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DIGITAL DEVELOPMENT AND COMPETITIVENESS INDEX AMONG SMALL PROTECTED AGRICULTURAL PRODUCERS. CORRELATION ANALYSIS

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ABSTRACT

The Covid-19 pandemic exacerbated the deep digital divide that exists between rural and urban areas in Mexico and the competitive impact of the use of Information and Communications Technology (ICT) on small Production Units (PU) of Protected Agriculture (PA) in Mexico. Thus in this research, we intended to determine the correlation between the State Digital Development Index (SDDI) and the competitiveness of 12 PUs from 7 states of the Mexican Republic, during 2021. For this, it was necessary to investigate DDI and determine levels of competitiveness in agricultural PUs, according to the UAQui scale, in order to demonstrate correlation between these values. This mostly revealed a directly proportional relationship, indicating the need to address the development of internet infrastructure, as well as the acquisition of technology, to enable these producers to connect with other links in the agri-food value chain, so as to systematize the administration of PUs, support their decision-making, and instigate an increase in production and thus of the PA of PUs.

Keywords: acceptance of technology, competitive advantage, management of technology, use of ICT.

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INTRODUCTION

The Covid-19 pandemic, which began in 2020, highlighted the digital divide in emerging economies, especially in rural areas, where internet service is of poor quality or in many cases, does not exist. Colom (2020) defined the term "Digital Divide" as "a division between the population that accesses and uses digital media and those who do not"; this includes digital media such as devices (personal computers, laptops, smartphones, digitalized analog media, video games, etc.), connections (internet, mobile telephony, digital broadcasting) or applications (email, search engines, e-commerce, electronic banking and also social networking sites).

In this context, various investigations that focus on the use of ICT in rural areas and among agricultural producers exist, such as the work of Chaves (2016), who surveyed Colombian coffee growers, finding that 85% lacked an internet connection and 65% were unaware of the existence of mobile applications with which they could manage their PUs, whereas Mancera and Sánchez (2022) found that in Colombia there are 11 million people living in rural areas, of whom only 26% have access to the internet, even though the government of that country has allocated resources for the development of digital centers that are accessible to the Colombian population. Similar statistics were found in Mexico, where Jiménez *et al*. (2016) conducted research in two municipalities in the State of Guerrero to discover that only 3% of the information consulted by livestock producers was by using ICT, despite the fact that throughout the country, several web portals and mobile applications exist, designed especially for agricultural and livestock producers (Rodríguez *et al*., 2018).

The COVID-19 pandemic forced several sectors of society into confinement, imposing the use of digital communication, which accelerated technological penetration in Latin America (Moreira and Villao, 2023). During this time in Mexico, the digital divide between urban and rural populations was very evident, mainly due to differences in the connectivity infrastructure in various federal entities, which can be corroborated by consulting the State Digital Development Index (SDDI) that documents digital development in Mexican federal entities (Mexico Digital Center, 2021). This index is specifically based on three fundamental indicators: 1) Infrastructure: covers the connectivity network, coverage, access, affordability, and quality, 2) Digitalization of people and society: which shows the capabilities and digital skills of users and includes the digitalization of priority services, digital government, and the laws that regulate it, and 3) Innovation and technological adoption in companies: reflects the levels at which companies implement their technological adoption process, cyber-security, use of electronic commerce, digital economy, in addition to the development of technological innovation (Centro México Digital, 2021).

According to Amador *et al*. (2022), during 2021, most urban areas in the country maintained communication and were able to carry out most of their activities, unlike rural areas where, due to the lack of internet infrastructure, communication was difficult. When comparing Mexico City (CDMX) with other states, in 2021, the DDI rated CDMX with the highest index, obtaining 216.88 points, a figure well above the national average, which stood at 147.38 points (Centro México Digital, 2021). For its part, regarding poverty, the National Council for the Evolution of Social Development Policy (CONEVAL, 2020) found that the same entity had presented a poverty rate of 26.6%, compared to the State of Chiapas, which was the entity in the last position in terms of DDI, reaching an index of 77.9 points (Centro México Digital, 2021), in addition to manifesting a poverty level (CONEVAL, 2020) of 75.5%, showing a clear correlation between these two indices.

Expressed differently, the importance of addressing the need for Mexican PUs to improve their levels of Competitiveness concerns 4 main aspects:

1) The Food and Agriculture Organization of the United Nations (FAO) estimates that by 2050, the world's population will reach 9.1 billion people, equivalent to a 34% increase of the current population, and 70% of the population is expected to live in urban areas compared to the current 49% (FAO, 2022). This demonstrates the need to increase efforts to produce more food and for this process to optimize the use of natural resources, in order to reduce the negative impacts of climate change. According to the National Council of Sciences and Technologies (CONACYT, 2018), Mexico is in a critical situation regarding the use of its water resources due to overexploitation, contamination and misuse of water sources, with agricultural activity using 84% of this resource in the State of Guanajuato alone.
2) In Mexico, agricultural PUs are classified according to the size of their surface area (Rodríguez, 2020), into: a) Small: those with an area of up to 5 ha, b) Medium: with an area greater than 5 ha going up to 20 ha and c) Large: with an area exceeding 20 ha. Furthermore, 71.8% of the PUs in the country are small, according to the National Institute of Statistics and Geography (INEGI, 2023), which is equivalent to 5'005,770 UPs, representing an enormous challenge for the federal government and its goal of achieving food sovereignty, as according to the World Food Program (WFP), the majority of people living in poverty are small producers (FAO and WFP, 2023). Similarly, concerning the payment of salaries, until 2022, the population employed in agricultural work was 11'120,516 people (INEGI, 2023), integrated as follows: 29.98%, as producers who work in their PU, 53.84%, family members who receive no salary, 4.15%, family members who did receive a salary and 12.02%, contracted workers (INEGI, 2023). The situation of small PUs worsens in the face of competition, as trade agreements between Mexico and other countries force them to lower their prices and decrease their profits (Bojórquez *et al.*, 2020), meaning they are forced to sell to intermediaries who keep most of the profit (Rodríguez, 2020), as demonstrated by INEGI (2019), with its National Agricultural Survey, showing that 53.1% of PUs sell their products to intermediaries. For their part, Infante *et al*. (2020) state that production in the Mexican agricultural sector presents problems of stagnation, declining competitiveness, fewer jobs, unfair competition, among other aspects, which highlight the importance of seeking technological strategies, so that small PUs can increase their food production and expand their market, with consequent growth and consolidation of the PU.
3) Regarding the issue of the Digital Divide, the Mexican Digital Center (2021) reported that there was a gap of 56.3 points between Mexico City and

Chiapas, in terms of digital infrastructure and 63 points for the indicator of digitalization of people and society, and that although, government policies include programs to help the countryside and reduce poverty (Rodríguez, 2020), in reality, Ceballos and Nopal (2021) found that small maize producers in the State of Hidalgo perceive this to be misleading, as delivery is conditioned according to the political party to which the producer belongs. This means that the Federal Government's goals of achieving food sovereignty in the country are not met, even though the United Nations (UN) found that in the world, approximately 2,330 million people suffered moderate or severe food insecurity during the year 2023 (UN, 2024).

4) Regarding exports, these are mostly carried out by large PUs, mainly to the United States and Canada. The Ministry of Agriculture and Rural Development (SADER, 2024) states that, in 2023, the value of these exports reached 51,874 million dollars, representing an increase of 3.9% compared to 2022. For their part, most small producers, find the idea of exporting unattractive, mainly due to issues related to the need to comply with export requirements, coupled with their low production capacity and lack of contacts with intermediaries for example, to help them establish their products in international markets.

The problem of the digital divide during the Covid-19 pandemic extended to all productive activities, particularly among small agricultural producers, as was the case of small horticultural and berry producers in the Maule region in Talca, Chile, where 94 small producers, out of a total of 123, have no access to the Internet and consider that the Covid-19 pandemic affected their marketing activity. Likewise, 45% of these producers agreed that the pandemic caused the digital divide to widen (Sepúlveda, 2022). The Internet facilitates access to countless websites and mobile applications to contact the different links in the agri-food value chain, as well as to consult information on markets and climate, among others (Rodríguez *et al*., 2018), helping producers to improve decision-making. The digital divide should therefore be treated as an important issue in order to analyze levels of competitiveness in this sector.

In this regard, the present research applied the UAQui scale (Rodríguez, 2020) to determine the levels of Competitiveness in the PU being studied and these results were correlated with the levels of digital divide presented by the DDI of the federal entities to which the 12 producers surveyed belonged.

Based on the above, the following research question arose: will bridging the digital divide in small protected agriculture PUs improve the level of Competitiveness of Protected Agriculture (PA)? Consequently, the purpose of this work was to determine the correlation between the ICT Development

Index for Mexico and the levels of Competitiveness in the PA of Pus, arriving at the following hypothesis: a lower DDI in the federal entities results in low levels of competitiveness in small PA of PUs. In this regard, Colom (2020) states that, according to the United Nations Organization (UN), the International Telecommunication Union (ITU) and the World Bank (WB), the digital divide functions as a socioeconomic indicator of growth and development. Thus, the digital divide corresponds to a political and economic problem and affects international competitiveness.

THEORETICAL FRAMEWORK

The term competitiveness has been evolving since 1985, when Michael Porter stated that each company has competitive strategies that may be either evident or tacit, but which should be oriented towards the target market (Benítez, 2012). Porter also studied the factors of competitive success and discovered that the most successful countries obtained their competitive advantage mainly because rivalry between companies forces them to continually innovate to improve their products (Rodríguez, 2020). For his part, Galván (2022) defines agri-food competitiveness as "the ability to create, produce and distribute products or services... maintaining increasing profits..., defending their own market against excessive import penetration" and emphasizes that to achieve this competitiveness, trigger factors must be taken into account, such as public spending, the adoption of technology and innovation, as well as international trade, which prioritizes sustainable agriculture, safeguards natural resources, reduces costs and supplies food needs.

Competitiveness as discussed up to this point focuses on the comparison between countries, but what happens when the producer is concerned about knowing whether he is competitive and at what level? For this purpose, Rodríguez (2020) devised the UAQui metric, which measures the competitiveness for the PA of PUs, where he distinguishes 4 main indicators; together these determine the level of competitiveness and consist of: profitability, yield, hectares cultivated and technology used in production; these together determine levels of competitiveness, ranging from 0 to 4, where 0 indicates that the PA of a PU is not profitable, while a PU of level 4 indicates robust competitiveness, with participation in international markets.

To calculate the profitability factor of the PU, in addition to calculating the Cost Benefit Ratio (C/BR) of production in a cycle, a comparison is made with information related to the production costs of a state Base Product System, provided by the Trusts Instituted in Relation to Agriculture (FIRA, 2021). The Product System, according to the Sustainable Rural Development Law, published in 2001 by the Chamber of Deputies (2024), is defined as "the set of concurrent elements and agents of the productive processes of agricultural products, including the supply of technical equipment, productive inputs, financial resources, primary production, collection, transformation, distribution and marketing", which are reflected in the profits or losses in a productive cycle, and depending on the crop in question, may be Spring-Summer, Autumn-Winter or in the case of Perennial crops, which are those with longer cycles, reaching up to 25 years (Secretaría de Desarrollo Agroalimentario y Rural (Secretary for Agricultural and Rural development)-SDAyR, 2020).

Regarding the digital divide, Dalio *et al* (2023) state that digital connectivity has become a right that enables people to access work, health, education, and public services; as well as establishing digital transformation as the route to development. The same authors add that the connectivity gap is not the only barrier in the case of the Latin American population, as 240 million Latin Americans lack internet service; equivalent to 38% of the Latin American population. The digital gap between populations also increases due to lack of digital skills, or literacy (Dalio *et al*., 2023).

The benefits of reducing the digital divide in the agricultural sector are clearly reflected in the production models of those who apply "Big Data" technology in the collection, storage, management, transfer and analysis of large quantities of data, to determine irrigation needs, predict environmental changes and thus, be able to improve yields, while reducing operating and energy costs (Sotomayor *et al*., 2021). However, in addition to existing technology, Sotomayor *et al*. (2021) consider the existence of advantages among some producers, in the form of digital enablement, in contrast to the impediments related to connectivity restrictions for other producers, broadening the digital divide between them.

METHODOLOGY

This research was quantitative and cross-sectional, with correlational scope and the sample was determined to be non-probabilistic, as most producers refused to participate in this study due to the insecurity that prevails in various parts of the country, resulting in only 12 small producers agreeing to answer the survey, on the condition that they remained anonymous and that the figures provided were only estimates. For this, 12 small PA of PUs were studied (specifically those that used greenhouse technology), with an area of less than 5 ha, from the federal entities of Coahuila, Queretaro, Guanajuato, Zacatecas, Michoacán, Oaxaca and Puebla, from which information was obtained about the production of red tomato, to calculate their level of competitiveness, for the spring-summer and fall-winter seasons of the year 2021. Besides this, the 2021 State Digital Development Index (SDDI) was consulted, where the Mexican

Digital Center (2021) presented the digital development indices and grouped the states according to four digital development groups:

- Leader: Entities with an SDDI greater than 183 points.
- Advanced: Entities with an SDDI greater than 147 points and less than or equal to 183 points.
- Entrepreneur: Entities with an SDDI greater than 111 points and less than or equal to 147 points.
- Basic: Entities with an SDDI less than or equal to 111 points.

We used SDDI (2021) to determine its correlation with respect to levels of Competitiveness in the small Pus, applying a survey that requested the following data: Name and address of the PU, tons harvested, hectares cultivated, yield (t/ha), price per ton, amount invested, as well as the technology used for production: type of greenhouse, type of soil, type of irrigation, type of inputs, use of fertilizers and PH, in addition to existence of appropriate drainage in relation to substrates, automatized climate and recycled water. In the following, we explain the UAQui methodology that was used to calculate the levels of Competitiveness in the Pus investigated, located in the federal entities of Coahuila, Queretaro, Guanajuato, Zacatecas, Michoacan, Oaxaca and Puebla, Information was obtained about red tomato production, to calculate their level of Competitiveness in the spring-summer and fall-winter seasons of the year 2021:

1. As a first step, the cost-benefit ratio (C/B R) of each PU was calculated, during the spring-summer and autumn-winter cycles of 2021 and the total income ($ sales) was divided by the total expenses ($ purchases), to determine the profitability of the PU, for that cycle.
2. The banking profit that the producer would have obtained if he or she decided not to sow was calculated, as the UAQui scale establishes that if the banking profit would exceed the net profit obtained from the harvest, the level of Competitiveness for the PU is automatically 0. Calculations were made based on information provided by Banorte (2023), indicating that the fund with the highest short term return for an investment of $1’000,000.00 during 2021 was the Banorte 40 Fund, with a return of 22.3%; this was used to determine the banking profit that each PU would have obtained, if it had decided not to produce in 2021.
3. Subsequently, the levels of Competitiveness in the surveyed PAs of PUs were determined by calculating the Competitiveness coefficient (cCo) for each PU, according to the UAQui scale:

$$cCo = \Pr C + cr + ch + tc \quad (1)$$

where *PrC* is the profitability coefficient that was calculated, applying the following equation (2):

$$\Pr C = \frac{\text{Net profit from the PU}}{\text{Utilities from the Base Product System}} \quad (2)$$

cp represents the coefficient of performance and was calculated with the following equation (3):

$$cr = \frac{\text{Actual performance (ha)}}{\text{Expected Performance (ha)}} \quad (3)$$

ch is the coefficient of hectares that was considered according to the following equation (4):

$$ch = \frac{\text{Number of hectares available (ha)}}{\text{Number of hectares cultivated (ha)}} \quad (4)$$

tc corresponds to the Technology coefficient obtained with the equation

$$tc = \frac{\text{Technology used in production}}{8} \quad (5)$$

The technology used in production, to calculate the technology coefficient (*tc*), according to the UAQui scale, is classified according to 8 technological characteristics that the PA PUs used during the cycle in question, which are: form of protection, cultivation area, irrigation, fertilizer and PH control, adequate drainage for the substrates, whether it uses automatic climate, if it has a system to recycle water, as well as the type of inputs that were applied to production (Table 1). This first classification is subclassified according to type of technology and has assigned values ranging from 0 to 1, depending on degree of sophistication. Thus, the maximum value for each technology is 1, so the maximum total will be 8.

Finally, the UAQui scale indicates that the result from the competitiveness coefficients indicates levels of competitiveness, as follows:

1) If the competitiveness coefficient is less than 1, the PU is not profitable.
2) If the competitiveness coefficient is equal to or greater than 1, but less than 2, the PU is considered profitable, but not competitive.
3) If the competitiveness coefficient is greater than or equal to 3, but less than 4,

Table 1. Technology used to calculate the technology coefficient.

Technology	Type	Value	Maximum value
Protection	Tunnels	0.25	1
	Shade netting	0.5	
	Greenhouses less than 5.5 m.	0.75	
	Tall greenhouses (5.5 a 6.5 m)	1	
Type of cultivated area	Soil	0.5	1
	Hidroponics	1	
Irrigation	Manual	0	1
	Semiautomatic	0.5	
	Automatic	1	
Control of fertilizers and PH	No	0	1
	Yes	1	
Adequate drainage for substrates	No	0	1
	Yes	1	
Automatic climate	No	0	1
	Yes	1	
Recycled water system	No	0	1
	Yes	1	
Inputs	Chemicals	0.5	1
	Organic materials	1	
Maximum total:			8

Source: self-elaborated, based on Rodríguez (2020).

the PU shows a competitiveness that reacts to changes in local and national markets.

4) If the competitiveness coefficient is greater than 4, the PU demonstrates robust competitiveness, with market participation.

Subsequently, the State Digital Development Indices were consulted, according to the indicators presented by Centro México Digital (2021) of the states to which the PUs being analyzed belonged (Table 2), to calculate the Pearson correlation, with respect to the levels of Competitiveness obtained.

RESULTS

According to UAQui methodology, and according to total income with respect to total expenses and results, these indicate that the C/BR of the PUs was greater than one (Table 3); it was found that PU 11 obtained a C/BR close to one, while PU 5 presents the highest C/BR, which in the first instance, might indicate that the spring-summer and autumn-winter cycles of the year 2021 were profitable for the PUs in the survey.

Subsequently, profit obtained from the sale of their product was compared with bank profit, revealing the bank profits that each PU would have received,

Table 2. Digital Development Index in the federal entities.

Entity	SDDI	Classification	Entity	SDDI	Classification
Mexico City	216.9	Leader	Tamaulipas	149.7	Avanzado
Queretaro	195.9	Leader	Campeche	149.1	Avanzado
Nuevo Leon	195.4	Leader	Morelos	146.9	Entrepreneur
Baja California Sur	184.1	Leader	Durango	135.1	Entrepreneur
Baja California	182.9	Advanced	San Luis Potosí	133.1	Entrepreneur
Colima	179.5	Advanced	Nayarit	132.2	Entrepreneur
Chihuahua	177.6	Advanced	Hidalgo	130.4	Entrepreneur
Aguascalientes	175.5	Advanced	Zacatecas	128.9	Entrepreneur
Jalisco	172.4	Advanced	Tabasco	127.4	Entrepreneur
Quintana Roo	171.1	Advanced	Michoacan	125.5	Entrepreneur
Sonora	169.7	Advanced	Puebla	115.5	Emprendedor
Guanajuato	161.7	Advanced	Tlaxcala	112.8	Emprendedor
Coahuila	161.4	Advanced	Veracruz	101.0	Basic
Sinaloa	155.3	Advanced	Oaxaca	79.0	Basic
Yucatan	153.2	Advanced	Guerrero	75.0	Basic
Mexico	151.3	Avanzado	Chiapas	71.1	Basic

Source: self-elaborated, with data from Mexican Digital Center (2021).

had they decided to invest their money in the bank. The result of the bank profit was compared with the profit from the sale of saladette tomatoes reported for 2021 (Table 4).

Results from Table 5 were presented in descending order, in terms of the net profit obtained from the sale of saladette tomatoes by the PUs that were analyzed, and the results show that this profit was clearly greater than if the producers had invested their money in the bank.

Table 3. C/BR of PUs for the yearly cycle 2021.

PU	Federal Entity	Total Costs (thousands of pesos)	Total income (thousands of pesos)	C/BR
5	Guanajuato	15,300.00	0,384.00	1.33
8	Guanajuato	21,450.00	27,825.00	1.30
4	Queretaro	19,875.00	24,715.63	1.24
3	Queretaro	33,000.00	40,857.60	1.24
12	Guanajuato	10,000.00	11,960.00	1.20
1	Coahuila	5,655.20	6,672.00	1.18
6	Zacatecas	3,560.00	4,120.00	1.16
7	Michoacan	1,750.00	1,950.00	1.11
9	Michoacan	3,500.00	3,762.00	1.07
10	Oaxaca	1,220.00	1,296.00	1.06
2	Coahuila	4,200.00	4,455.00	1.06
11	Puebla	3,000.00	3,114.00	1.04

Source: self-elaborated based on a survey of producers, 2022.

Table 4. Banking profits as compared to production profits.

PU	Size of PU (has)	Federal Entity	Total costs (thousands of pesos)	Total income (thousands of pesos)	Net profit (thousands of pesos)	Banking profit (thousands of pesos)
3	4	Queretaro	33,000.00	40,857.60	7,857.60	735.90
8	3	Guanajuato	21,450.00	27,825.00	6,375.00	478.34
5	2	Guanajuato	15,300.00	20,384.00	5,084.00	341.19
4	2.5	Queretaro	19,875.00	24,715.63	4,391.25	443.21
12	4	Guanajuato	10,000.00	11,960.00	1,960.00	223.00
1	4	Coahuila	5,655.20	6,672.00	1,016.80	126.11
6	2	Zacatecas	3,560.00	4,120.00	800.00	78.50
9	2	Michoacan	3,500.00	3,762.00	766.00	80.28
10	1	Oaxaca	1,220.00	1,296.00	391.00	27.21
11	2	Puebla	3,000.00	3,114.00	260.00	66.90
2	3	Coahuila	4,200.00	4,455.00	255.00	93.66
7	1	Michoacan	1,750.00	1,950.00	200.00	39.03

Source: self-elaborated based on a survey of producers, 2022.

Subsequently, the data relating to saladette tomato production systems from each federal entity to which the surveyed producers belonged were consulted on the FIRA portal (2021) and the data per hectare planted was presented. The data consulted, mainly referred to social costs, social income, as well as social utility for one hectare (Table 5), as producers did not report on other income or expenses, such as bank loans, insurance payments, among others.

The data in Table 4, together with the data provided by the producers, were used to calculate the profitability coefficient (PrC) for each PU (Table 6). Data were presented in ascending order in terms of PrC. Results indicate that PrC were less than 1, indicating that according to FIRA, PU utility was lower than the expected social utility of the tomato product system for their federal entities (2021).

Table 5. System data for saladette production by federal entity.

Federal Entity	Social costs (1 ha)	Social income (1 ha)	Social profit (1 ha)
Puebla	2,102,956.00	2,310,000.00	207,044.00
Oaxaca	1,158,358.00	1,421,000.00	262,642.00
Morelos	761,524.00	1,100,000.00	338,476.00
Michoacan	4,437,015.00	5,920,000.00	1,482,985.00
Zacatecas	1,862,891.00	2,375,000.00	512,109.00
Queretaro	8,823,565.00	11,900,000.00	3,076,435.00
Guanajuato	8,964,108.00	12,000,000.00	3,035,892.00
Coahuila	1,364,924.00	2,240,000.00	875,076.00

Source: self-elaborated with data from FIRA (2021).

Table 6. Result for the Profitability Coefficient (PrC) for each PU.

PU	PU size (ha)	Federal Entity	PrC
5	2	Guanajuato	0.84
8	3	Guanajuato	0.70
3	4	Queretaro	0.64
4	2.5	Queretaro	0.63
6	2	Zacatecas	0.55
1	4	Coahuila	0.29
10	1	Oaxaca	0.29
11	2	Puebla	0.28
12	4	Guanajuato	0.16
7	1	Michoacan	0.13
2	3	Coahuila	0.10
9	2	Michoacan	0.09

Source: self-elaborated based on data from the 2022 survey.

In this regard, producers from PU 10, 11, 12, 7, 2 and 9 stated that they had suffered problems selling their product due to the pandemic causing isolation and business closure policies, so much so that they were forced to sell to intermediaries, who paid a price below the market price.

Likewise, we attained coefficients of performance (cp), hectares (ch) and technology, with which the competitiveness coefficient for each PU (CoC) was calculated, as well as its corresponding level, according to the UAQui scale (Table 7).

These results indicated that the production yield for PU 3, 5 and 1 was 100% (cp=1), shown by the information provided by their producers, whereas PU

Table 7. Competitiveness levels obtained for the surveyed PUs.

PU	Federal Entity	*PrC*	*cp*	*ch*	*tc*	*CoC*	Level of competitiveness
3	Queretaro	0.64	1.00	0.95	0.78	3.37	3
5	Guanajuato	0.84	1.00	0.95	0.53	3.32	3
4	Queretaro	0.63	0.98	0.92	0.66	3.19	3
8	Guanajuato	0.70	0.95	0.93	0.53	3.11	3
1	Coahuila	0.29	1.00	0.88	0.78	2.95	2
2	Coahuila	0.10	0.92	0.93	0.53	2.48	2
6	Zacatecas	0.55	0.83	0.75	0.25	2.38	2
12	Guanajuato	0.16	0.96	0.95	0.28	2.35	2
7	Michoacan	0.13	0.83	0.80	0.22	1.99	1
11	Puebla	0.28	0.75	0.65	0.25	1.93	1
9	Michoacan	0.09	0.79	0.70	0.25	1.83	1
10	Oaxaca	0.29	0.58	0.50	0.25	1.62	1

Source: self-elaborated based on a survey of producers, 2022.

9 presented a yield close to 50% (cp=0.58), as the producer stated that he had pest problems.

Another result that influenced levels of competitiveness was the technology coefficient. In PU 6, 12, 7, 11, 9 and 10, the cultivation area was on soil, irrigation was applied manually, there were no adequate drainage systems for the substrates, and they used inputs of chemical origin. The above results coincide with the UAQui scale, which indicates weak competitiveness in the face of threats from the local market.

In this way, the PUs in the States of Michoacán, Puebla and Oaxaca, presented a level of competitiveness of 1, manifested in the very low coefficients of profitability and technology, indicating that although the utility of their product was greater than the bank profit, the results obtained for their coefficients indicate lack of competitiveness, so they depend on government support to survive. Contrarily, UPs 3, 5, 4 and 8, presented a level of competitiveness of 3, which means that they present a level of competitiveness in relation to the markets, so that these PUs could use ICT as strategies, to contact new suppliers and clients, that would enable them to decrease production costs, as well as increase their opportunities to place their products and improve their prices, in order not to depend on their current suppliers and clients.

With the competitiveness levels obtained for each PU and the state DDI provided by Centro México Digital (2021), the Pearson correlation could be calculated according to the states to which each PU belonged and their average use of ICT (Table 8).

This calculation resulted in a highly significant and directly proportional correlation of 0.882, which corroborates the research hypothesis, assuming that

Table 8. Comparison of results showing level of competitiveness of the State DDI.

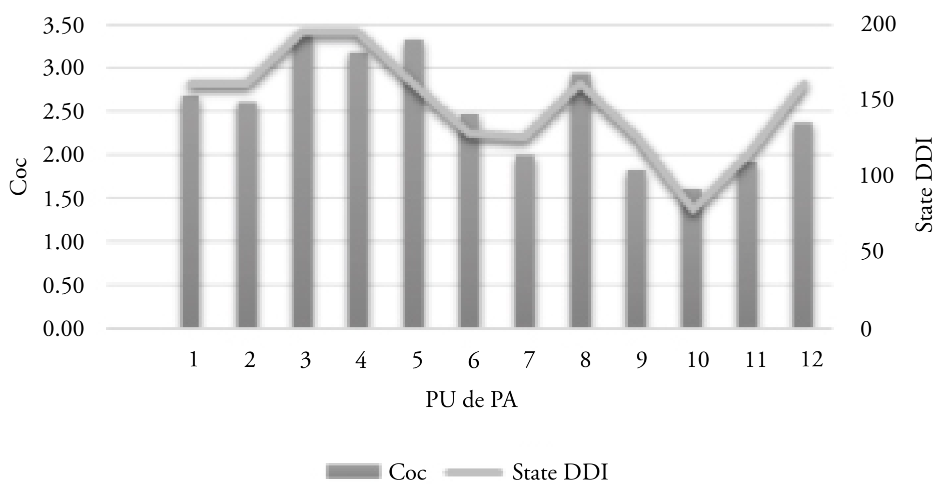
PU	Federal Entity	Level of competitiveness	State DDI
3	Queretaro	3	195.9
5	Guanajuato	3	161.7
4	Queretaro	3	195.9
8	Guanajuato	3	161.7
1	Coahuila	2	161.4
2	Coahuila	2	161.4
6	Zacatecas	2	128.9
12	Guanajuato	2	161.7
7	Michoacan	1	125.5
11	Puebla	1	115.5
9	Michoacan	1	125.5
10	Oaxaca	1	79

Source: self-elaborated based on a survey of producers, 2022.

in general, the PUs located in states with the highest DDI present a higher level of competitiveness, a result that contrasts with the PUs located in states with the lowest DDI that presented a low level of competitiveness. In addition, we present this correlation graphically (Figure 1), where the PUs were organized according to the results in Table 8. The x-axis in Figure 1 represents each PA PU analyzed in this research; the bars correspond to the cCo coefficients of each PU, the line refers to the DDI of each state to which each PU belongs and evidently PU 3 reached the highest point in the graph, as it presented a competitiveness level of 3 and is located in the State of Queretaro. According to the Mexicand Digital Center (2021), it had a state DDI of 195.9 which was the highest of the entities, considering their PUs.
In contrast, the PUs of the States of Michoacán, Puebla and Oaxaca were located at the lowest points on the graph, due to their low levels of competitiveness, as well as the state DDI 2021, which confirms the perceived correlation.

DISCUSSION

The results obtained coincide with Arteaga and Villarroel (2023), who found a significant relationship between the use of digital platforms and profitability among agricultural producers in the Mantaro Valley in Huancayo, Junín, Peru, highlighting the need for technological infrastructure in rural areas of the states of the country studied, as well as portals and applications developed according to the characteristics of the producers, to facilitate the administration of their PU and improve their communication with other links in the food chain, in such a way that it can increase their profits and consequently, their level



Source: self-elaborated based on data from survey, 2022.
Figure 1. Comparison between competitiveness levels *vs*. DDI.

of competitiveness. This is the case with Chinese producers, where policies aimed at a digital economy have helped to raise the quality of their food, by promoting the production of green agricultural products (Yao and Sun, 2023). Contrarily, low scores, in terms of the infrastructure index presented by the index manifested in the DDI (2021), coincide with the digital divide identified by Contreras *et al*. (2022), among indigenous coffee producers in some Oaxacan communities in Mexico; here, the percentage of people who have access to computers did not reach 10%, although the use of cell phones reached almost 66%, as shown by the National Agricultural Survey (INEGI, 2019), which found that only 7.9% of producers used the internet, even though 88.1% of them used cell phones in their PU.

Furthermore, this also coincides with the research carried out by Sotomayor *et al*. (2022), who found that only between 4.7 and 10.2% of the PUs have access to the Internet in the States of Veracruz, Chiapas, Puebla, State of Mexico, Oaxaca and Guerrero (southern zone), compared to those found in the State of Coahuila, which correspond to 40.6% of PUs. This problem affects the low use of technologies in the administration of agricultural PUs, as Madrid (2019) maintains that, for coffee producers in Turrialba, there are few specialized applications that "seek inclusion and sustainability in rural areas", so most of them use their smartphones infrequently and only to access social networks.

For his part, Ojeda (2022) states that sustainable and efficient agricultural production is achieved by using cutting-edge information technologies that, in turn, will boost the economy in the countries that apply it, so that investment in infrastructure and equipment in rural areas must be essential for producers to begin using this technology for competitive advantage, in such a way that it enables them to increase their levels of competitiveness.

However, in order to reduce the digital divide, in addition to technological infrastructure, it is necessary that producers become aware of the usefulness of technology (Rodríguez, 2020). Otherwise, as in Tanzania, it may result in the government investing in several agricultural digital innovation projects, which cannot be implemented, mainly because producers consider that these projects do not meet all their needs (Mushi *et al*., 2022). Therefore, we consider it important to train and raise awareness among producers in the use of technology developed to manage their PU and decision-making (Arteaga and Villarroel, 2023). Likewise they should take advantage of mobile applications to carry out banking transactions or to be able to communicate with the different links in the agri-food chain (Dalio *et al*., 2023). Digital awareness among producers can also help reduce product waste through the use of sensors to monitor its transfer (Muñiz *et al*., 2021). This will benefit PUs by increasing their profits, maximizing the performance of their production and, therefore, their levels of competitiveness.

CONCLUSIONS

The survey was applied to PU of PA, because the UAQui scale focuses on measuring the level of competitiveness of agricultural PU that use some protection technology but does not consider PU that use technology for open fields. In addition, although a probabilistic research could not be carried out, due to insecurity problems, it was possible to work with data from small-sized PU of PA, making it possible to delimit the subjects being studied. The above, together with the locations in different entities, made possible the comparison between the levels of competitiveness and the state DDI. Moreover, the results made it possible to verify the suggested hypothesis, finding a highly significant correlation between the levels of competitiveness of the PU of PA and the digital development index in these states, revealing that federal entities with greater use of ICT present the most competitive PU of PA.

These results also showed that, in Mexico, the digital divide is a problem that affects the competitiveness of the PA PUs and therefore production, which in turn affects food security; however, the increase in the use of cell phones by producers is notable, representing the way to encourage greater use in administrative activities and decision-making of PUs.

These results coincide with those found in other studies, so this research suggests that a collaborative effort between the federal and state governments is required, as well as companies that provide telecommunications services, to invest in infrastructure and equipment that provides good quality internet service, in addition to computers and smart phones, for the administration and management of the PA of PUs.

Similarly, there is concern about designing training strategies that will result in effective adoption of technology, taking into account the characteristics of PUs, as well as those of the producers (age, level of studies, among others), which is why we suggest participation of Higher Education Institutions, as well as Research, in the Technological Adoption process, with training in stages, so that during the first stage, extension agents are trained as trainers and in the second stage, producers, with extension agents as their trainers. The above will reduce the digital gap between producers from different states, increasing state DDI, as well as levels of competitiveness in the PUs of PA. This will be reflected in the increase in food production, as well as in the growth of the PUs, with a consequent increase in the country’s GDP.

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