description*	*Weighting*
Conditions of the home (housing questionnaire)			0.20
1	No soil floor	Most of the floor of the home is not soil	0.029
2	Drinking water	Piped water available inside the home	0.029
3	Drainage	Drainage or sewerage connected to the public network	0.029
4	Electricity	Electricity available	0.029
5	Refrigerator	Refrigerator available	0.029
6	Washing machine	Washing machine available	0.029
7	Vehicle	Car or SUV available	0.029
ICT assets in the home (household questionnaire)			0.40
8	Internet	Internet connection available in the home	0.05
ICT assets in the home (household questionnaire)			0.40
9	Computer	Desktop computer (keyboard, monitor and CPU are separate) or a laptop (keyboard, monitor and CPU are physically integrated) available	0.05
10	Mobile phone	Mobile phone (any of the members) available	0.05
11	Landline phone	Landline telephone available (can be a fixed mobile phone)	0.05
12	Digital TV	Flat screen (digital TV, LCD or LED) available	0.05
13	Tablet	Tablet (virtual keyboard and pointer on the touch screen) available	0.05
14	Video game console	Video game console available	0.05
15	Pay TV	Pay TV service available	0.05
Digital skills (user questionnaire)			0.40
16	Mobile banking	Has used online banking in the last three months.	0.08
17	Electronic commerce	Has made online sales or purchases in the last 12 months (excluding work-related purchases and including those made for their own business).	0.08
18	Digital payments	Has made online payments for purchases or services in the last 12 months.	0.08
19	Electronic government	Has carried out any of the following activities in the last 12 months: has communicated with the government, consulted government information, downloaded government forms, has carried out government procedures or interacted with the government in some other way.	0.08
20	Online education	Has used the internet in the last three months for any of the following activities: job training, taking courses to supplement education, taking tutorials on a topic of interest or other types of training.	0.08
		Total	1.00

Note: The skills section reports the definition of ENDUTIH 2023. Compared to 2015, there are some differences in the content of the instrument: Mobile banking: in 2015, users were asked whether they had carried out online banking transactions in the last 12 months. E-commerce: in 2015, users were asked if they had ordered or bought products or made purchases online (including those for their own business and excluding those for their work) in the last 12 months. Digital payments: in 2015, users were asked whether they had made payments online in the last 12 months. E-government: in 2015, information was collected for only three activities: interacting with the government, downloading government forms and filling out and submitting government forms; and Online education: in 2015, only the option "To support education" was collected.

Source: prepared by the author based on ENDUTIH data from 2015 to 2023.

Figure 1. ICT and regional variables influencing economic state growth, 2015-2023



Notes: DESIMEX (Digital Economy and Society Index of Mexico); the dependent variable is real GDP in millions of pesos (for convenience, GDP). Boxes 1, 2 and 3 list the variables used to construct the DESI: housing conditions, ICT availability and digital skills. The economic variables are listed in the lower right-hand corner. GFCF: gross fixed capital formation (millions of pesos) or public investment; EXP: exports (millions of USD); FDI: Foreign Direct Investment (millions of USD); individual ICT variables: internet user inside or outside the home in the last three months (IU), mobile phone user (MU), internet service at home (IS) and computer at home (DC) and the DESI (DESIMEX).
Source: prepared by the author using the Mermaid tool (2025) and information from ENDUTIH-INEGI (2015 to 2022; 2023b), INEGI (2023c, 2023d, 2023e) and the Ministry of the Economy (2023).

States were classified as having high or low GDP, based on real GDP per capita in 2023 (see Annex 4), was made to measure the differentiated effect of digitalization variables on economic growth (Abramovitz, 1986; Diaz *et al.*, 2016; Singh and Kumari, 2023) or what Koutroumpis (2009) refers to as network externalities, in the sense of a non-linear effect of ICTs on growth, resulting in higher than proportional returns when certain levels of critical mass are reached. The values of aggregate variables in each groups of states (see Annex 5) reflect the different stages of economic and digital development. For instance, the variable of internet use is presented as an initial phase, while variables such as computer availability in the home or the DESI variable indicate a higher level, related to specialized internet use.[10]

5. ECONOMETRIC MODELING AND RESULTS

Due to the non-contemporary relationship between digitalization variables and economic growth, dynamic panel models are proposed. As a result of the structure of the data and the context of the analysis (states within a country rather than countries), two regression techniques could be tested: first, the GMM difference method (Arellano and Bond, 1991) and, second, the GMM system method (Blundell and Bond, 1998; Roodman, 2009). The first model eliminates unobserved fixed effects and uses lags of the endogenous and exogenous variables as instruments to eliminate endogeneity issues (Ruiz-Porras, 2012). Both types of models adjust aspects of panel data, serial correlation, heteroscedasticity and endogeneity.

The GMM system model allows us to overcome the shortcomings of the traditional Arellano and Bond (1991) model. One such case is when the instruments are weak or invalid. In this case, the GMM system model can combine variables in levels and differences to solve the problem of potentially endogenous explanatory variables and overcome heteroscedasticity problems through more robust estimates.

For convenience, all variables were transformed into logarithms to facilitate the analysis and interpretation of results in terms of elasticities and isolate the instantaneous effect of each independent variable on the dependent variable. The canonical dynamic panel regression model in levels is as follows:

$$y_{i,t} = \alpha y_{i,t-1} + \beta_i X_{i,t} + \eta_i + \varepsilon_i \qquad (1)$$

Where:

i = represents the states (32 states);
t = the years (2015 to 2023);
α = coefficient that measures the persistent effect of the dependent variable;
$Y_{i,t}$ = is the dependent variable for unit *i* at time *t*;

$Y_{i, t-1}$ = lagged dependent variable;

$X_{i,t}$ = vector of independent variables (explanatory variables, the DESI, individual ICTs and aggregate ICTs);

β_i = Vector of coefficients associated with the variables;

η_i = Specific unobserved effects of unit i;

ε_i = Idiosyncratic error.

Due to the reduced number of periods and the relatively small number of groups, the model type with exogenous independent variables was not used, i.e., lag operators were not used for these variables in order to have greater control over the number of instruments (Mileva, 2007). Previously, the procedure was carried out to validate the panel data model as the best model specification, i.e., the Breusch-Pagan Lagrange Multiplier (BPLM) test was run to determine the presence of a panel effect. In all three cases, the null hypothesis was rejected (see Table 2).

Table 2. Validation of panel model specification

Compared models	*Test*	*Chi^2*	*Prob > Chi^2*	*Decision*
FE vs. RE (all states)	BPLM test	521.66	0.00	Panel effect
FE vs. RE (states with high GDP)	BPLM test	257.24	0.00	Panel effect
FE vs. RE (states with low GDP)	BPLM test	283.36	0.00	Panel effect

Notes: FE, fixed effects models; RE: random effects models.

Source: own estimates.

Six regressions are run using dynamic panel specifications. The first three use dynamic models of the differenced GMM estimators type are run, which are particularly useful when there are many groups and few periods and when exogenous, predetermined, and/or endogenous independent variables can be included (Labra and Torrecillas Bautista, 2018). The remaining three use dynamic GMM system models were run in order to reaffirm the results and use more variables as instruments (Roodman, 2009).

The technique developed by Arellano and Bond (1991) addresses endogeneity and multicollinearity problems through the use of instrumental variables.

The functional form of the dynamic model of the GMM system to eliminate individual effects (h i) is as follows:

$$\Delta y_{i,t} = \alpha \Delta y_{i,t-1} + \beta' \Delta X_{i,t} + \varepsilon_{i,t} \quad (2)$$

To obtain differentiated results in the coefficients for each sample (all states, states with high GDP and states with low GDP) and based on references in the literature (Farhadi *et al.*, 2013; Gerpott and Ahmadi, 2015; Jyoti and Singh, 2023), we analyze the DESI index variable and the four individual TIC variables simultaneously.

Substituting the variables, the regression is as follows:

$$\begin{aligned} GDP_{i,t} = \alpha_0 + \alpha GDP_{i,t-1} + \beta_1 DESI_{i,t} + \beta_2 IU_{i,t} + \beta_3 MU_{i,t} \\ + \beta_4 SI_{i,t} + \beta_5 DC_{i,t} + \beta_6 IP_{i,t} + \beta_7 EXP_{i,t} \\ + \beta_8 FDI_{i,t} + d\_2020 + \varepsilon_{i,t} \end{aligned} \quad (3)$$

Where:

$GDP_{i,t}$ = Dependent variable. Real GDP at 2013 prices.

$\alpha GDP_{i, t-1}$ = Term representing the memory effect or dependence on the past.

DESI = Digital Economy and Society Index, composed of 20 variables in three categories.

IU = Internet user, at least once in the last three months (user questionnaire).

MU = Mobile phone user, at least once in the last three months (user questionnaire).

SI = Internet connection at home (household questionnaire).

DC = Home computer, desktop or laptop (household questionnaire).

IP = Public investment or gross fixed capital formation. In Mexican pesos.

EXP = Value of merchandise exports, resulting from Mexico's trade with the rest of the world. In USD.

FDI = Foreign Direct Investment flows at the end of each year. In USD.

*d*_2020 = Allows us to capture the effect of the fall in GDP due to the Covid-19 pandemic.

α_0 = Constant. A value is obtained for each of the three samples used.

$\varepsilon_{i,t}$ = Error term representing the unexplained variability in the model.

A positive effect is expected for all explanatory variables. Subindex *i* considers the 32 states in the first two regressions; 16 states with high GDP in the next two regressions; and 16 states with low GDP in the last two regressions.

The GMM system model allows moment conditions to be added at different levels. In general, this model is ideal because: *1)* it allows two estimators to be calculated, the GMM difference estimator and the augmented estimator or GMM system (Bond, 2002); *2)* more efficient estimators are achieved in two stages than in one stage and it allows for finite sample correction of the two-step covariance matrix (Windmeijer, 2005), achieving reliable and robust estimators; and *3)* it eliminates the problem of instrument proliferation.

The expressions of the two equations of the GMM system panel data model are:

$$y_{i,t} = \alpha_i + \gamma y_{i,t} + \beta x_{i,t} + v_{i,t} \qquad \text{(in levels) (4)}$$

$$\Delta y_{i,t} = \alpha_i + \gamma \Delta y_{i,t-1} + \beta \Delta x_{i,t} + \Delta v_{i,t} \qquad \text{(in differences) (5)}$$

Similarly, when substituting the variables in the model, the equation expression reads as follows:

$$\begin{aligned} GDP_{i,t} = {} & \alpha_i + GDP_{i,t-1} + \beta_1 DESI_{i,t} + \beta_2 IU_{i,t} + \beta_3 MU_{i,t} \\ & + \beta_4 SI_{i,t} + \beta_5 DC_{i,t} + \beta_6 IP_{i,t} + \beta_7 EXP_{i,t} + \beta_8 FDI_{i,t} + \beta_9 d\_2020 + \varepsilon_{i,t} \end{aligned} \qquad (6)$$

After substituting the variables and specifying the GMM system panel data model (Roodman, 2009),[11] the equation was run in Stata software. The results of both specifications are presented in Table 3.

6. DISCUSSION AND IMPLICATIONS

Dynamic panel econometric modeling is ideal for overcoming problems of endogeneity, multicollinearity and serial correlation in samples with many cross sections and few periods. The effect that the DESI would have on economic growth in Mexico is tested.

The main finding of the model is the explanatory power of the DESI on economic growth. Considering all states, a 1% increase in this index boosts national GDP by 0.054%-0.058% (ceteris paribus); a similar effect to the 0.064% found by Rabanal (2024), who used the percentage of households with an internet connection and the 0.06% found by Katz and Koutroumpis (2013), who used a digitalization index. For the group of states with high GDP, the effect of the DESI is more than double, at 0.134%. This value is slightly higher than the WB estimate for developed countries (Qiang *et al.*, 2009) of 0.121%, which uses broadband internet connectivity as a variable, slightly lower than Alderete's (2017) estimate of 0.184% and similar to the value found by Farhadi *et al.* (2013) of 0.15%. The results also align with Singh and Kumari's (2023) findings of only positive effects of telecommunications variables in the group of rich countries, with an increase in GDP of 0.08% and 0.06%, using variables such as landline telephone subscriptions and internet users, respectively.

Table 3. Estimation of the impact of digitalization variables on economic growth using dynamic panel models, 2015-2023

	GMM Differences			*GMM system*		
Variable / Group of states	*All*	*With high GDP*	*With low GDP*	*All*	*With high GDP*	*With low GDP*
L.GDP	0.103***	0.129***	0.118***	0.508***	0.649***	0.377***
	[-0.0273]	[-0.0425]	[-0.0295]	[-0.0541]	[-0.118]	[-0.117]
DESI	0.0583**	0.134**	0.0518	0.0538**	0.136	0.0206
	[-0.0252]	[-0.0528]	[-0.0337]	[-0.0254]	[-0.0852]	[-0.0639]
Internet users	0.046	0.140*	0.0193	-0.0107	-0.15	-0.00503
	[-0.0349]	[-0.0799]	[-0.042]	[-0.037]	[-0.26]	[-0.212]
Mobile phone users	-0.264***	-0.484**	-0.221	-0.00575	0.26	-0.0342
	[-0.058]	[-0.195]	[-0.162]	[-0.106]	[-0.503]	[-0.239]
Internet service	-0.0224	0.0529	-0.0252	-0.0303	-0.0212	-0.0662*
	[-0.0283]	[-0.0463]	[-0.0413]	[-0.021]	[-0.0518]	[-0.0369]
Computer in the home	-0.0344	-0.139**	-0.0318	0.123**	0.0154	0.233**
	[-0.0352]	[-0.0689]	[-0.0442]	[-0.0574]	[-0.0931]	[-0.0943]
Public investment	0.00908***	0.0100***	0.00772**	0.0152***	0.0174***	0.00881***
	[-0.00269]	[-0.0011]	[-0.00328]	[-0.00321]	[-0.00184]	[-0.00289]
Exports	0.0629***	0.0103	0.0660***	0.0214***	-0.019	0.0589***
	[-0.0165]	[-0.0146]	[-0.0148]	[-0.00648]	[-0.0141]	[-0.0159]
FDI	-0.000434	-0.00152	-0.000252	0.00144	-0.00125	0.00101
	[-0.00178]	[-0.00263]	[-0.00189]	[-0.00164]	[-0.00351]	[-0.00229]
d_2020	-0.0627***	-0.0686***	-0.0678***	-0.0909***	-0.0961***	-0.0843***
	[-0.0035]	[-0.00446]	[-0.00289]	[-0.00378]	[-0.00932]	[-0.0106]
Constant	12.13***	12.83***	11.65***	5.706***	3.819	7.029***
	[-0.453]	[-0.78]	[-0.713]	[-0.896]	[-2.386]	[-1.886]
Observations	224	112	112	224	112	112
Wald	1 001.41	1 428.82	2 586.56	2 964.3	1 479.82	375.22
Groups/Instruments	32/17	16/17	16/17	32/24	16/24	24/16
Sargan test	0.0002	0.0241	0.0500	0.0189	0.5201	0.7075
AR(1)	0.4367	0.7040	0.0378	0.0040	0.0134	0.0250
AR(2)	0.3151	0.7926	0.3189	0.7410	0.6345	0.8117

Notes: standard deviation values in brackets.

Source: prepared by the author.

In states with low GDP, the DESI has no effect on economic growth. This is consistent with the argument that a critical mass is needed to take advantage of digitalization (Koutroumpis, 2009; Mariscal, 2022). The mobile phone user variable confirms that Mexico has surpassed a certain stage of development as there is a negative effect on economic growth, especially among rich states, although the provision of quality services and non-concentrated market structures remain pending (Mariscal, 2022).

Interestingly, the effect of the computer availability variable is positive for the dynamic system model specifications and that the effect is greater among poor states. A 1% increase in the DESI increases GDP by 0.233%. This latter result contrasts with that of Jacobsen (2003), who found a positive effect of personal computers in developed countries from 1990 to 1999, but not in developing countries. Jacobsen considered personal computers to be necessary goods in developed countries and luxury goods in developing countries. The idea that computers are non-essential goods is consistent with the percentage of Mexican households with computers, which fell from 44.9% to 43.8% between 2015 and 2023 (INEGI 2015 and 2023). This result appears to contradict the effect of the COVID-19 pandemic on the intensive use of the internet, technology and electronic devices.[12]

Another noteworthy item is the effect of aggregate variables on economic growth. An increase in public investment invariably has a positive effect on economic performance, especially for states with a high GDP compared to those with a low GDP. Regarding exports, this effect only applies to rich states, where a 1% increase in public investment raises GDP by 0.063% to 0.066%, consistent with the industrial, manufacturing and export profile of these states. The null effect in states with a low GDP indicates the pattern of economic growth and historical growth strategy, focused on foreign trade and investment, as opposed to the lagging states in the south-southeast.

Regarding the validity of the models, first, Wald's statistics indicate that the coefficients of the explanatory variables in the model are statistically significant overall, i.e., they impact GDP behavior (a weak argument since it indicates that at least one of the coefficients has a value different from zero). Secondly, the number of instruments must be less than the number of groups. Only models with the entire sample meet this condition and the data panel used negatively influences it. Dividing the sample into two automatically reduces the number of groups. Furthermore, it is not appropriate to validate the Sargan test in this type of model since the use of instruments causes over-identification of the model.[13] Thirdly, the goal is to ensure that there is no second-order serial correlation in the residuals (AR 2). The null hypothesis that there is no autocorrelation was not rejected in all specifications so the models are valid.

The results of the econometric modeling reveal the possible path to be followed by public policymakers in terms of telecommunications investments and sector promotion. For low-income states, the greatest multiplier effect would come from increasing the availability of computers (in excess of those documented in literature), public investment and exports. For high-income states, digitalization would generate greater economic dividends in terms of aggregate income, employment and industrial development- For economically lagging states, the most pressing strategy would be to invest in physical infrastructure and connectivity (means of transport) and encourage productive vocations in the service sector.

7. CONCLUSIONS

A data panel was constructed for Mexico, broken down by state from 2015 to 2023. This allowed us to investigate the causal relationship between an economic and social digitalization index and economic growth. A positive and statistically significant effect was validated: a 1% increase in the DESI boosts total GDP by 0.058%. This effect doubles when considering the sample of states with high GDP, reaching 0.134%. Consistent with the reviewed literature, relating economic growth to digitalization using information from households or individuals as the unit of analysis is feasible. Likewise, the findings confirm and suggest the following: *i)* the leadership of states with greater economic progress and the potential use of digitalization as an industrial policy instrument; *ii)* the close relationship between economic performance, digitalization and human capital; and *iii)* the validation of stylized facts on the positive and differentiated impact of digitalization variables on economic growth; and *iv)* the importance of focusing on the issue of digital skills to maximize the potential of connectivity, provided there are institutional capacities, physical and technological infrastructure and market regulation.

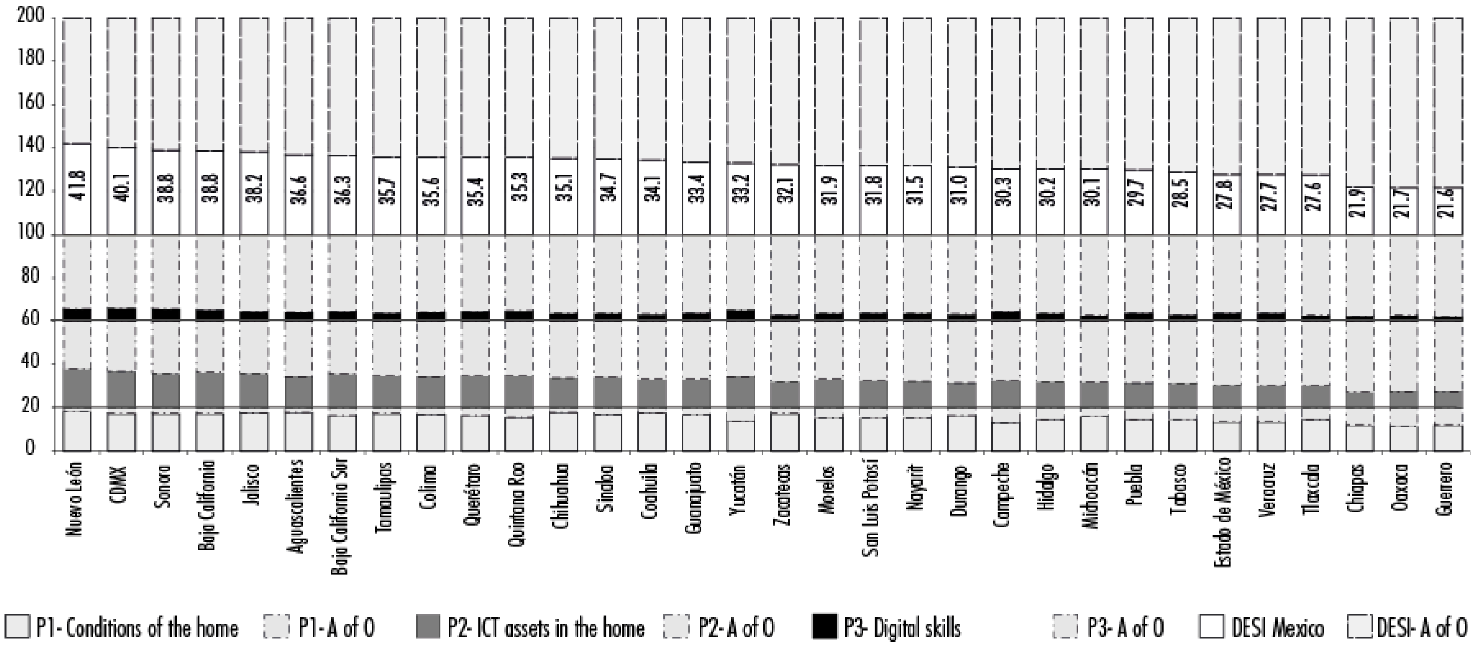
Based on a review of the literature and studies conducted for Mexico, this research is novel in the following ways: *i)* it measures and analyzes a digital economy and society index over time for the 32 states. This is commonly carried out for groups of countries by international organizations (ITU, 2024b; EC, 2022). In Mexico most studies using ICT-related indices are cross-sectional (Escobar and Sámano, 2018; Martínez-Domínguez and Mora-Rivera, 2020; Rodríguez, 2019); *ii)* it empirically validates the impact of a digitalization index on economic growth. It does so using microeconomic and secondary source information. It differentiates the effect according to the economic level of the states, unlike studies that use individual ICT variables (Figueroa Hernández *et al.*, 2021; González, 2020; Rabanal, 2024); and *iii)* positioning the close relationship between ICTs and economic growth as an area with real potential to boost the national economy.

It should be noted that this study had two limitations: the lack of information on household income or expenditure, which was unavailable in the ENDUTIH and the absence of human capital variables such as tertiary education, investment in science and technology and productivity. It is important to note that the analysis was carried out during a period of economic slowdown, when the average annual growth rate of real GDP was 0.28% and real GDP per capita was -1%. These elements should be considered when designing an ambitious and long-term digital industrial policy. There is still room for further analysis of the digitalization process in Mexico at the regional or territorial level, taking into account productive, scientific and resource allocation vocations. This research therefore opens the door for future research on the impact of the digital economy in the economic and social spheres.

Clearly, the reduction in spending on fixed internet connectivity and computers in Mexican households is due to the economic situation and the economic slowdown. Therefore, any strategy to promote connectivity in the digital age must involve designing subsidy programs for connectivity, increasing the development of freely accessible content and promoting collaboration between private entities and the government. A new public policy on digital matters must be developed that focuses on the digital economy and responds to the challenges of a hyper-connected society.

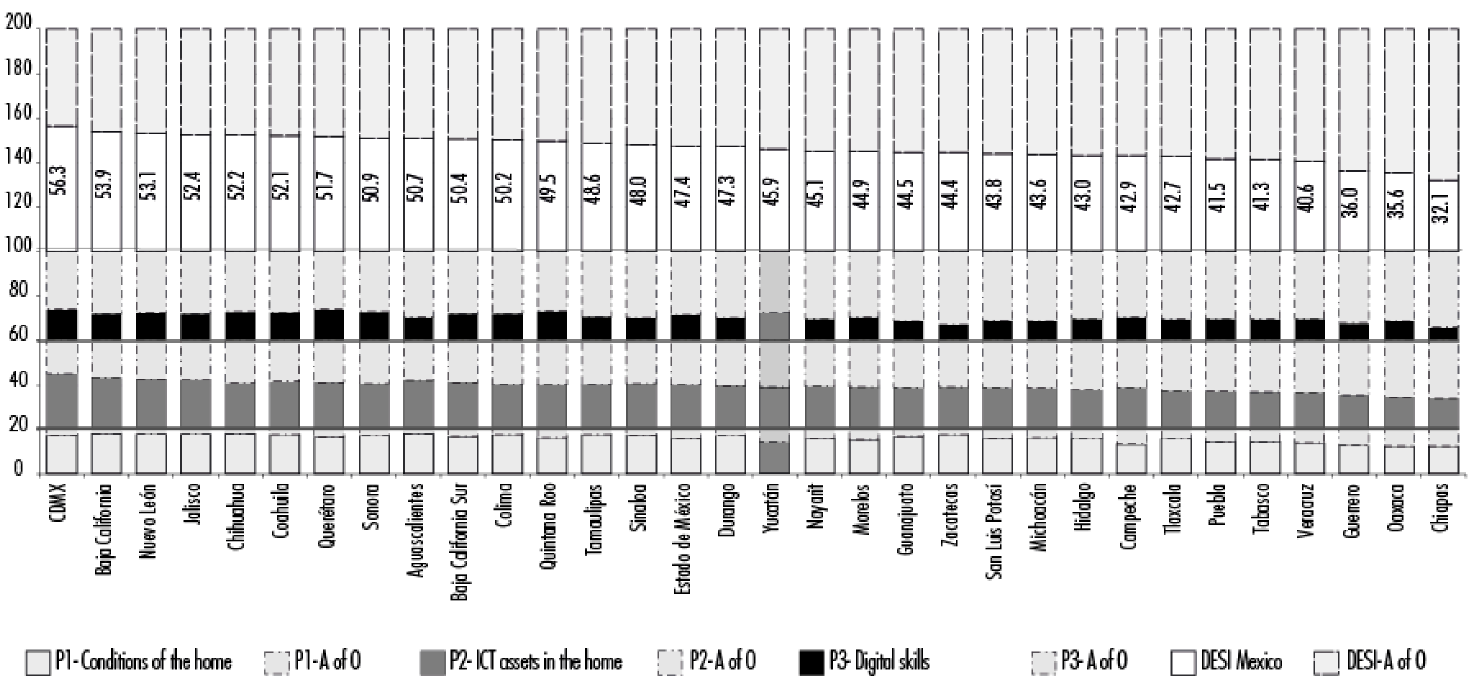
ANNEXES

Annex 1. Breakdown of DESI, by federal state, 2015



Note: A of O: Area of opportunity
Source: prepared by the author.

Annex 2. Breakdown of DESI, by federal state, 2023



Note: A of O: Area of opportunity
Source: prepared by the author.

Annex 3. Comparison of DESI by federal state, 2015 and 2023

Note: The national average values and the highest and lowest values for each year are highlighted.
Source: prepared by the author.

Annex 4. States by economic level, 2023

High GDP			*Low GDP*		
Federal state	*Real GDP per capita (thousands of pesos)*	*Real GDP (millions of pesos)*	*Federal state*	*Real GDP per capita (thousands of pesos)*	*Real GDP (millions of pesos)*
Campeche	466.1	442 891	Quintana Roo	159.1	321 394
Mexico City	377.5	3 481 063	Sinaloa	159.0	499 562
Nuevo León	301.0	1 866 999	Durango	155.0	294 354
Coahuila	270.2	896 051	Yucatán	146.4	359 047
Tabasco	261.7	642 406	Zacatecas	130.5	219 609
Sonora	248.7	766 319	Michoacán	129.2	639 506
Baja California	227.3	911 445	Veracruz	126.1	1 025 312
Chihuahua	224.1	884 885	Hidalgo	125.7	405 858
Querétaro	220.8	564 790	Morelos	123.4	250 672
Aguascalientes	203.0	306 698	Estado de México	122.6	2 146 366
Jalisco	199.3	1 741 264	Nayarit	122.6	158 693
Tamaulipas	198.5	731 448	Puebla	114.0	787 229
Baja California Sur	192.1	166 738	Tlaxcala	100.5	141 971
Colima	190.7	144 401	Oaxaca	94.9	405 915
San Luis Potosí	173.3	507 977	Guerrero	82.8	298 486
Guanajuato	167.5	1 075 927	Chiapas	61.7	366 896

Source: prepared by the author.

Annex 5. Average values for economic and ICT variables for the period 2015 to 2023

Variables	*Total*	*High GDP*	*Low GDP*
Real GDP (millions of pesos)	733 695.7	945 966.8	521 424.6
Real GDP per capita (thousands of pesos)	193.9	260.2	127.6
Internet users	68.4	73.8	63.0
Mobile phone users	78.2	82.3	74.2
Households with internet	56.7	63.9	49.4
Households with computers	38.1	43.0	33.2
DESI Mexico	41.9	45.31	38.5
Real public investment (millions of pesos)	2 552.4	2 531.7	2 573.2
Foreign Direct Investment (millions of dollars)	1 049.4	1 568.2	530.7
Exports (millions of dollars)	12 886	21 805.8	3 966.2

Source: prepared by the author.

Bibliography

Abramovitz, M. (1986). Catching up, forging ahead, and falling behind. *The Journal of Economic History, 46(2).* https://doi.org/10.1017/S0022050700046209

Aghion, P. and Howitt, P. (1998). *Endogenous growth theory.* MIT Press. https://doi.org/10.1177/107049659800700313

___________ (2008). *The economics of growth.* MIT Press. https://mitpress.mit.edu/9780262012638/the-economics-of-growth/

Alderete, M. V. (2017). An approach to the broadband effect on Latin American growth: A structural model. *Cuadernos de Economía; Bogotá, 36(71).* http://dx.doi.org/10.15446/cuad.econ.v36n71.54717

Arellano, M. and Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies, 58(2).* https://doi.org/10.2307/2297968

___________ and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics, 68(1).* https://doi.org/10.1016/0304-4076(94)01642-D

Blundell, R. and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87(1).* https://doi.org/10.1016/S0304-4076(98)00009-8

Bond, S. R. (2002). Dynamic panel data models: A guide to micro data methods and practice. *Portuguese Economic Journal, 1(2).* https://doi.org/10.1007/s10258-002-0009-9

Brenes-González, H. A. B.-. (2023). El uso del internet y su relación con el crecimiento económico: análisis para Nicaragua. *Revista Científica Profundidad Construyendo Futuro, 19(19).* https://doi.org/10.22463/24221783.4030

Bukht, R. and Heeks, R. (2017). *Defining, conceptualising and measuring the digital economy*. https://doi.org/10.2139/ssrn.3431732

Chen, L. and Kimura, F. (eds.) (2019). *Developing the digital economy in ASEAN.* Routledge. https://doi.org/10.4324/9780429504853

Centro México Digital (CMD) (2024, November). *IDDE 2024—CMD* [Asociación Civil]. CMD. https://centromexico.digital/idde/2024/

Datta, A. and Agarwal, S. (2004). Telecommunications and economic growth: A panel data approach. *Applied Economics, 36(15).* https://doi.org/10.1080/0003684042000218552

Díaz, H. E., Sosa, M. M. and Cabello, A. (2016). Educational level and differential impact of broadband on economic growth. *IOSR Journal of Economics and Finance* (IOSR-JEF), *7(3).* https://doi.org/10.9790/5933-0703030110

___________, Sosa, M. M. and Cabello, A. (2018). Uso de tic y productividad en México: un análisis subsectorial. *Revista de Métodos Cuantitativos para la Economía y la Empresa, 25(1).* https://doi.org/10.46661/revmetodoscuanteconempresa.2528

EC (2022). *Digital Economy and Society Index (DESI) 2022 [Report]. Shaping* Europe's digital future. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-DESI-2022

___________ (2024). Digital Decade DESI Visualisation tool. *DESI 2023 dashboard for the Digital Decade.* https://digital-decade-DESI.digital-strategy.ec.europa.eu/datasets/DESI/charts

Escobar, R. and Sámano, Y. M. (2018). Disponibilidad regional de la infraestructura de telecomunicaciones. Un análisis multivariado. *El Trimestre Económico, 85(340).* https://doi.org/10.20430/ete.v85i340.537

Farhadi, M., Rahmal, I., Sarmidi, T. and Kasimin, H. (2013). The role of Information and Communication Technology (ICT) development in economic growth: A dynamic Panel Data Approach. *International Journal on Advances in Information Sciences and Service Sciences, 5(12).* https://doi.org/10.4156/AISS.VOL5.ISSUE12.8

Figueroa Hernández, E., Pérez Soto, F. and Godínez Montoya, L. (2021). El impacto del internet en el crecimiento económico de México. In Rózga Luter, R. E., Serrano Oswald, S. E. and Mota Flores, V. E. (coords.). *Innovación, turismo y perspectiva de género en el desarrollo regional* (vol. V, pp. 75-92). UNAM-IIEC. https://ru.iiec.UNAM.mx/5597/

Fernández-Portillo, A., Almodóvar-González, M. and Hernández-Mogollón, R. (2020). Impact of ICT development on economic growth. A study of OECD European Union countries. *Technology in Society, 63, 101420.* https://doi.org/10.1016/j.techsoc.2020.101420

Gerpott, T. J. and Ahmadi, N. (2015). Advancement of indices assessing a nation׳s telecommunications development status: A pls structural equation analysis of over 100 countries. *Telecommunications Policy, 39(2).* https://doi.org/10.1016/j.telpol.2014.11.007

González, J. M. (2020). *Crecimiento económico y difusión tecnológica: el caso de internet de banda ancha* [Tesis, Colegio de la Frontera Norte], p. 89. https://posgrado.colef.mx/tesis/20181404/

Hanafizadeh, M. R., Saghaei, A. and Hanafizadeh, P. (2009). An index for cross-country analysis of ICT infrastructure and access. *Telecommunications Policy, 33(7).* https://doi.org/10.1016/j.telpol.2009.03.008

Instituto Nacional de Estadística y Geografía (INEGI) (2015). https://www.inegi.org.mx/programas/dutih/2015/

___________ (2016). https://www.inegi.org.mx/programas/dutih/2016/

___________ (2017). https://www.inegi.org.mx/programas/dutih/2017/

___________ (2018). https://www.inegi.org.mx/programas/dutih/2018/

___________ (2019). https://www.inegi.org.mx/programas/dutih/2019/

___________ (2020). https://www.inegi.org.mx/programas/dutih/2020/

___________ (2021). https://www.inegi.org.mx/programas/dutih/2021/

___________ (2022). https://www.inegi.org.mx/programas/dutih/2022/

___________ (2023a). *Comercio Electrónico* [Gobierno]. Economía y Sectores Productivos. https://www.inegi.org.mx/temas/vabcoel/

___________ (2023b). Encues*ta Nacional sobre Disponibilidad y Uso de Tecnologías de la Información en los Hogares* (ENDUTIH) 2023. https://www.inegi.org. mx/programas/ENDUTIH/2023/

___________ (2023c). *Información económica*. Exportaciones por Entidad Federativa (ETEF). https://www.inegi.org.mx/programas/exporta_ef/#tabulados

___________ (2023d). *Estadística de finanzas públicas estatales y municipales.* https://www.inegi.org.mx/sistemas/olap/Proyectos/bd/continuas/finanzaspublicas/FPEst.asp

___________ (2023e). *Producto Interno Bruto Trimestral, Año base 2018*. https://www.inegi.org.mx/programas/GDP/2018/

International Telecommunications Union (ITU) (2024a). *International Telecommunications Union—DataHub*. DataHub. https://datahub.ITU.int/

___________ (2024b). *Measuring digital development—ICT Development Index 2024*, p. 39. International Telecommunications Union. https://www.ITU.int/hub/publication/d-ind-ict_mdd-2024-3/

Jacobsen, K. F. L. (2003). *Telecommunications—A means to economic growth in developing countries? CMI Report, R 2003: 13, 55.* https://www.cmi.no/publications/1732-telecommunications-a-means-to-economic-growth-in

Jiménez, M., Matus, J. A. and Martínez, M. A. (2014). Economic growth as a function of human capital, internet and work. *Applied Economics, 46(26).* https://doi.org/10.1080/00036846.2014.925079

Jyoti, B. and Singh, A. (2023). *Does digitalization have a causal relationship with economic development?: An experience from a country-wise panel data statistical analysis* (pp. 34-61). https://doi.org/10.4018/978-1-6684-8397-8.ch003

Katz, R. (2009). Estimating broadband demand and its economic impact in Latin America. Proc. 3rd ACORN-REDECOM, 1-20. https://shorturl.at/Rnp6Y

Katz, R. and Koutroumpis, P. (2013). Measuring digitalization: A growth and welfare multiplier. *Technovation, 33(10).* https://doi.org/10.1016/j.technovation.2013.06.004

___________, Jung, J. and Valencia, R. (2023). Brecha de conectividad y necesidades de inversión en América Latina y el Caribe: una perspectiva económicofinanciera. *IDB Publications*. https://doi.org/10.18235/0005075

Kling, R. and Lamb, R. (2000). *IT and organizational change in digital economies: a sociotechnical approach.* https://doi.org/10.7551/mitpress/6986.003.0017

Koutroumpis, P. (2009). The economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy, 33(9).* https://doi.org/10.1016/j.telpol.2009.07.004

Labra, R. and Torrecillas Bautista, C. (2018). Estimating dynamic Panel Data. A practical approach to perform long panels. *Revista Colombiana de Estadística, 41(1).* https://dialnet.unirioja.es/servlet/articulo?codigo=9592913

Lera-López, F., Gil Izquierdo, M. and Billón Currás, M. (2009). *El uso de internet en España: influencia de factores regionales y socio-demográficos.* http://hdl.handle.net/10486/668559

___________, Marco, R. and Billon, M. (2021). Internet banking: A new digital divide between the European regions? *The Digital Disruption of Financial Services.* Routledge. https://doi.org/10.4324/9781003199076-1

Mariscal, J. (2022). El largo camino hacia el acceso universal: aún no llegamos. *Revista de Economía Mexicana, 7.* http://www.economia.UNAM.mx/assets/pdfs/econmex/07/07%20Judith%20Mariscal.pdf

Martínez-Domínguez, M. and Mora-Rivera, J. (2020). internet adoption and usage patterns in rural Mexico. *Technology in Society, 60.* https://doi.org/10.1016/j.techsoc.2019.101226

Mermaid. Diagramming and charting tool (2025). https://mermaid.js.org/

Mileva, E. (2007). Using Arellano-Bond dynamic panel GMM estimators in Stata. Economics Department, Fordham University, *64(1).* https://shorturl.at/m8692

Milošević, N., Dobrota, M. and Barjaktarovic Rakocevic, S. (2018). Digital economy in Europe: Evaluation of countries' performances. *Zbornik Radova Ekonomskog Fakultet Au Rijeci, 36.* https://doi.org/10.18045/zbefri.2018.2.861

Minges, M. (2000). *Counting the Net: internet Access Indicators* [Conference presentation]. INET conference 2000, Japan. www.isoc.org/isoc/conferences/inet/00/cdproceedings/8e/8e_1.htm

Norton, S. W. (1992). Transaction costs, telecommunications, and the microeconomics of macroeconomic growth. *Economic Development and Cultural Change, 41(1).* http://www.jstor.org/stable/1154226

OECD (2020). *A roadmap toward a common framework for measuring the digital economy. Report for the G20 Digital Economy Task Force* (p. 123) [Report]. OECD. https://www.ITU.int/en/ITU-D/Statistics/Documents/publications/OECDRoadmapDigitalEconomy2020.pdf

___________ (2024). *OECD Digital Economy Outlook 2024, vol. 1.* https://www.OECD-ilibrary.org/content/publication/a1689dc5-en

WIPO (2023). *Índice Mundial de Innovación 2023: la innovación frente a la incertidumbre.* Global-innovation-index. https://www.wipo.int/web/global-innovation-index/2023/index

Pradhan, R. P., Arvin, M. B., Bahmani, S. and Norman, N. R. (2014). Telecommunications infrastructure and economic growth: comparative policy analysis for the G-20 developed and developing countries. *Journal of Comparative Policy Analysis: Research and Practice, 16(5).* https://doi.org/10.1080/13876988.2014.960227

___________, Mallik, G. and Bagchi, T. P. (2018). Information Communication Technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. *IIMB Management Review.* https://doi.org/10.1016/j.iimb.2018.01.001

Qiang, C. Z.-W., Rossotto, C. M. and Kimura, K. (2009). *Information and Communications for Development: Extending Reach and Increasing Impact* (p. 320). https://doi.org/10.1596/978-0-8213-7605-8

Quiroga-Parra, D. J., Torrent-Sellens, J. and Murcia-Zorrilla, C. P. (2017). Las tecnologías de la información en América Latina, su incidencia en la productividad: un análisis comparado con países desarrollados. *DYNA, 84(200).* https://doi.org/10.15446/dyna.v84n200.60632

Rabanal, C. (2024). La paradoja de la productividad y el uso de internet en países de América Latina. *Problemas del Desarrollo. Revista Latinoamericana de Economía, 55(219).* https://doi.org/10.22201/iiec.20078951e.2024.219.70183

Ragnedda, M. (2019). Conceptualising the digital divide. *Conceptualising the digital divide* (pp. 27-44). https://doi.org/10.2307/j.ctvh4zj72.6

Rodríguez, J. G. (2019). Adopción de internet en México: propuesta de un Índice de Telecomunicaciones. *Ensayos Revista de Economía, 38(2).* https://doi.org/10.29105/ensayos38.2-1

___________, Armenta, C. E. R. and González, E. G. R. (2024). Influence of ICT and household assets in the penetration of digital economy in Mexico: An empirical analysis. *Journal of Telecommunications and the Digital Economy, 12(1).* https://doi.org/10.18080/jtde.v12n1.876

Roodman, D. (2009). How to do Xtabond2: An Introduction to Difference and System GMM in Stata. *The Stata Journal, 9(1).* https://doi.org/10.1177/1536867X0900900106

Ruiz-Porras, A. (2012). La investigación econométrica mediante paneles de datos: historia, modelos y usos en México. MPRA Paper. https://mpra.ub.unimuenchen.de/42909/1/MPRA_paper_42909.pdf

Schumpeter, J. A. (1942). *Capitalism, socialism y democracy.* Routledge. http://catalogo.econo.unlp.edu.ar/meran/getIndiceFile.pl?id2=2374

Secretaría de Economía (2023). Flujos de Inversión Extranjera Directa. https://shorturl.at/UXVW6

Singh, S. K. and Kumari, R. (2023, October). *ICT influence on economic growth of low-income countries with the participation of HICs.* Research Square. https://doi.org/10.21203/rs.3.rs-3415465/v1

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics, 70(1).* https://doi.org/10.2307/1884513

___________ (1987). We'd better watch out. *New York Times Book Review,* 1-2. https://shorturl.at/wmMN3

Swan, T. W. (1956). Economic growth and capital accumulation. *Economic Record, 32(2).* https://doi.org/10.1111/j.1475-4932.1956.tb00434.x

Tapscott, D. (1996). *The digital economy: promise and peril in the age of networked intelligence.* McGraw-Hill. https://shorturl.at/uT84c

Tello, E. (2008). Las tecnologías de la información y comunicaciones (TIC) y la brecha digital: su impacto en la sociedad de México. *Revista de Universidad y Sociedad del Conocimiento, 4(2).* https://www.redalyc.org/articulo.oa?id=78011231006

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics, 126(1).* https://doi.org/10.1016/j.jeconom.2004.02.005

Zaballos, A. G. and López-Rivas, R. (2012). Socioeconomic impact of broadband in Latin American and Caribbean countries. *IDB Publications.* https://doi.org/10.18235/0009082

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[1] One noteworthy aspect is that, although his research focused on promoting innovation as a growth strategy, the results for 2023 highlight the fact that Mexico fell in the GII rankings between 2015 and 2023, dropping from 57th to 58th place (WIPO, 2023).

[2] Katz and Koutroumpis (2013) used the concept of *digitization* as a synonym for digitalization and technological progress. However, the former relates to an eminently technical process, the conversion of physical documents or information (paper or images, for example) or analog format to digital format, without altering the original content, while the latter refers to the use of digital technologies in processes, business models, automation, robotics or, ultimately, in the use of Artificial Intelligence (AI) in production, educational or government management processes, to name a few.

[3] The EC has been compiling the Digital Economy and Society Index (DESI) since 2014, considering four categories in 31 indicators: human capital (7), connectivity (8), digital technology integration (11) and digitalization of public services (5), with the aim of better understanding the phenomenon of digitalization, the progress and lag of European countries over time and guiding policies and strategies that promote the digital and economic transformation of the region.

[4] The selection of the sample by age groups depends on the analysis to be carried out. For example, Lera-López *et al.* (2021) select people over the age of 25 when associating internet use with the average number of years of schooling; Lera-López *et al.* (2009) select people over the age of 16.

[5] The values for 2019 were estimated using interpolation, which did not alter the trend of the indicators used.

[6] Years prior to 2015 were not used in the survey because they are not comparable (INEGI, 2015 to 2023), in addition to changes in the definitions and nomenclature of the variables.

[7] At the country level, the indicator par excellence as a baseline for technological infrastructure is the number of fixed broadband Internet subscriptions. The ITU reported 26.64 million for Mexico in 2023 (ITU, 2024a), while the number of households with fixed Internet connectivity in the ENDUTIH was 26.15 million.

[8] By 2023 (INEGI, 2023b), 58.1% of households cited economic factors as the main reason for not having internet access, followed by lack of interest and not knowing how to use it (24.7% and 8.9%, respectively).

[9] To gauge the differences, it was found that, when comparing the years 2015 and 2023, the GDP per capita of the richest state was 11.3 and 7.6 times, respectively, that of the state with the least progress. In the case of DESI, the ratio remained at 1.7 times (considering that the DESI scale is smaller).

[10] For Ragnedda (2019), these variables would fall between the second and third phases of the digital divide.

[11] Also known as the GMM system estimator model (Arellano and Bover, 1995), which assumes that there is no autocorrelation in idiosyncratic errors and requires that panel-level effects are not correlated with the first difference of the first observation of the dependent variable. In practical terms, the *xtdpdsys* command was run in Stata with: *1)* the inclusion of the lagged dependent variable as a regressor; 2) the use of a lag as a covariate or instrument for the dependent variable, *lags(1) maxldep(1); 3)* the twostep instruction to account for the GMM system to limit the proliferation of instruments; and *4)* the inclusion of *artests(2)* to test for first-order and second-order serial autocorrelation in the errors in differences of the estimated model. Finally, *xtdpdsys* is an extension of the *xtabond* model specification.

[12] On the one hand, it led to a trend toward the widespread use of technology (in schools, at work, in new business models and occupations) and, on the other, economic pressure on households caused by the economic slowdown, rising inflation and reduced income.

[13] According to the literature (Roodman, 2009), validating whether or not instruments are overidentified in the dynamic model using the xtabond2 command in Stata is recommended. This command runs the Hansen test, which allows the overidentification restriction to be validated (a Chi2 p-value above 0.05 validates the use of the instruments).