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DIGITAL DEVELOPMENT IN MEXICO: A CAUSAL ANALYSIS OF TECHNOLOGY ADOPTION AND INNOVATION

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Abstract

The evolution of technology is redefining traditional management practices and encouraging innovation and digitalization worldwide. The aim of this research is to identify the necessary and sufficient conditions that lead a high digitalization level in Mexico. From the innovation perspective, this study explains and outlines the main theoretical foundations. Through the Qualitative Comparative Analysis (QCA) methodology, a sufficiency and necessity tests were conducted based on the data obtained from the Mexico Digital Center in 2024. The results suggest that companies in Mexico need to implement processes that enable technological adoption, apply cybersecurity more deeply, encourage the use of e-commerce, increase innovation, and develop a digital economy environment, as having the simultaneous presence of these factors enables a higher level of digital development. The results serve as a guide for decision makers to stablish business practices that facilitate the digitalization process in the current time.

Keywords: Innovation, High digitalization level, Companies in Mexico, QCA.

1. Introduction

The complex and sophisticated technologies are redefining traditional management practices and stimulating innovation in economies. Digital development is defined as the process of adopting, adapting, and applying advanced or digital technologies to improve productive, institutional, governmental, and social capacities (Federal Telecommunications Institute, 2021). These technologies are transversal in nature, affecting all sectors in a country (economic, social, political, and cultural), and if implemented correctly, they promote efficiency, productivity, and real-time access to a wide variety of services, making them a key driver of technical and socioeconomic progress (Arellano, 2020).

Economies use several indicators to measure competitiveness and economic growth. In fact, they also consider certain components to determine the degree of digital development, and link it to the capacity for adoption, adaptation and management of advanced technologies in productive structures (ECLAC, 2024). In the región of Latin America, Mexico is the country that leads the digitalization process, because the geographical and commercial proximity to the United States and Canada. Also, the efforts of federal government favor this leadership and should not be underestimated, since it has promoted the reconfiguration of various proceses and

practices such as manufacturing, distribution, marketing and consumption of goods and services (INESDI Business Techschool, 2023).

Starting from 2014, Mexican government has implemented projects to define the path to digitalization and, through special programs for science, technology, and innovation, it has created strategies that prioritize digital technologies for public and private businesses. These Initiatives are based on the experience of developed economies, which have demonstrated that efforts to improve digital infrastructure and advanced platforms guarantee greater efficiency in government and industrial operations. Since policies, regulations, and projects promoting digitalization were implemented in Mexico, digital development has brought several benefits in recent years. For example, Mexico's ICT sector has shown growth rates higher than the national economic average (5.7% compared to 2.3% between 1994 and 2018) (Morales, 2020). Also, dynamic industries such as telecommunications, software, and advanced manufacturing have been created and developed (Hernández, 2021; MIT Sloan Review México, 2022). In the market, business innovation and competitiveness have been facilitated, in order to support efficiency in the operation of processes and in the use of resources (Federal Telecommunications Institute, 2021). Additionally, conditions for foreign direct investment (FDI) and the modernization of strategic sectors, such as manufacturing and technological services, have improved (MIT Sloan Review México, 2022) and costs have been reduced in productive sectors, increasing efficiency and access to global markets.

It is important to emphasize that the effective use of technologies in the digital age is only possible if substantial changes are made within businesses, government structures, and social organizations. Together, these changes create new opportunities to reduce the economic backwardness and social inequality in developing economies like Mexico. In fact, these opportunities can also represent challenges or obstacles if its effective appropriation is not assumed as a national priority matter. Digital transformation must be followed by policies governing technological infrastructure and industrialization (ECLAC, 2024).

The current technological context demands the definition of the factors or indicators necessary to enable a high digitalization level in economies in order to provide key information and certainty to developing countries when proposing public policies, initiatives, roadmaps, and business projects aimed at raising industrial technological levels. Therefore, it is imperative to answer the following research question: What are the necessary and sufficient conditions for innovation and technological adoption that allow a high level of digital development in Mexico?

This paper is structured as follows. The second section contextualizes the digitalization process in Mexico and theoretically describes the concepts underlying the methodological analysis. The third section explains how the fsQCA methodology works and clarify the data collection process. The fourth section presents the results obtained through the suffiency and necessary analysis. Finally, the discussion and conclusions of this study are presented.

2. Literature review

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2.1 Digital development in Mexico

In 2014 the Mexican government, through federally led projects, has engaged the Federal Telecommunications Institute and other agencies to define the path to digitalization in the country. Special programs for science, technology, and innovation, and strategies have been created to support the development of digital technologies. These strategies allow local government and companies to make various analyses to understand the link between digitalization and patterns of production, consumption, communication, and interaction in modern societies (Arellano, 2020).

The Special Program for Science, Technology, and Innovation (SPSTI) remained in effect from 2014 to 2018. The last president administration of Mexico's maintained the "Internet for All" Priority Program, which emerged from the "Economy axis" included in the 2019-2024 National Development Plan (NDP). This program enabled the integration of the population into internet and mobile phone technology nationwide and aimed to ensure financial inclusion and the potential for increased e-commerce. Simultaneously, the Mexican government implemented the planning process for the Development of the National Digital Strategy and Technology Policy and established six initiatives to drive the country's digitalization process.

In October 2024, Dr. Claudia Sheinbaum was elected as the president of Mexico, and took the leadership of the National Development Plan (NDP) 2024-2030, which was published in April 2025. In her term in office, she is considering several policies, strategies, and actions related to digitalization and innovation in Mexico. In the document "Preliminary Project: 100 Steps to Transformation" (PPSF) (2024), it is exposed, by the current president's team, that one of her priorities is the creation of initiatives, projects, in digitalization matter, that will serve as the basis for the digital transformation process in Mexico. On the one hand, the proposal for a new General Law on Simplification and Digitalization must contain clear and simplified regulations on digitalization. On the other hand, the creation of a National Digitalization Agenda and the development of the Citizen Portal for Electronic Registration of Procedures and Services will streamline citizen processing. These actions demonstrate the current government's interest in continuing the National Digital Strategy derived from the NDP 2019-2024. In industrial terms, efforts are focused on improving digital infrastructure and platforms to ensure greater efficiency levels in business operations.

In this regard, the International Chamber of Commerce (ICC) created development and economic growth proposals for the Mexican government for the period 2024-2030. The document includes five themes, covering (ICCM, 2024): 1) inclusive green growth, 2) innovation for all, 3) peace and prosperity, 4) financing for development, and 5) trade and investment. In the "innovation for all" section, it makes several recommendations on topics such as digitalization, cyber security, artificial intelligence, and intellectual property. The results of his study focused on describing digitalization and cyber security, since Mexico is a crucial host of FDI in several strategic sectors, and these two aspects must be addressed.

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In the field of digitalization, the ICC highlights several proposals, such as the creation and publication of a digital agenda with clear, responsible strategies, budgets, and short, medium, and long term goals; the creation of conditions for achieving significant connectivity in the country; the promotion of digital skills development for teachers, trainers, and the economically active population; the promotion of the deployment of digital infrastructure, platforms, content, and services; the installation of Edge Data Centers (facilities that extend the "edge" of the Internet in the country) beyond existing traditional centers; the promotion of mechanisms for digital financial inclusion; and the use of digital tools in government to achieve more efficient processes, among other aspects of significant relevance to society (ICC, 2024). Regarding cyber security, the ICC's recommendations focus on protecting individuals and legal entities against cybernetics by strengthening risk prevention and management; establishing a specific national regulatory framework for cyber security and a national coordinating body; creating a budget for training, systems, and infrastructure to prevent and mitigate cyber security threats; protecting personal data through broader legislation than currently exists; and mitigating cyber fraud (ICC,2024). The aforementioned initiatives and proposals are aimed at promoting innovation through a National Digitalization Plan that improves connectivity in the country, reduces spectrum costs, and generates targeted incentives and subsidies for individuals, the government, and businesses.

To ensure that efforts are focused on strategic concepts, Mexico can utilize different tools of digitalization information and measurement, such as the Digital Development Index (IDDE, by its acronym in spanish), developed by the Centro México Digital (CMD), founded in 2020. To date, this center has provided valuable data for each entity in the country, as well as information on digitalization globally. The IDDE bases its digitalization index on three pillars: 1) Infrastructure, 2) Digitalization of people and society, and 3) Innovation and technological adoption in companies. Each pillar contains various indicators that help interpret and analyze Mexico's current situation in this area. A total of 12 subpillars construct the index.

The IDDE aims to understand the complexity of Mexico's digital transformation and turn it into a valuable tool for several purposes:

a) Evaluate the degree of digitalization of the states; b) Determine the challenges, strengths, and opportunities in the digital transformation process of the entities; c) Provide specific recommendations to help accelerate the digital transformation; and d) Identify and quantify the relationship between digitalization and the economic and social development of the states.

The coverage and implementation of the digitalization strategy of previous government is evident today in the figures presented by the CMD. For example, by 2024, the states showing the greatest digital development are Mexico City, Nuevo León, Baja California Sur, Querétaro, and Chihuahua, with an IDDE of 227, 210, 199, 198, and 189, respectively. Figure 1 shows the level of digital development in Mexico's states by color. The most intensely pigmented areas are those with the highest IDDE, while the least pigmented areas represent those with

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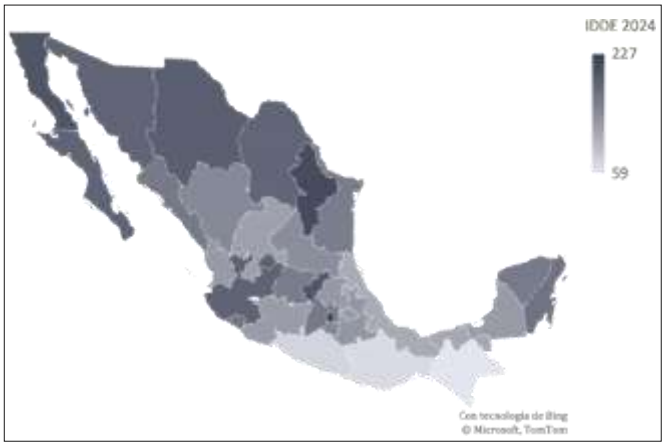
the lowest IDDE. The highest value for this index in 2024 was 227 for Mexico City, while the lowest value was 59 for Chiapas.

Figure 1. Digital development by entities in Mexico in 2024.



Source: Prepared by the authors based on data from the *CMD* (2024).

In Mexico, the analysis and study on the subject of digitalization is still limited, therefore this work aims to determine the causal influence of the indicators that correspond to the third pillar of the IDDE (Innovation and technological adoption in companies) on digital development. The results allow us to study the business economic dynamics regarding technological management in Mexico in the era of digitalization.

2.2 Innovation and technological adoption

Economic growth is a tool that measures the development and progress of countries. Innovation is a factor related to growth and contributes to social development, business progress, and the modernization of production methods. Nations are investing in research and development to improve their living conditions, as innovation enables them to address constant technological change, which has simultaneously created threats and opportunities for current government practices and projects, established business models of industries and companies, investment and financing methods, and the demand for skills in the labor market.

Products derived from an innovative process can be the answer to counteracting environmental damage, technological inequality, and the social challenges facing developing countries, with proposals and projects that embrace the concept of sustainability and integrate the implementation of technologies specific to the digital economy. This context can lead to a greater implementation of technologies, specific to the digital economy, and also can achieve greater resource preservation and more efficient management.

The application of digital technology must be accompanied by the preparation of the workforce in terms of sustainability, investment in research, the creation of new products, and investor access to stock markets, through the development of the public and private sectors and the improvement of people's living conditions. The

challenge is to know which technologies are most suitable for each country regarding its social, political, environmental, and economic conditions. Mexico is already working in various areas that the government and businesses community consider essential to continue the digital transformation: adoption of new technologies, the digital economy, ecommerce, innovation, and cyber security (CMD, 2024).

The innovation process and the products derived from it require of specialized talent, machinery, equipment, and financing. Furthermore, it should not be overlooked that the person or team that creates and directs the application of an innovation must analyze the implementation options to ensure that a sound decision is made and that the need it seeks to satisfy is met.

The implementation process for new technologies involves the way they will be introduced into the organization, the capacity of specialized personnel to operate said technology, the economic and time costs, and the possible modifications that must be made to the environment. Consequently, the technology adoption process impacts organizational aspects such as strategy, cultural practices, technological infrastructure, workforce, and social infrastructure (Navaridas et al., 2020; Pillai et al., 2020).

According to Duque and Díaz et al. (2024), in the digital environment, the technological adoption process focuses on how digital tools are not only implemented but also accepted and integrated into the organization's daily activities and routines. In this study, innovation and technology adoption are determined by three factors: personnel with basic technological tools, companies with technological tools, and internet use in companies.

2.3 Digital economy

ECLAC (2013) defined the digital economy as a facilitator of growth, innovation, structural change, and social inclusion in countries around the world. Its implementation requires specific and advanced technologies that create an enabling environment for recognizing, integrating, analyzing, and utilizing digital data. Data and information are the foundation of all advanced internet-based services (UN, 2021).

The digital economy requires, according to three components (ECLAC, 2013): a) the broadband network infrastructure, b) the information and communications technology (ICT) applications industry and c) the end users (individuals, companies and the government), who define the degree of absorption of digital applications through their demand for services.

In his study Rong (2022, p.20) defines the digital economy as "a range of economic activities that include the use of digitized information and knowledge as a key factor of production, modern information networks as an important space of activity and the effective use of information and communication technologies (ICT) as a driver of productivity growth and economic structural optimization". In this article the digital economy is defined by internet enabled firms, broadband-enabled firms, e-band firms and patent applications.

2.4 E-commerce

Digital transformation has forced companies to buy and sell goods and services in non-traditional ways. E-commerce is now a resource for companies to market products and services, helping them stay current and

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competitive in the market. E-commerce is an activity that involves the purchase and sale of products through technological means (García, 2016).

Digital platforms and the internet are e-commerce tools that streamline a company's sales process and expand the market for the goods and/or services it offers. Companies of all sizes already incorporate this practice, not only because it provides a faster way to reach distant markets, but also because it helps them control, analyze, and monitor their data more immediately and efficiently. This research considers e-commerce, including online purchases and sales, as critical activities that reinforce a company's supply and management processes.

2.5 Cyber security

The protection of critical assets such as processes, systems, intellectual property and confidential data has become an essential necessity for companies (Luján et al., 2024), since they increasingly depend on digital technologies to operate, manage and monitor their tasks and activities (Infante et al., 2024; Rodríguez et al., Zhao et al., 2024). Cyber security is defined as a collection of technologies and processes designed to protect computers, networks, programs, and data from malicious activity, attacks, damage, or unauthorized access (After good, 2017). Cyber security protects any computer systems of the organization from cyber-attacks; these attacks are typically intended to hack information for later disclosure (Quirumbay et al., 2022).

In the case of businesses, there is information that must be protected, otherwise business continuity could be disrupted, affecting profits. Cyber security is not only a business issue; it has also been included in matters of defense and national security. Governments create and implement detailed initiatives and actions that offer citizens certainty that their data is protected. Likewise, government agencies implement measures and systems that protect their processes and information from the rest of the world. This study measures cyber security based on the actions implemented by companies in this area the personnel dedicated to this activity.

2.6 Innovation in companies

Innovation is a means to meet the needs of society that arise over time. Innovation in companies is defined as the ability of organizations to transform ideas into tangible or intangible products of value. This must have a purpose related to improving conditions that boost the well-being of society. According to the Oslo Manual, innovation is "the introduction of a new or significantly improved product (good or service) or process, or the introduction of a new marketing or organizational method applied to business practices, work organization, or external relations" (Organization for Economic Cooperation and Development, 2018, p.49).

Innovation occurs when a previously planned change is introduced to achieve intended results (Delgado, 2022). The literature has generally proposed three different types of innovation: incremental innovation, radical innovation, and disruptive innovation (Machuca et al., 2023). This process has a transformative vision wherever it is applied; however, it must be remembered that changes also involve certain challenges. In the era of digitalization, governments face structural challenges, as they must pay special attention to ICT infrastructure, the skills of talent to develop and operate technology adoption process, and society's adaptability to use it.

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Innovation can be measured through various concepts and indicators, such as the number of new product launches, the number of patents, the incorporation of new capital goods, the use of new materials, the existence of R&D departments, the number of resources allocated to technological development, the training of talent, etc. (Lugones, n.d.). This research uses the number of patent applications, STEM graduates, and funding allocated to science, technology, and innovation organizations.

3. Methodology

3.1 FsQCA methodological approach

This study uses QCA as a methodological tool. This approach develops a causal analysis of a phenomenon studied in various fields of knowledge, including the social sciences (Rihoux et al., 2013). It also explains how a desired outcome is achieved based on different solutions, where multiple conditions (or variables) interact in a nonlinear manner (Calderón and Rodríguez, 2023). This tool is known as a comparative method based on the foundations of Boolean algebra and set theory (Ragin, 1987; 2000; 2006; Pappas and Woodside, 2021), which shows a high level of formalization and explanatory complexity (Berg-Schlosser, 2008). The use of QCA not only has theoretical implications but can also inform effective practices in management and strategic decision making (Medina et al., 2017).

QCA, manage three techniques or variants for data analysis and pro cessing: crisp set QCA, multi-value QCA, and fuzzy-set QCA (Ragin, 2000; 2008). These differ in the type of conditions they handle (dichotomous, multi-dichotomous, and fuzzy, respectively) (Ragin, 2008). This study uses the third variant, fuzzy-set QCA, which is distinct from the others because it offers a way of operationalizing data based on the idea of "degrees of membership", from the perspective of set theory.

3.2 Data collection

The data used for this study is information from the CMD, represented in the concepts used by the IDDE in 2023. The IDDE manages three main pillars: 1) Infrastructure, 2) Digitalization of people and

Table 1. Expected result and causal conditions.

Society, and 3) Innovation and technological adoption of companies. This research only used indicators corresponding to the third pillar, and compared them with the digital development index by each Mexican state, since it is of particular interest to analyze business dynamics regarding technological management in the era of digitalization.

The IDDE provides information based on all states in Mexico; however, this data is concentrated and broken down at the state level. Therefore, this study considers the companies included in the CMD in a consolidated manner individually. Table 1 shows the causal conditions selected for this study and the desired outcome, and also describes the indicators for each concept.

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3.3 Data calibration

Data calibration is an operation specific to the fuzzy-set QCA variant (Medina et al., 2017). At this stage, the researcher obtains the fuzzy values (values ranging from zero to one (0,1)) for each condition, also considering the desired outcome (Waggeman, 2012; Zeng et al., 2024). Calibration is not a mechanical operation; it requires the researcher's theoretical and substantive knowledge to define the position of the theoretical anchors. This way, the degree of belonging of each condition with respect to the desired outcome can be determined (Manzo, 2019). The data used to carry out the calibration are those produced by the third pillar (innovation and technological adoption) of the IDDE for the 32 federal states.

Once each condition is calibrated, the software returns fuzzy values. Values closer to one indicate a higher level of belonging, while values closer to zero indicate a lower level of belonging to the expected outcome. Table 2 presents the conditions and expected outcomes analyzed in this research, along with their fuzzy values.

Table 2. Calibrated values of the expected outcome and causal conditions.

Expected result

Description

High digitalization level (HDL)

Level of digital transformation

Selected conditions

Adoption of new technologies (ANT)

Staff with innovative technological tools in companies

Cyber security (CS) Cyber security actions in companies

IT and cyber security specialist

Electronic Commerce (EC)

Online purchases and sales

Digital Economy (ED)

Companies with internet

Companies with electronic band

Companies with broad band

Innovation (INN)

Patent applications

STEM graduates

Budget for science, technology and innovation institutions

Level of digitalization	**Adoption of new technologies**	**Cibersecurity**	**Electronic commerce**	**Digital economy**	**Innovation**
0.51	0.32	0.15	0.63	0.62	0.54

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0.56	0.42	0.47	0.65	0.67	0.45
0.76	0.75	0.84	0.77	0.84	0.41
0.38	0.29	0.84	0.3	0.45	0.26
0.2	0.38	0.53	0.13	0.14	0.14
0.63	0.66	0.47	0.56	0.63	0.76
0.6	0.48	0.47	0.53	0.63	0.77
0.45	0.41	0.15	0.6	0.62	0.23
0.7	0.37	0.47	0.38	0.87	0.88
0.44	0.56	0.84	0.31	0.37	0.39
0.56	0.88	0.84	0.27	0.34	0.67
0.14	0.11	0.15	0.14	0.13	0.23
0.38	0.38	0.53	0.19	0.3	0.71
0.53	0.5	0.84	0.42	0.48	0.6
0.25	0.32	0.15	0.17	0.25	0.32
0.41	0.79	0.84	0.18	0.21	0.47
0.44	0.66	0.84	0.2	0.32	0.53
0.35	0.54	0.53	0.35	0.29	0.24
0.87	0.87	0.84	0.87	0.87	0.83
0.17	0.24	0.47	0.12	0.12	0.19
0.32	0.32	0.47	0.26	0.22	0.62
0.8	0.87	0.84	0.82	0.73	0.79
0.6	0.44	0.84	0.78	0.79	0.11
0.44	0.54	0.47	0.37	0.32	0.59
0.45	0.32	0.15	0.41	0.57	0.53
0.67	0.75	0.84	0.62	0.7	0.44
0.38	0.56	0.84	0.17	0.29	0.47
0.48	0.6	0.47	0.38	0.51	0.41
0.25	0.32	0.47	0.15	0.22	0.31
0.35	0.48	0.84	0.23	0.27	0.32
0.45	0.54	0.84	0.41	0.37	0.37
0.35	0.32	0.15	0.5	0.3	0.44

Source: Prepared by the authors.

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3.4 Hypotheses and explanatory conditions

This study makes use of the QCA methodology to determine the necessary and sufficient conditions for innovation and technological adoption that enable a high level of digitalization in Mexico. The research hypothesis that seeks to answer the previously established research question is presented below.

H1: The simultaneous adoption of new technologies, cyber security, e-commerce, the digital economy, and innovation is necessary and sufficient to achieve a high digitalization level in companies established in Mexico.

The model representation of the hypothesis to be tested in terms of the QCA methodology is as follows:

ANT*CS*CE*ED*INN→HD

To test the proposed hypothesis, the QCA method's necessity and sufficiency analyses are performed. These help to determine the presence and absence of these conditions in the different configurations that lead to the expected result. Before presenting the results, it is important to point out the difference between a sufficient condition and a necessary condition.

In the context of QCA and based on set theory, the sufficient condition can be explained as follows (Ragin, 2000). In a universe where this condition exists, the expected outcome will also be present. This means that the presence of the sufficient condition automatically implies the presence of the outcome, but not vice versa. This suggests that there could be not just one but several sufficient conditions that can simultaneously explain the expected outcome. In contrast, the presence of a necessary condition is found in all selected cases (observations), and these cases also contain the expected outcome. Therefore, the presence of a necessary condition implies the presence of the outcome, and vice versa.

4. Results

4.1 Necessity analysis

The development of the specialized market in Mexico requires certain conditions for growth and consolidation within any industrial sector. Currently, the CMD (2024) indicates that the conditions that favor the digital development of companies are the adoption of new technologies, cyber security, e-commerce, the digital economy, and innovation. In Mexican entities that belong to areas where industrial conglomerates are strengthening, these conditions must be present to remain competitive.

Table 3 shows the consistency and coverage values for the conditions chosen for the analysis. According to QCA, the consistency threshold for a condition to be considered almost always necessary is 0.8 (Ragin, 2008), so values above this threshold indicate a strong fit with the expected outcome. The results in Table 3 show that the condition with the highest value is the adoption of new technologies (0.912576), while the condition with the lowest value is e commerce (0.817081).

Table 3. Necessary conditions for the development of digitalization of companies in Mexico.

Tested condition	Consistency value	Coverage value
Adoption of new technologies	0.912576	0.848655

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Cibersecurity	0.871554	0.701299
Electronic commerce	0.817081	0.944056
Digital economy	0.896436	0.92313
Innovation	0.867518	0.858855

Source: Prepared by the authors.

4.2 Sufficiency analysis

The QCA sufficiency analysis determines several aspects of each solution (complex, parsimonious, and intermediate). First, it identifies the different configurations of the chosen conditions that can lead to the desired outcome (Ragin, 2008). Second, it shows the presence and absence of these conditions in each configuration. Third, it identifies the most suitable condition for achieving the outcome.

The complex solution does not consider any logical reminders and it produces the most complex result. This solution shows all possible configurations even if there are no empirical cases within that configuration; therefore, it plays a minor role when it comes to interpreting the results. The complex solution in this research shows seven alternatives to obtain the desired outcome. The most suitable configurations, according to Table 4, are the fifth and seventh, since the consistency value reaches 1.00. The fifth configuration represents the simultaneous presence of ANT, EC, DE, and INN, and the other configuration establishes the simultaneous presence of ANT, CS, EC and DE.

Configurations of conditions	**Raw coverage**	**Unique coverage**	**Consistency**
CS*~EC*~DE	0.64425	0.0242099	0.743789
~EC*~DE*INN	0.662408	0.00336248	0.872454
~ANT*EC*DE*~INN	0.568931	0.00874251	0.983721
~ANT*~CS*DE*INN	0.521856	0.0181573	0.986023
ANT*EC*DE*INN	0.669805	0.0921318	1
ANT*~CS*~EC*DE*~INN	0.466039	0.00067246	0.99569
ANT*CS*EC*DE	0.686617	0.0356423	1
Coverage solution:			
0.963685			
Consistency solution			
0.770845			

Table 4. Complex solution

Source: Prepared by the authors.

To interpret the results obtained by QCA, researchers focus on both parsimonious and intermediate solutions, since analyzing both solutions can help detect central and peripheral causal conditions (Fiss, 2011).

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The parsimonious solution considers any logical reminder that will help generate a logically simpler solution (this produces the most concise or simple result). Table 5 shows three alternatives to obtain the expected result with the presence of only one condition in each configuration. The most pertinent and viable path according to the parsimonious solution is the second, where the DE is present, since the coverage value obtained is 0.896436 and the consistency value is 0.92313, both higher than those displayed for the other two alternatives. This configuration only presents the DE as a sufficient condition to achieve a high digitalization level, and although it is the simplest solution, it can be applied to micro or small companies that are just venturing into digitalization, but not to those with a longer track record in the market or that are large leaders with a greater market share.

Table 5. Parsimonious solution.

Configurations of conditions	Raw coverage	Unique coverage	Consistency
CS	0.871554	0.0195023	0.701299
DE	0.896436	0.0235372	0.92313
INN	0.867518	0.00336248	0.858855
Coverage solution: 1			
Consistency: 0.672851			

Source: Prepared by the authors.

Finally, the intermediate solution, which is the most suitable in the process of interpreting the results because it considers the presence of logical reminders (patterns of combinations of conditions not observed empirically despite the fact that they are observed theoretically) (Rihoux and Ragin, 2009; Schneider and Wagemann, 2010), shows seven configurations to achieve the expected result. The most suitable configuration is the fifth because it shows the highest coverage value and the consistency value is equal to 1.00. This configuration represents the simultaneous presence of four conditions: ANT, EC, DE, and INN. This implies that it is sufficient for a company, of any size, to include strategies in these four areas so that it can achieve a higher digitalization level in the short or medium term and better position itself compared to its competition.

Table 6. Intermediate solution.

Configurations of conditions	Raw coverage	Unique coverage	Consistency
CS*~EC*~DE	0.64425	0.0242099	0.743789
~EC*~DE*INN	0.662408	0.00336248	0.872454
~ANT*EC*DE*~INN	0.568931	0.00874251	0.983721
~ANT*~CS*DE*INN	0.521856	0.0181573	0.986023
ANT*CE*DE*INN	0.669805	0.0921318	1
ANT*~CS*~EC*DE*~INN	0.466039	0.00067246	0.99569
CS*EC*DE*~INN	0.558171	0.0228649	0.978774

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Coverage solution: 0.950908

Consistency solution: 0.761033

Source: Prepared by the authors.

4.3 Consistency and coverage parameters

In the previous results, both in the sufficiency analysis and in the necessity analysis, the presence of the consistency and coverage parameters is mentioned, which help to understand the given solutions and serve to evaluate the empirical importance of the solutions (Ragin, 2000, 2008). Consistency measures the degree to which the solution terms and the solution as a whole are subsets of the outcome. Coverage indicates the proportion of cases that follow a given path to obtain the outcome in question (Fiss, 2011; Ragin, 2000, 2008). The raw and unique coverage scores for different solutions serve to assess the extent to which a solution explains the outcome.

5. Discussion

In the field of science policy and innovation the national innovation systems (NIS) is a basic framework for analyzing innovation processes and designing systematic policies (Cho and Park, 2022). NIS is the perspective that explains the complex process of innovation where various actors and factors convey to highlight the interdependency and interactions they compose. Also, describe the dynamic network of institutions, organizations, policies, and resources that create a conducive environment for better innovative performance through ideas, information, funds, facilities, resources, and shared benefits (Weerasinghe et al., 2024). In the case of Mexico, the Government faces the challenge of transforming the country into a digitally advanced globally competitive nation, and the strategies that bring it closer to a more advanced technological level are based on the national policies, governmental institutions, and organization's resources.

The findings in this study derived from QCA methodology, convey with NIS perspective as it replace linear thinking about innovation by a more holistic perspective. QCA stands out for being a methodology that explains how a desired outcome is achieved based on different solutions, where multiple conditions interact in a nonlinear manner (Calderón and Rodríguez, 2023). Also NIS provided a valuable framework for manage and promote innovation efforts across individuals, groups, and organizations within a nation (Weerasinghe et al., 2024). The results suggest that Mexico underpin innovation through diferent intiatives covering the area of digital transformation, supported by government plans and programs implemented over the past two six-year terms, such as the Special Program for Science, Technology, and Innovation 2014-2018, the Internet for All Program 2019-2024, and the National Digital Strategy and Technology Policy, both during the same period. The government is currently working on the "Preliminary Project: 100 Steps to Transformation", the base document for the 2024-2030 NDP. The priorities for digitalization are the creation of initiatives, projects, and laws that motivate the national digital strategy.

The NIS perspective explains the formulation of national-level system configurations that nurture, develop, and apply innovation for societal progress (Ndicu et al., 2024). This systematic configuration (inputs, actors, and

functions) emphasizes the importance of wellconnected relationships to reach effective outcomes. This study exposes how Goverment policies play an important role on guidelines guidelines that drive digital transformation, organizations such as the CMD collect, analyze, and publish highly relevant information and data on this matter. The IDDE, developed by the CMD, is an index based on three pillars: 1) Infrastructure, 2) Digitalization of people and society, and 3) Innovation and technological adoption in companies. These pillars help to interpret and to analyze the current situation in Mexico by entity, but additional studies are also required to provide more specific results. Based on the analysis of several indicators that comprise the third pillar, this paper develops a comparative qualitative study that identifies the necessary and sufficient conditions for innovation and technological adoption that enable a high digitalization level in Mexico.

Identifying which indicators are necessary and sufficient for Mexi co to achieve a high digitalization level provides certainty when proposing public policies and business initiatives aimed at raising the country's industrial technological level. To achieve this goal, the fuzzy set QCA methodology was implemented, which explains the causality of different conditions in an expected outcome. A necesity sufficiency analyses were conducted to determine which conditions constitute the foundation for achieving digitalization and which are essential for Mexico. Therefore, the fulfillment of the hypothesis is explained through the sufficiency and necessity tests, and the implications of this study are described throug the necessity test.

The necessity analysis expose consistency values greater than 0.70, which, according to the methodology, is the threshold for considering a necessary condition. This result suggests that Mexico develop strategies that strengthen the level of digitalization though processes that enable technological adoption in companies, the application of CS, the use of EC, and the development of the DE and INN. The NIS perspective must consider now digitalization to explain innovation in developing economies through the incoporation of the four conditions mentioned. Digitalization is now driving innovations.

Businesses must evaluate their policies and processes to ensure that the aforementioned conditions are met, and if not, modify them to increase their digitalization rate and improve their competitiveness. In fact, they must recognize the need to incorporate advanced technology and raise awareness and train their employees on this subject, as otherwise, their competitiveness will be limited and their value chain management will be more restricted. This implies an impact on the number and types of contracts they can secure with clients and suppliers who are at a higher level of digitalization.

For its part, the sufficiency analysis, based on the intermediate solution, shows that the simultaneous adoption of new technologies, e-commerce, the digital economy, and innovation is sufficient to raise the digitalization level; however, the result leaves out cyber security. This fact should not be completely interpreted as reality, since even if a company manages to increase its digitalization through the use of advanced digital technologies, it cannot ignore the backup, custody, and encryption of its data, as these are now considered critical resources in the

industrial sphere. Any type of information, considered critical, that generates a competitive advantage for companies is valuable and therefore must be protected.

The relationship between telecommunications infrastructure, advanced technologies, cyber security, and the specialized skills of professionals in managing advanced technologies is considered a relevant topic in the business disciplined, as they are among the drivers of Mexico's digitalization. Together, they can develop sustainable practices that improve the quality of life of the country's inhabitants.

6. Conclusions

Digital development raises crucial questions about the incorporation of new government policies, the behavior of companies, and the new processes that workers must perform to face the changes that digitalization causes in the industrial and economic dynamics of nations. According to the results of the fsQCA methodology used in this research, it is suggested that companies in Mexico implement technological adoption processes, apply cyber security more deeply, encourage the use of e-commerce, increase innovation, and develop a digital economy environment, as the presence of these factors is necessary for a high level of digital development.

The findings are a guide for companies to establish practices that facilitate the process of digitalization in the current era, as it is not enough for decision-makers to have the will to adopt new forms of operation that allow for an interconnected digital business environment. Rather, it is about considering specif conditions according to the profile of each economy that allow an efficient technological transition process, with the aim of improving the performance and competitiveness of companies. For Mexico, ANT, EC, DE, and INN are sufficient conditions that, when present simultaneously, allow a higher digitalization level. New theoretical perspectives as NIS mus consider these conditions in the recent innovation models. The adoption process to a digital environment defines the technological gap of each economy and only a few will obtain more advantages. A suggestion for Mexican firms is based on the creation and implementation of policies and projects directed to achieve a key change using as a reference the conditions presented in this study.

A limitation of this study is that only indicators from the third pillar of the IDDE (innovation and technological adoption in companies) were considered for the analysis of sufficiency and need presented. Future studies recommend a more generalized analysis of the digitalization level of the economy, and to achieve this, data from the first two pillars of the IDDE can be used. Another alternative is to develop three different models for each pillar and compare them to obtain results for each pillar, considering the 32 federal states. This latter option offers governments and business leaders in each state the opportunity to analyze their individual digitalization strategies.

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