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FRAUD RISK ASSESSMENT IN ORGANIC CERTIFICATION. A REFLECTION ON THE CAUSES THAT GIVE RISE TO IT

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Abstract

This study analyzes the risk of fraud in a local Participatory Organic Certification market, recognizing that such risk is multi-causal and cannot be reduced solely to economic incentives. It assumes that fraud should not be understood as an isolated act, but rather as the result of a set of structural and contextual conditions. The main objective was to identify the factors that influence the propensity for fraud, paying special attention to the relationship with the government, personal factors, perceptions of performance and trust in the Participatory Organic Certification Committee (POCC), as well as the presence of greenwashing practices and the perception of income adequacy by market players: operators, collaborators, and the POCC itself. The methodology was based on a Rapid Fraud Risk Assessment (RFRA) complemented by a survey of variables associated with its potential occurrence. The results show that while economic incentives play a role, they are not the only factors contributing to fraud risk. Other factors, such as institutional weakness, the competitive environment, and economic constraints, also play a role. Although direct fraud was not detected, the analysis indicates conditions that could lead to fraud, underscoring the importance of managing its prevention. This work proposes a complex interpretation of the phenomenon, which goes beyond the traditional linear view and highlights the need to strengthen cooperation between stakeholders to preserve the integrity of the certification system.

Keywords: Greenwashing, local markets, organic production, risk analysis.

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Introduction

Organic agriculture has been on a trajectory dating back almost a century. Before World War II, a group of farmers began to express concern about certain observable changes in food production. In 1925, Steiner's Agricultural Notebooks were published, and in 1946, the first comparative experiment between organic and conventional production was established (Soto, 2020). Its growth continued, and by the end of the 20th century, several European countries, primarily Italy, Austria, Sweden, Germany, Spain, and France, had already converted part of their farms to organic systems (Padel, 2001). The expansion of organic agriculture continued to other countries, including Mexico.

Organic agriculture has different definitions. Zamilpa *et al*. (2015) identify three: i) for the FAO, it is a system that eliminates the use of synthetic inputs and replaces them with management practices that maintain and increase soil fertility; ii) for the USDA, it consists of the use of methods that preserve the environment and avoid most synthetic materials, following a set of standards; and iii) for Mexico, it is the production and processing of food and derived products, with regulated use of external inputs, as well as restrictions or prohibitions on the use of synthetic chemical products. It is therefore a complex system or innovation based on the substitution of synthetic inputs and/or materials for others without regulatory restrictions.

The elimination or restriction of chemical synthesis products in food production has some advantages, such as greater carbon capture in soils, which is usually higher under organic treatments, lower energy consumption per production area, faster recovery from extreme weather events and more nutritious products, according to some meta-analyses (De Schaetzen, 2019). These benefits are often recognized by consumers, and some studies show that general knowledge about them (López, 2019) and, specifically, about health-related benefits (Araya-Pizarro & Rojas-Escobar, 2021) are often decisive in guiding the purchase and payment of premiums for these types of products. This generates some benefits for producers and sellers, among which the premium price stands out.

Due to its conceptual and practical nature, which involves differentiating food products by replacing synthetic chemical inputs, organic agriculture faces several problems, including poor product handling throughout the supply chain and the risk of organic fraud. According to the Agricultural Marketing Service (2023) organic fraud is "the misrepresentation, sale, or labeling of non-organic agricultural products as organic" (p. 3550) and the main causes include the lack of direct control over some links in the supply chain and the overpricing that organic products usually have. Consequently, in addition to representing economic gains for the person who commits fraud, the problem with these practices is that they have negative effects on consumers' credibility and willingness to purchase (Gil *et al*., 2000).

Building on the above, in this study, fraud is conceived as the act of presenting organic labeling on products that do not have the corresponding certification. While a traditional approach could lead to its treatment as a dichotomous variable: fraud or non-fraud, the approach adopted here aligns with the concept of fraud risk, which allows us to approach the phenomenon not as an isolated event, but as a process conditioned by various associated variables and potential causes. This perspective is useful for identifying the structural, organizational, and social factors that contribute to the occurrence of fraud. In this sense, it is justified to adopt a broader definition of risk that allows for a more contextualized analysis of the phenomenon.

Risk, following the theoretical framework proposed by Jerez (2023), can be understood, in a traditional sense, as the "expected frequency of unwanted effects arising from exposure to a contaminant" (p. 623) or specific threat. However, this view is expanded to distinguish between voluntary and involuntary risks, introducing ethical and individual agency dimensions. From the social sciences, particularly sociology, the concept transcends the purely technical diagnosis of hazards to articulate spatial, social, and subjective factors: contemporary analysis considers the location, frequency, intensity, and duration of the threat, but also human exposure, social vulnerability, and subjective perception of risk. This last dimension is crucial for understanding how to assess and address risks (Jerez, 2023).

In this sense, fraud risk is understood as the potential occurrence of fraudulent acts based on certain regulatory or social conditions that favor their occurrence. The interest derived from this concept lies in the identification and characterization of the associated variables that contribute to their occurrence. Applied to the field of organic certification, fraud risk refers to the presence of factors that make it possible to present products that are not certified as organic. Therefore, its study should not focus on the result, the fraud, but on its causes.

Emphasizing the causes of fraud risk can lead to its proper management, insofar as it allows for the identification of the severity of the initial risk, the assessment of the effectiveness of existing controls, the estimation of the current level of risk once these controls have been applied, the anticipation of the effect of additional measures and, finally, the establishment of a risk threshold considered acceptable by the responsible authority (European Commission, 2014). This approach to fraud risk management also complements the regulatory approach focused on control, such as that proposed by the Agricultural Marketing Service (2023), which relies primarily on verification of organizational integrity, the regulatory definition of fraud, the existence of audit trails, and traceability in the supply chain.

While these elements help us achieve regulatory compliance, their focus is on documentary and retrospective fraud detection. In contrast, a risk management approach incorporates a forward-looking perspective: it not only considers existing regulatory and social controls and their effectiveness, but also allows for anticipating vulnerability scenarios, assessing the need for additional measures, and establishing acceptable risk levels based on the context. In this way, fraud risk analysis is not limited to verifying compliance, but actively contributes to fraud prevention.

In Mexico, the risk of fraud has not been addressed in depth. The term is not included in the Organic Products Law (2006), nor in the criteria for authorizing the use of the term "organic" (National Health Service, 2017), nor in the guide for the certification of producer groups (National Health Service, 2024), which are the main regulatory and technical documents for organic agriculture in the country.

In fact, these institutions' monitoring of this issue has been limited. The identified cases of fraud in Mexico correspond to a list of 20 certificates that were falsified by different companies between 2012 and 2024 (Figure 1) and published by the Agricultural Marketing Service (2025).

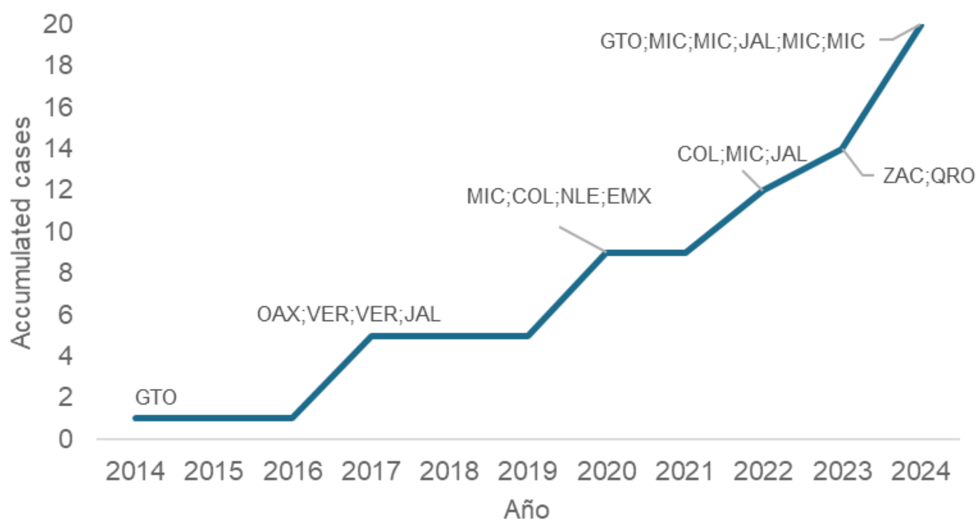

Figure 1. Cases of organic product fraud identified in Mexico
Source: Agricultural Marketing Service (2025).

The role of the Organic Products Act (2006) is, among other things, to ensure that products labeled as organic comply with its provisions. According to this legislation, organic is defined as:

"Labeling term referring to a product of agricultural activities obtained in accordance with this Law and the provisions derived from it. The terms "organic," "ecological," "biological," and the names with prefixes "bio" and "eco" used on product labels are considered synonyms and are equivalent terms for national and international trade purposes (p.3)".

Unlike the causes of fraud in organic agriculture in the United States, and the examples suggested by the Agricultural Marketing Service (2023), the problem in Mexico may have other attributes. For example, the informal sector in Mexico is primarily composed of trade (33.3%) and agricultural (10.8%) activities (Center for Public Finance Studies, 2018), so supply chain control and monitoring may not be effective tools. Furthermore, the problem has other nuances if only operators of the participatory organic certification scheme are considered (National Health Service, 2021), whose production volumes are usually lower than those of the traditional certification scheme.

Therefore, the objective of this contribution is to analyze the risk of fraud in a local market, using participatory certifications, as a multifactorial process, leading to a broader understanding of the causes of fraud and fraud risk. The relevance of this objective lies in the possibility of influencing this issue at different levels: individual, organizational, political, and consumer, in addition to control and monitoring.

Organic agriculture is a production system that integrates ecological processes, the responsible use of biodiversity, and the closure of local cycles, with the goal of preserving the health of the soil, ecosystems, and people. This approach, promoted globally by organizations such as the International Federation of Organic Agriculture Movements (IFOAM, 2008), seeks to reduce dependence on external inputs, eliminate the use of synthetic agrochemicals, and promote sustainable agricultural practices based on productive diversification. In Mexico, the regulatory framework is established in the Organic Products Law (LPO) and its Regulations, which defines criteria for the production, processing, labeling and marketing of organic products, prohibiting the use of genetically modified organisms (GMOs) and regulating the use of the National Distinction for those products that comply with established standards (SENASICA, 2022).

In this context, participatory organic certification (SCOP) emerges as a mechanism formally recognized by the LPO for small, organized producers who market directly to consumers. While it shares principles with Participatory Guarantee Systems (PGS), such as mutual trust, transparency, and collective learning, SCOP is distinguished by its legal basis in Mexican regulations and by its operation through a Participatory Organic Certification Committee (CCOP), responsible for issuing opinions and monitoring compliance with standards (Nelson *et al*., 2016).

PGS, as defined by IFOAM (2008), are local verification systems that combine field visits, self-assessments, training workshops, and collective decision-making. They operate successfully in countries such as Brazil, India, New Zealand, and France. In Mexico, although PGS do not have full legal recognition, experiences such as the Chapingo Organic Market, the Alternative Market of Oaxaca, and the Mexican Network of Organic Markets and Markets have consolidated social legitimacy and a relevant role in agroecological networks.

The existence of organic markets is not without risks associated with non-compliance with regulations. Fraud in this context occurs when a product is marketed as organic without complying with guidelines at any stage of the production chain, whether in production, collection, processing, storage, or sale. The "Circle of Fraud" model identifies factors that, either individually or in combination, favor the emergence of these practices, including complex legislation, imbalances between supply and demand, pressures on economic income, lack of government oversight, "greenwashing" practices, market opportunities without sufficient controls, personal characteristics of the actors, disorganized market expansion, and interest combined with technical ignorance.

The Ethical Fraud Theory, developed by Payan and Stanley (2019), provides an explanatory framework on how individuals can justify fraudulent behaviors when they perceive them as consistent with their values or as a legitimate response to economic or social needs.

In the field of organic production, this approach provides insight into how contexts of economic pressure or institutional weakness can lead to tolerance or even acceptance of non-compliant practices. Tools such as the Rapid Fraud Risk Survey (RFRS), used by audit and risk management specialists, are useful for identifying structural and operational vulnerabilities in community organizations and markets, and enable preventive measures to be implemented before critical risks materialize.

Understanding the functioning of the SPG and SCOP is enriched by considering the moral economy models proposed by Scott (1976) and Thompson (1991), who argue that economic relations in rural communities are guided by principles of reciprocity, equity and subsistence guarantee. These values, while strengthening social cohesion and community resilience, can become fertile ground for justifying fraudulent practices when economic or market conditions deteriorate. In such scenarios, violating formal norms can be interpreted as a livelihood defense strategy, rather than a purely illicit act.

In community markets, governance and legitimacy are key elements to ensuring the ethical sustainability of certification systems. Effective governance requires clear rules, accountability mechanisms, and active participation of stakeholders in decision-making, while legitimacy is reinforced by transparent processes and social oversight exercised by the community itself. Anticipating and managing fraud risks, through tools such as the RFRA and community policing strategies, is essential to sustaining consumer confidence and protecting the long-term integrity of organic systems.

Methodology

To analyze the risk of fraud, in line with the stated objectives, this research develops a case study of the Chapingo Organic Market (TOCh). This project, sponsored by the Autonomous University of Chapingo, is being carried out within its facilities. TOCh was founded in November 2003 as an initiative to connect local producers with organic operations and promote local consumption. Since its founding, it has operated consistently on Saturdays, and in recent years also on Sundays.

The TOCh is a space that offers organic products certified through participatory organic means, in accordance with Article 24 of the Organic Products Law (Ley de

Productos Oránicos, 2006). Its objective is to promote the direct sale of organic products from producers to consumers, through short supply chains. In line with its creation, this space ensures that the products purchased by consumers meet organic production criteria (Rindermann *et al*., 2019). TOCh was founded in November 2003 as an initiative to connect local producers with organic operations and promote local consumption. Since its founding, it has operated consistently on Saturdays, and in recent years also on Sundays.

In short, TOCh is a space that offers organic products, which have participatory organic certification, in accordance with the provisions of article 24 of the Organic Products Law (2006). Fraud risk detection analysis is particularly interesting in this case because it has a framework that combines elements of scientific research and training since its inception, providing a certain level of confidence to consumers regarding the authenticity of the products' origin. These elements are not available to consumers in other retail spaces.

It is important to note that the analyzed market should not be interpreted as a case of fraud, but rather as a unit of observation used to examine risk conditions associated with the phenomenon, with the aim of meeting the objectives of this research to influence fraud prevention at various levels. The approach adopted is not intended to assign blame, but rather to identify structural and operational factors that, as in any system, can create vulnerabilities if not addressed promptly.

Collection and analysis of information

The information was obtained through interviews with active operators (individuals or groups of people who carry out organic operations) and their collaborators. Active operators are those TOCh users who have a Participatory Organic Certification certificate and a physical sales space within the market facilities. Collaborators, for their part, are individuals or businesses that complement the market's offerings by providing inputs or products, and who are also subject to verification monitoring.

The operators and collaborators completed two data collection instruments, which we describe in the following section. The instruments were administered during the following time periods:

Accompanying visits by the Participatory Organic Certification Committee to each member at least once

Workshops, talks and integration activities

Days of sale.

Instruments for collecting and analyzing information

The Rapid Fraud Risk Assessment (RFRA) and a survey with closed, binary, and ordinal questions were used as data collection instruments to analyze the determinants of fraud risk. The RFRA was applied to various analysis groups related to organic operations: production, processing, sales, training, and technology adoption. The indicators analyzed using the RFRA are presented in Table 1.

Table 1. Indicators analyzed in the RFRA.

Analysis group	Indicators
Production	Production unit transition; production unit management; use of GMOs; post-harvest production.
Transformation	Product processing; cleaning the processing area.
Marketing	Marketing; sale of conventional products; labeling; product transportation; producer-consumer relationship.
Training and technology adoption	Training; replication of organic production in the locality.
Coexistence	Compliance with internal regulations; attendance and punctuality; committee calls; teamwork.

Source: self-elaborated.

This assessment consists of a series of indicators, which vary for each analysis group, in which criteria are established and a score is assigned on a range of 1 to 4, where 1 is the highest degree of fraud risk and 4 is the lowest. Table 2 shows two indicators broken down into their criteria and respective scores:

The analysis of the RFRA indicators allows us to establish a threshold between compliance and fraud risk. These results provide an initial insight into how fraud risk is perceived and experienced within the case studied. Further details about the instrument are available in Chapa-Ignacio (2022).

This instrument was applied to operators. During the study period, the market consisted of fifteen operators, but the ERRF was only applied to the nine that produced, processed, and/or sold food. The other operators not consulted through this instrument sold non-food products or already had third-party certification.

On the other hand, the fraud determinants analysis survey was conducted at the TOCh physical location. The questions were designed to gather specific information aimed at detecting knowledge of organic production legislation, personal characteristics, the performance of the Certification Committee, the environment of greenwashing, and income (Table 3).

Table 2. Detailed evaluation. Two examples of RFRA indicators.

Dimension	Indicator	Criterion	Scale
Production	Transition of the production unit	It has not undergone transition and offers its products immediately as organic	1
		It's been a year since the transition, and it offers its products as organic	2
		It's been two years since the transition, and they offer their products as organic	3
		It's been three years since the transition, and it offers its products as organic	4
Marketing	Labeled	Does not perform any product labeling	1
		It has a general information sheet of its products	2
		It has labeling, but not according to the standard	3
		It has labeling according to the standard	4

Source: Prepared by the authors using data from the interview design.

Table 3. Potential causes of fraud analyzed by survey.

Potential cause	Potential cause
Government Aspects	He values the lack of knowledge of sanctions, the absence of the government, and the lack of understanding of the LPO.
Elements of a personal nature	Analyzes the propensity for anger, conflict involvement and resolution, and defense of points of view.
Perception of CCOP performance and confidence	Measures perception on a scale from poor to excellent.
Elements of greenwashing	Evaluate the perception of greenwashing practices in the environment: advertising, product offerings, and the increase in alternative spaces.
Perception of income	Assesses income as sufficient or insufficient, according to perceptions.

Source: ource: self-elaborated based.

The information in this survey assesses the interaction of several fraud risk factors as dimensions. This survey was administered to fifteen TOCh operators, five collaborators, and six members of the participatory organic certification committee. Data were collected and organized for analysis using descriptive statistical methods and contextualized through direct observations.

Results

Rapid Fraud Risk Assessment

Among the TOCh operators in force in 2022, at the time of the study, compliance was 15% and the risk of fraud 85% (Figure 2). These results could be influenced by the COVID-19 pandemic, as some operators decided to abandon the project due to the temporary closure of the TOCh during the lockdown, while others joined.

Figure 2. Fraud risk.
Source: self-elaborated based on RFRA.

These results could be explained, as mentioned above, by the restructuring of the TOCh regarding the incorporation of new operators. In addition, the isolation measures associated with the COVID-19 pandemic also played a role. In compliance with official and lockdown regulations, operators received less support, oversight, and monitoring of their activities, as well as limited guidance regarding regulations. This assertion, as we will see later, is supported by the survey results.

Figure 3 shows how the ERRF performs in relation to the nine operators active in 2022. The results indicate that, while only one of them fully complies with the evaluated indicators, the others only show partial noncompliance, demonstrating progress and a favorable margin for achieving full compliance.

These findings not only identify specific improvement opportunities for each operator, but also provide a basis for guiding targeted actions based on the indicators evaluated. However, beyond identifying the areas that need to be addressed, this paper

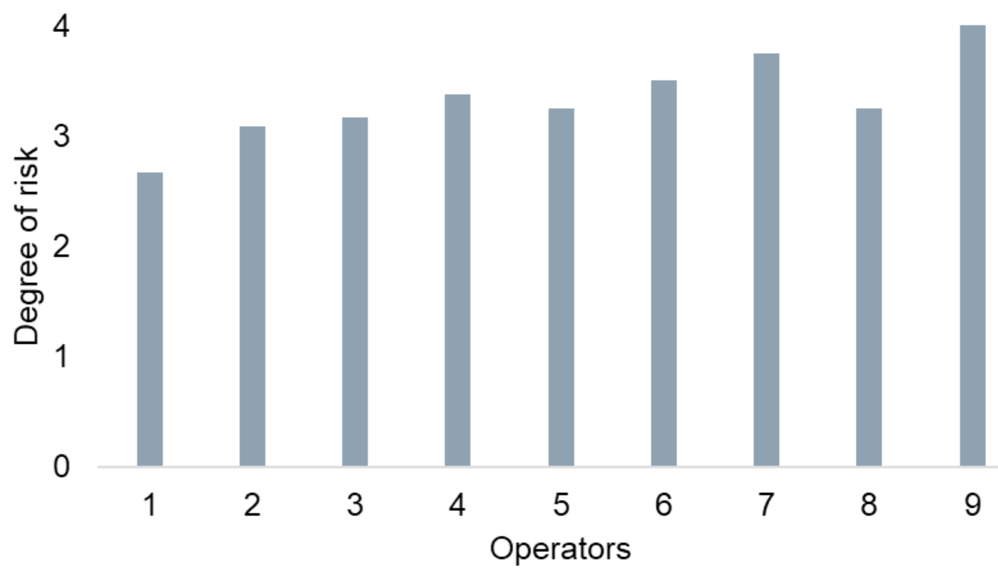

Figure 3. Fraud risk distribution among operators.
Source: self-elaborated based on RFRA.

seeks to delve deeper into the structural and contextual causes that shape the risk of fraud. The following section addresses these multiple causes, supported by empirical evidence, to better understand the factors that cause fraud and explain its prevalence over time.

Determinants of fraud risk

The survey to identify fraud risk determinants was administered to 26 stakeholders: operators, collaborators, and members of the participatory certification committee. The government was asked whether it could be considered absent, based on the number of workshops, talks, or actual training on organic production topics, as well as the monitoring and sanctioning of spaces it carries out, all of which is represented in Figure 4.

It is worth mentioning that 61% understand the law and its documents. This understanding can be related to the various training sessions offered within the TOCh to its active operators. Likewise, the lack of attendance explains why some operators claim to be unfamiliar with the law. On the other hand, 64% point out that there is an absent government due to the difficult access to training related to organic production due to its high cost and the fact that those that are available to the public do not address issues related to local production.

Likewise, 67% of respondents report being unaware of any sanctions imposed by regulatory bodies such as SENASICA on those who violate organic regulations. This data provides a first insight into the representation of each element of the fraud cycle and how they may interact with each other.

Figure 4. Government aspects as a potential cause of fraud.
Source: self-elaborated with data from the survey.

To comply with certification, operators are subject to an organic products law, regulations for organic production, and guidelines for the operation of organic products. This can be problematic due to contradictions, omissions, and the lack of access to the legislation for users who, even if familiar with it, are unable to access it. Regarding personal character, it was evaluated whether the respondents consider that they get upset easily, how they participate in conflicts, in their resolution within the group and if they defend their points of view during meetings (Figure 5).

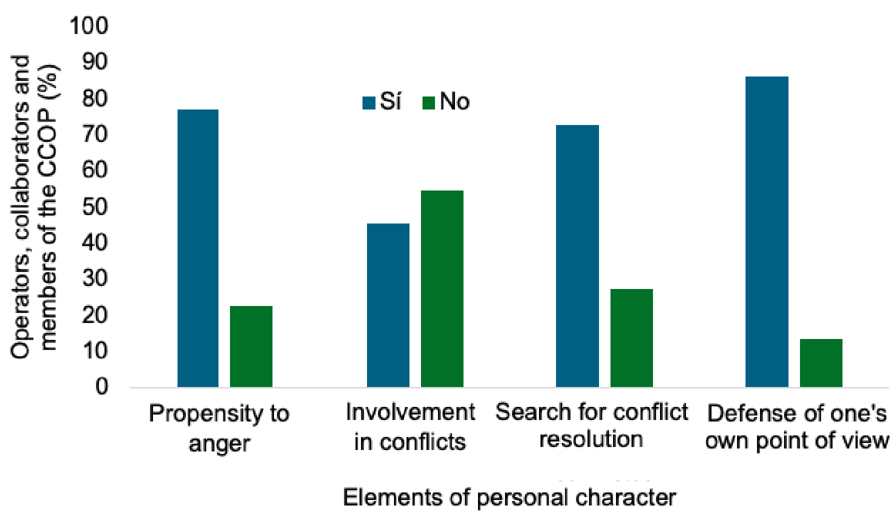

Figure 5. Personal factors as a potential cause of fraud.
Source: Prepared by the authors based on RFRA.

As shown in the graph above, most respondents (72%) expressed interest in participating in conflict resolution, which represents a positive aspect for the operation. According to testimonies and observations, the lack of agreements resulting from conflicts has, on occasion, led to the delay and cancellation of projects intended for collective benefit. On the other hand, 22% stated that they get angry easily, which causes conflict and creates fractures in their living environments. This, coupled with the fact that 13% of respondents stated they do not defend their point of view, fuels the rise in disagreements. This demonstrates that personal character is an important factor in achieving organic production.

Cohesion among respondents favors the de-individualization of organizational operations. In a context characterized by a perceived remoteness from the government and its statutes, social cohesion facilitates communication aimed at understanding norms, which can lead to the adoption of certain behaviors (Valente, 2012). Cohesion among respondents favors the de-individualization of organizational operations. In a context characterized by a perceived remoteness from the government and its statutes, social cohesion facilitates communication aimed at understanding norms, which can lead to the adoption of certain behaviors (Valente, 2012).

One of the potential causes of fraud risk is the perception of the performance of and trust in the Participatory Organic Certification Committee (POCC). In this area, aspects related to the respondents' evaluation of committee members were assessed. This dimension is especially relevant for certified organic agriculture under the participatory scheme, since the committee acts as a mediator between the operators and the provisions of the guide for the implementation and establishment of the participatory organic certification system, through training and verification processes (National Health Service, 2021).

As with the analysis of the other potential causes, the perception of performance and trust in the POCC was assessed by all respondents, even if they included committee members. This is supported by the fact that, although it is a single body, it is comprised of six individuals with their own assessments of the committee's functioning. The results of the analysis are shown in Figure 6.

The graph indicates that 18% of respondents consider the Participatory Organic Certification Committee (POCC)'s activities to be excellent. This assessment may be associated with the level of involvement of certain operators, who maintain close involvement with the committee and have detailed knowledge of its functions. Meanwhile, 55% considered the POCC's performance to be good. This suggests that, overall, there was little room for improvement at that time. However, 27% rated the committee's performance as average or poor. Meanwhile, 55% considered the POCC's performance to be good.

This suggests that, overall, there was little room for improvement at that time. However, 27% rated the committee's performance as average or poor. Meanwhile,

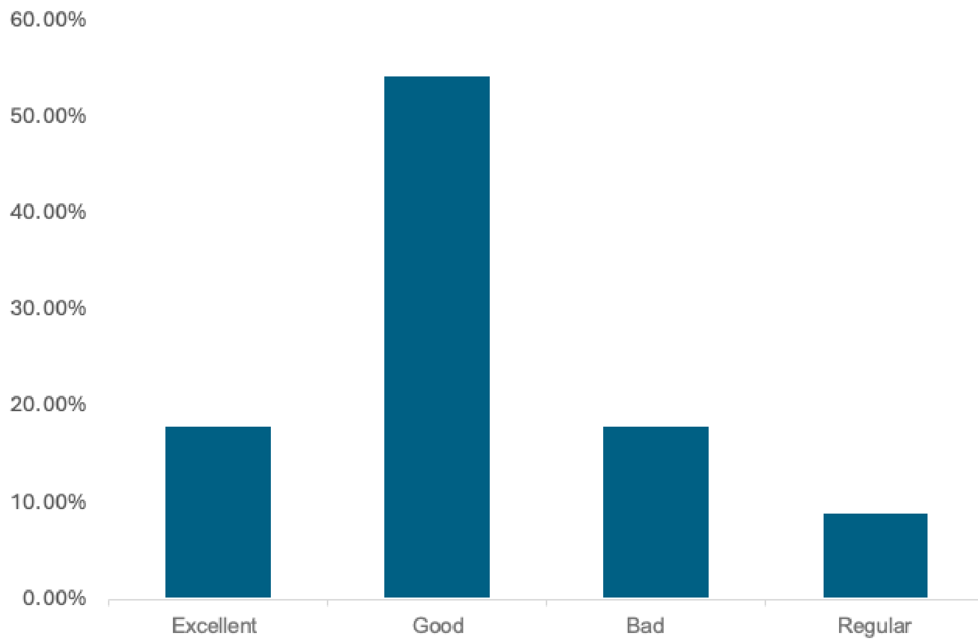

Figure 6. Perceptions of POCC performance and trust as a potential cause of fraud.
Source: Prepared by the authors based on RFRA.

55% considered the POCC's performance to be good. This suggests that, overall, there was little room for improvement at that time. However, 27% rated the committee's performance as average or poor.

A possible explanation for this differential perception emerges from the qualitative analysis of the testimonies and direct observations collected during the study. These identified a tension related to the reinforcement of compliance mechanisms, specifically regarding the request for documentation required for certification processes. Some operators did not have these documents and were not willing to provide them, arguing that "they weren't asked for them before, so why now?" This type of statement suggests resistance to changing procedures, which could be negatively impacting certain members of the group's assessment of the committee.

Up to this point, our analysis has focused on the structure: governance, committee, and operators. This structure shapes the theory of change implicitly established in the official documents cited earlier in this document. However, we studied a variable external to the structure, which relates to the behavior of competitors.

Although competitor behavior has been classically studied within value networks, with an emphasis on its proliferation and intensity due to its effects on prices, advertising, and innovation (Barrera *et al*., 2013), in the context of organic agriculture, it is also necessary to analyze competition from the perspective of greenwashing. This is defined as:

"A selective amplification of positive environmental information, which produces a distorted and biased image in favor of "green" aspects, interpreted as positive by consumers" (Hallama et al., 2011, pp 1-2).

Based on the observations reported by operators, it was analyzed whether there was a perception of practices related to greenwashing, such as: the offer of organic products without certification, the use of labels such as "eco", "bio" or "natural" in non-certified spaces, and the perception of an increase in this type of alternative markets.

As shown in Figure 7, respondents indicated that the most frequent manifestation of greenwashing is the sale of uncertified products presented as organic, ecological, or biological (77%), terms that, for legal purposes, are considered synonymous (Organic Products Law, 2006). Furthermore, 73% of respondents perceived an increase in the number of sales spaces for products presented as organic without certification.

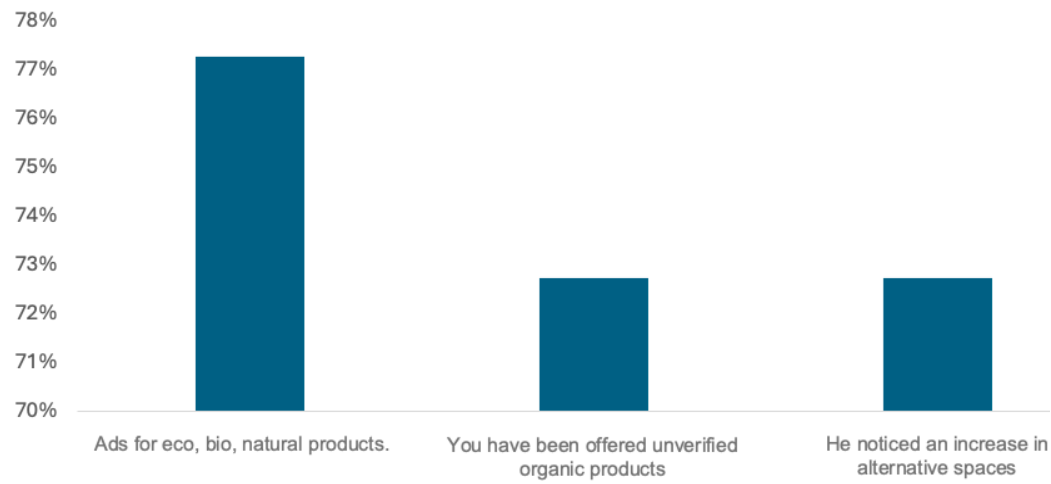

Figure 7. Elements of greenwashing as a potential cause of fraud.
Source: Prepared by the authors based on RFRA.

This expansion, characterized by its lack of regulation, suggests a disorganized growth of the alternative market, which is consistent with the perception of a weak institutional presence. The absence of effective government oversight and control mechanisms seems to facilitate the proliferation of these spaces, contributing to informality and the risk of practices such as greenwashing.

Furthermore, 73% of respondents report having been offered unverified organic products. Three forms of greenwashing stand out: i) the sale of non-certified products, ii) the use of ambiguous labels in unregulated spaces, and iii) direct offers without verification. However, the latter constitutes a new incentive system. This system encourages informality and the simulation of regulatory compliance, by generating economic benefits for certain competitors without the corresponding assumption of the costs associated with certification (Delmas & Cuerel, 2011).

As a result, there is a weakening of trust in formal control mechanisms and an intensification of unfair competition. As Shakhnazarov (2024) points out, the growing consumer preference for sustainable products is not necessarily reflected in an equivalent increase in responsible purchasing, due to the distrust generated by the increasingly common presence of imprecise, ambiguous, or unverifiable environmental claims.

The last variable considered is the perception of income adequacy, understood as the respondents' assessment of the improvement in their economic capacity through increased income from the sale of certified products. Its inclusion allows for an examination of the material conditions that influence the ability to meet the requirements of the organic certification process. Since this process involves an investment of financial resources and time, the perception of insufficient income constitutes a potential structural impediment to sustained participation. It is worth remembering that documented cases of fraud, both in the United States and Mexico, have been linked to the presence of economic incentives that distort regulatory compliance. The results of this analysis are presented in Figure 8.

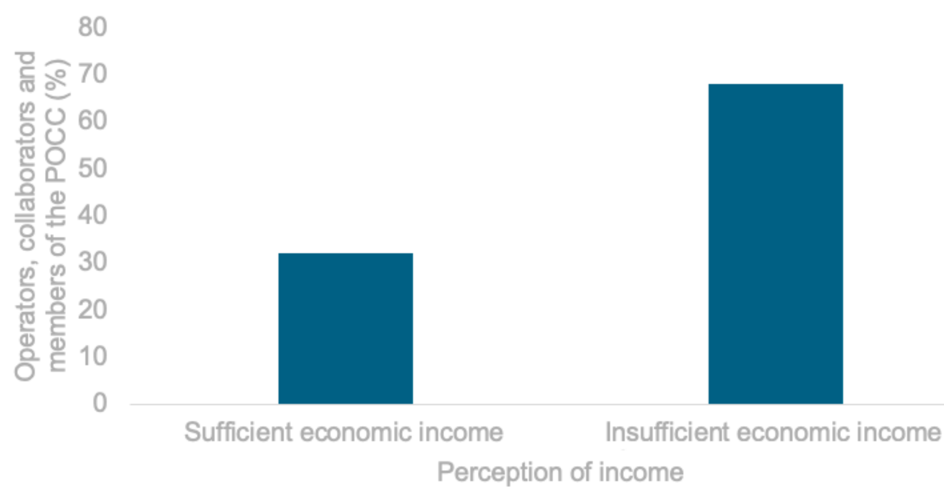

Figure 8. Perception of income as a potential cause of fraud.
Source: Prepared by the authors based on RFRA.

The graph above shows that 68% of active respondents consider their income insufficient, while only 31% of the total report having enough income to cover their needs. This distribution highlights a scenario of economic vulnerability that can impact compliance with certification requirements and, consequently, the propensity for irregular practices. Even considering differences in scale, an analysis by Zhang (2022) of capital-intensive firms in 47 countries and territories has shown that financial constraints are a determining factor in the adoption of greenwashing strategies, a form of fraud previously analyzed in this study. Therefore, the configuration of the financial environment can exert a direct influence on actors' behavior in relation to regulatory compliance.

The findings led to the identification of multiple risk factors that, if not properly managed, can lead to the development of fraud scenarios. Addressing these factors doesn't require tracking them in the order in which they emerge, but rather prioritizing their impact and their potential to affect regulatory compliance. Likewise, structural conditions beyond the direct control of operators, collaborators, and the Committee were identified, particularly those linked to current legislation and the limited presence or action of government agencies. This requires multilevel intervention that combines community efforts with institutional frameworks appropriate to the circumstances of the stakeholders, to safeguard the integrity and credibility of the participatory organic certification system.

There are various risks that, if not properly managed, can lead to fraud. It is important to note that mitigating these elements does not require following the order in which they arise. Likewise, situations were identified whose resolution is beyond the scope of the implementers, such as those related to legislation or government regulations.

Discusion

The results of this study confirm that, while Participatory Guarantee Systems (PGS) and Participatory Organic Certification Committee (POCC) are effective tools for verifying organic quality in community markets, their effectiveness depends largely on the governance structure and socioeconomic context in which they operate. As reported by Nelson *et al*. (2016), the active participation of producers and consumers in the evaluation process strengthens trust and social legitimacy, but also generates vulnerabilities when supervision is insufficient, or rules are not applied consistently.

In this sense, the presence of factors identified in the Circle of Fraud model, such as lack of technical knowledge, disorganized market expansion, and the absence of state supervision, creates favorable conditions for the violation of regulations (Payan & Stanley, 2019). These authors explain that, under economic pressures or perceptions of injustice, actors can justify fraudulent behavior as morally acceptable, which is consistent with observations in Latin American organic markets, where regulatory compliance is relativized in the face of the need to guarantee subsistence (Scott, 1976; Thompson, 1991).

The Fraud Risk Rapid Survey (FRRS) application has proven to be a useful tool for identifying vulnerabilities before they lead to actual breaches. This finding is consistent with studies on risk management in agrifood chains, where early detection of critical points is essential to preserving system integrity (Spink *et al*., 2017). However, its effectiveness depends on integrating the results into clear decision-making and community feedback processes.

Comparing with GSP experiences in Brazil, Chile and Argentina, it is observed that in those cases where there is legal recognition and institutional support, such as the Brazilian case under the Ministry of Agriculture, the risk of fraud is reduced thanks to clearer inspection protocols and incentives for compliance (Meirelles, 2019). In contrast, in contexts without a solid legal framework, self-regulation is the primary tool, which increases the dependence on social cohesion and community pressure to ensure compliance.

The moral economy models proposed by Scott (1976) and Thompson (1991) allow us to understand that, in markets where exchange relations are mediated by principles of reciprocity and equity, fraud is not always perceived as an immoral act, but as a strategy to balance structural disadvantages. While this approach helps interpret certain behaviors, it also underscores the need to strengthen agroecological education and producers' technical capacities to prevent community solidarity from becoming a justification for noncompliance.

Taken together, the findings of this study suggest that the ethical sustainability of PGS and SCOP depends not only on transparency and participation, but also on organizations' ability to anticipate risks, strengthen accountability mechanisms, and adapt to the economic and regulatory pressures of the context. The integration of preventive tools such as the RFRA, accompanied by ongoing training and institutional support, is a key strategy to ensure that community markets not only maintain their legitimacy but also strengthen the resilience of the agroecological systems they support.

Conclusions

The identification of fraud determinants, beyond theoretical approaches, demonstrates that all elements, both in isolation and in interaction, pose a potential risk of fraud. However, when these factors combine, the risk could be amplified, suggesting the need to address them preventively and/or remedially. Based on the data collected, the hypothesis regarding the existence of variations in fraud risks was confirmed, concluding that these changes present a positive trend and can be effectively associated with the elements that make up the fraud cycle.

In this context, the mention of fraud risk should not be understood as a diagnosis of fraud in the analyzed market, but rather as a reflection on how certain economic, institutional, organizational, and market dynamics can create an environment prone to its emergence, even in systems committed to organic certification. This approach responds to the objective of understanding fraud risk as a multi-causal process encompassing various dimensions (individual, organizational, political, and consumer), allowing for a broader and more in-depth view of its causes. Finally, this analysis serves as a wake-up call to the actors who shape the theory of change in the certification system, especially regarding the relationship between the government, committees, and operators. It is essential that they strengthen collaboration and oversight mechanisms to mitigate risks and safeguard the integrity of the system.

This analysis moved beyond the linear view that attributes fraud exclusively to economic motivations. By considering economic, institutional, and organizational factors in an integrated manner, a more complex and multifaceted understanding of the risks associated with fraud was achieved. This approach recognizes that, although economic incentives are an important element, they are not the only determinants of fraud. Incorporating stakeholder perceptions, identifying potential internal tensions within the certification committee, and assessing the trust placed in governance structures could contribute to a more realistic characterization of the environment. The existence of latent conflicts, insufficient technical resources, or ambiguity in certification processes also represent specific manifestations of risk conditions. Identifying these dynamics implies a structural fragility that requires attention. The coordination of diagnosis, prevention, and strengthening from the organization, but also from the government, is essential to preserve the credibility of the certification system. In this sense, risk management should not be limited to ex post controls, but should include mechanisms for social monitoring, continuous improvement, and participation of the stakeholders involved.

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AGRICULTURAL TECHNOLOGIES IN MEXICO: A REVIEW OF DEVELOPMENT APPROACHES AND STRATEGIES FROM A RURAL PLANNING PERSPECTIVE

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Abstract

This review analyzes the relationship between agricultural technology and rural development strategies in Mexico, using an inclusive and territorially differentiated planning approach. Through a narrative review with evaluative elements, it examines structural, institutional, and cultural barriers that limit technology adoption by small-scale producers. It identifies deficiencies in the coordination between research centers, public policies, and local actors, as well as the predominance of top-down transfer models. The analysis proposes strengthening territorial innovation systems that integrate participatory co-innovation, cultural relevance, and community-based research. It also proposes differentiating strategies according to the type of agriculture (peasant, corporate, and export) to allocate resources with distributive justice, equity, and efficiency. The study concludes that innovation in rural areas is a technical, social, and political process that requires a profound redesign to contribute to equity, sustainability, and territorial justice.

Keywords: rural development, agricultural innovation, technology transfer, territorial planning.

Introduction

Rural development has been one of the most complex challenges for public policies in Latin America, particularly in countries like Mexico, where structural inequality between the countryside and the city is manifested not only in terms of income or infrastructure (De Janvry & Sadoulet, 2004), but also in access to knowledge, technology and innovation (Sanabria, 2013). In this context, the incorporation of agricultural technologies has been promoted as an indispensable means of increasing productivity, reducing poverty, and closing the gaps between producers. However, the way in which these technologies have been generated, disseminated, and adopted has been marked by a profound disparity between their potential benefits and their actual transformative capacity in the most disadvantaged sectors (peasants, rural women and youth, indigenous and indigenous peoples, among others) (Binswanger, 1991).

Agricultural technology encompasses innovations, inventions, and discoveries that enable people to improve agricultural production and productivity (Sharma *et al*., 2022), encompassing equipment, inputs, and practices such as improved seeds, fertilizers, automated irrigation, machinery, and digital practices applied to crop management. These technologies are often developed in research centers and multinational companies, disseminated through standardized strategies, often without an assessment of the social, ecological, and economic contexts where they will be implemented (Cernea, 2005; Figueroa, 1990).

The relationship between agricultural technology and derived benefits requires review from an inclusion perspective. Agricultural development policies have tended to assume that simple technology transfer automatically leads to improvements in rural productivity and income. This linear approach has been widely criticized for omitting structural barriers, such as lack of credit, technical assistance, infrastructure, or markets, which hinder the effective adoption of technologies by small producers (Echeverría & Elliott, 2002; World Bank, 2006).

The problem identified in this review lies in the persistent gap between technology generation and its effective adoption by small-scale producers, who face multiple constraints: low levels of investment and financing that limit research and development of improved varieties; a lack of stable regulatory frameworks, high development costs, liability risks, and limited experience in managing biotech crops; as well as weak seed systems and markets and agricultural support services (Anthony & Ferroni, 2012).

Technological solutions designed by research centers and multinational corporations often respond to the logic of export and profitability. Even public policies have prioritized increasing yields with limited results in reducing poverty (Berdegué, 2002). In this context, state action tends to focus on the dissemination rather than the generation of technologies adapted to the region, neglecting the strategic role of universities and local research.

Faced with this situation, rural development planning requires reinterpretation as a dynamic, integrative process adapted to territorial specificities. Rather than limiting itself to designing policies focused solely on increasing productivity, it is necessary to formulate strategies that recognize the diversity of actors, territories, resources, and institutional capacities. This requires decentralizing innovation, strengthening local capacities, and directing efforts toward generating localized knowledge (from the territories), constructed in a participatory manner and with an explicit commitment to social equity. As Schejtman and Berdegué (2004) argue, rural territorial development must transcend economic accumulation to consider the social, institutional, and cultural conditions that make innovation possible.

The objective of this review is to critically analyze the relationship between agricultural technology and rural development strategies, incorporating a perspective that recognizes planning as a junction of capabilities, resources, and public policies. It is proposed as a theoretical and methodological contribution aimed at promoting more equitable, sustainable, and effective rural development paths.

Methodology

This research is based on a narrative review with an emphasis on evaluative elements. The review is understood as an interpretive and reasoned analysis of the scientific, technical, and institutional literature related to agricultural technologies and their connection with development strategies from a planning perspective. Unlike systematic reviews, which focus on answering specific empirical questions using quantitative synthesis methods, narrative reviews offer a more flexible and comprehensive approach, especially relevant for addressing the complexity inherent in the interaction between technology, public policy and rural development (Vera-Carrasco, 2009; Guirao-Goris *et al*., 2007).

This type of review allowed for the integration of multiple theoretical approaches and empirical cases, the identification of knowledge gaps, and the development of conceptual proposals that address the structural challenges observed in the literature. The incorporation of evaluative elements also involves critically assessing the quality, applicability, and relevance of the reviewed approaches, considering their actual or potential impact on small-scale producers and historically excluded rural areas.

Thus, the documents and sources selected for this review respond to four thematic criteria that guide the search and analysis of the material: 1) technologies in agriculture, which considered texts that address the processes, approaches and results of the dissemination of technological innovations (such as improved seeds, fertilizers, irrigation, machinery, digital technologies), especially in Latin American rural contexts, prioritizing documents that critically analyze the gap between technology generation and adoption; 2) rural development planning, which included sources that conceptualize territorial, strategic and participatory planning in rural areas, focusing on the institutional mechanisms for articulation between levels of government, social actors and development objectives; 3) agricultural policies, which included documents analyzing regulatory frameworks, structural reforms, subsidy schemes, rural extension, and trade agreements as determinants of technological access and appropriation; and 4) agricultural development models, which selected texts that explore historical and contemporary models of agricultural sector development (conservationist, industrial-urban, diffusion, high-profitability inputs), including the differentiated effects based on the scale of production and type of agriculture (peasant, corporate, export).

For the selection of documents based on the thematic criteria, relevance, timeliness, theoretical foundation, and regional applicability were considered. The inclusion of different epistemological perspectives was also assessed: structuralist, institutional, critical, and territorial. Thus, the review was based on a selection of documents composed of academic, institutional, and technical sources from recognized authors, research centers, and multilateral organizations (Table 1).

Table 1. Document selection criteria.

Thematic criteria	Sources	Applicability
Academic and theoretical literature	Figueroa (1990);	Structural analysis of agricultural development and rural poverty
	Schejtman y Berdegué (2004);	Rural territorial development proposal
	Rogers (2003).	Classical theoretical basis on the diffusion of innovations
International institutions and organizations	Documents of the CIMMYT, CIAT, IRRI y CIP;	Emphasis on strategies for technological generation and diffusion
	technical reports of the FAO;	Inclusive agricultural innovation, food security and rural extension
	Reports of the CEPAL.	Development planning, territorial inequality and agricultural policies
Public policies and legislation	Review of national initiatives.	Analysis of agricultural policy programs in Mexico and Latin America
		Rural extension, support for small producers and technology transfer
Case studies	Technical reports, theses, institutional documents and grey literature.	Critical analysis of the current model

Source: Self-elaborated with data from the review.

The search was conducted in a targeted manner using databases such as Scopus, Redalyc, Scielo, Google Scholar, and institutional portals (FAO, CEPAL, CIMMYT), prioritizing materials published in the last two decades, without excluding fundamental classic texts.

Document analysis was carried out in four sequential phases (Figure 1). The first phase involved analytical reading and thematic coding. This stage included categorizing the texts according to theoretical approaches, scales of analysis (local, national, global), and type of actor (institutional, community, international). The second phase involved identifying recurring patterns in the transfer process, proposed solutions, the role of universities, and the direction of production.

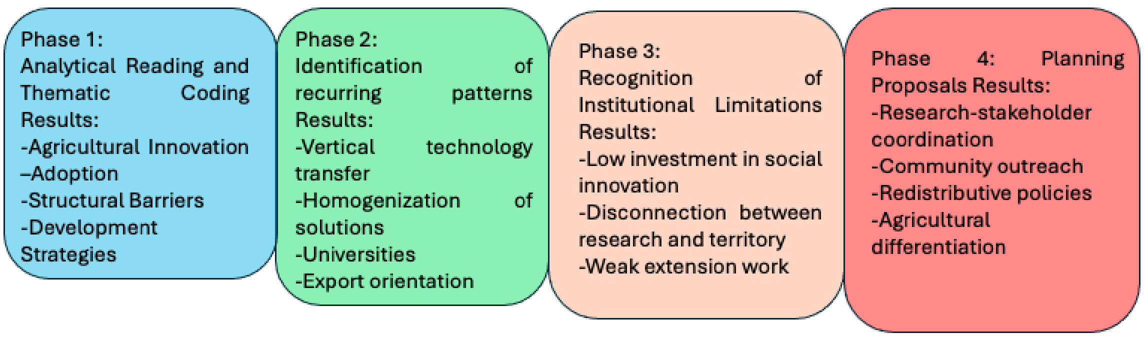

Figure 1. Phases of documentary analysis.
Source: Self-elaborated.

The third phase focused on recognizing institutional limitations, including the disconnect between research centers and rural areas, as well as the weakness of extension work as a planning and support tool. Finally, the fourth phase involved identifying overcoming proposals, such as networked social innovation, participatory knowledge generation systems, the development of appropriate technologies, university-community coordination, and stakeholder-focused territorial planning.

Overall, the study provided a critical interpretation that serves as a basis for analyzing agricultural development planning strategies from an inclusive perspective.

Conceptual foundations

Agricultural development strategies

An analysis of agricultural development strategies in Latin America, and particularly in Mexico, allows for the identification of at least four models that have guided state and international agency intervention in rural areas: the conservation model, the urban industrial impact model, the technological diffusion model, and the high-profitability input model.

The conservation model emphasizes preserving traditional rural production conditions, valuing peasant knowledge (Cervantes-Herrera *et al*., 2016), natural resources, and recognizing cultural diversity, but without generating significant transformations in the productive structure or in the market integration of producers. A potential limitation is that it may not generate significant transformations in the productive structure, sustainably improve income, or fully integrate with national development.

The urban industrial impact model is based on the subordination of agriculture to the needs of urban industrial growth. In this approach, the countryside serves as a food supply and resource transfer for industrialization, as occurred during the import substitution model in Mexico (Kay, 2009). Agriculture is not conceived as a strategic sector, but rather as a functional support for urban-industrial growth.

The technology diffusion model (Rogers, 1983) promotes the transfer of externally generated innovations to the agricultural sector through institutional mechanisms such as rural extension, training services, and technology adoption programs. Although this model has been effective in explaining technological changes, such as that of organic agriculture (Padel, 2001), it has also been criticized for its poor adaptation to local contexts and for primarily benefiting producers with greater capital and organizational capacity.

Finally, the high-yield input model is based on technological packages intensive in external inputs (improved seeds, fertilizers, pesticides, machinery), the adoption of which requires high levels of investment. This model is closely linked to the Green Revolution paradigm, which, while allowing for productivity increases in certain regions, deepened structural inequality by excluding low-income producers (Altieri & Nicholls, 2008).

Figueroa (1990) identifies two major structural constraints on agricultural development: the rigidity of agricultural supply and the excess of rural labor. The former refers to the inability of the agricultural sector to respond efficiently to changes in demand, due to factors such as technological backwardness, land concentration, and limited productive infrastructure. The latter refers to the relative overpopulation in the countryside, which results from the low capacity to absorb employment in the urban-industrial sectors, maintaining a large mass of workers in conditions of low productivity and poverty. Both constraints interact to generate a vicious cycle of rural poverty, where low productivity prevents income improvements, and the absence of employment alternatives perpetuates dependence on agricultural work, often under subsistence conditions.

From the structuralist perspective, represented by authors such as Prebisch (1950) and Furtado (1961), agricultural development cannot be conceived as a homogeneous or automatic process. Active state intervention is required to modify the structures that reproduce inequality. In this sense, the linear view of modernization is criticized, which posits an inevitable transition from "traditional" to "modern" forms of production, ignoring the social conflicts, power relations, and structural conditions that impede this transition.

Structuralist approaches claim that agricultural development models exported from developed countries are inadequate for Latin American realities, and that the uncritical adoption of technologies can deepen the marginalization of peasant sectors (Kay, 2009; Echeverría & Elliott, 2002).

Diffusion of innovations

The diffusion of innovations theory, proposed by Rogers (2003), establishes that the adoption of new technologies occurs through a process in which individuals or social groups go through the stages of awareness, persuasion, decision-making, implementation, and confirmation. This process depends on communication channels (formal and informal), the time it takes for each individual to adopt the innovation, and the social characteristics of the system.

Rogers (2003) identified five types of adopters: innovators, early adopters, early majority, late majority, and laggards. According to this theory, the adoption rate depends on the innovation's compatibility with users' values and needs, its complexity, observability, relative advantage, and testability.

Although Rogers' model has been widely used, its application in rural contexts in the Global South has been questioned. Vertical diffusion, from international research centers to rural communities, has proven ineffective in many cases. This type of transfer ignores local conditions, social dynamics, and the ancestral knowledge of producers. Furthermore, it reproduces relationships of technological dependence and limits food sovereignty (Cernea, 2005; Altieri & Toledo, 2011).

The main criticism is that this transfer model assumes producers are passive agents, recipients of external knowledge, when they are active subjects with their own knowledge and distinct rationales. The lack of contextual adaptation and participation in knowledge generation has been one of the causes of the failure of many agricultural innovation programs.

ONGs, international organizations such as the FAO, the BID, the WB, and international research centers (CIMMYT, CIAT, IRRI, CIP) have for decades promoted the dissemination of agricultural innovations with the goal of reducing poverty and increasing productivity. While they have achieved significant successes, particularly in strategic crops, their impact on rural sectors has been limited due to the technocratic nature of their approaches and the lack of coordination with local institutions.

The market, for its part, acts as a selective diffusion mechanism, where the most profitable technologies expand rapidly, while those that do not guarantee immediate benefits are left behind. This deepens inequalities, as low-income producers cannot access high-cost technologies or compete with large agroindustries (Schejtman & Berdegué, 2004).

Rural development planning

Rural strategic planning is understood as a decision-making process aimed at the structural transformation of rural areas, which articulates stakeholders, resources, knowledge, and public policies based on shared objectives. Unlike normative and centralized planning, strategic planning is based on environmental analysis, the recognition of local capacities, and the participation of multiple stakeholders (CEPAL, 2015; FAO, 2020). This approach allows for the design of differentiated strategies according to the characteristics of the area, overcoming the homogeneity with which rural policies have traditionally been conceived.

Administrative and political decentralization is a key component for effective rural development planning. It involves transferring powers and resources to local governments and encouraging the active participation of communities, peasant organizations, universities, and other territorial stakeholders (Bebbington, 2007).

The territorial approach proposes understanding development not only as economic growth, but as a process of social construction that recognizes cultural identity, local ecosystems, and the history of the territory. This entails replacing top-down intervention models with participatory planning processes, where rural stakeholders themselves define priorities and solutions.

One of the most persistent shortcomings of innovation and development policies has been the failure to differentiate strategies based on the type of market to which production is directed. While agriculture for export requires specific standards, certifications, and technologies, production for local markets or self-consumption requires adapted, accessible, and culturally relevant innovations.

Differentiated rural planning allows for the design of specific policies for peasant agriculture, focused on improving access to appropriate technology, basic infrastructure and short marketing channels, without requiring their transformation into agro-exporting companies (Altieri & Toledo, 2011).

Review of the Mexican experience

The history of economic development in Mexico, particularly during the import substitution period (1930–1982), reflects a clear subordination of the agricultural sector to the national industrialization project. During this period, the State implemented a development strategy focused on the growth of the urban-industrial sector, using rural surpluses in the form of cheap food, low rural wages, and fiscal transfers to finance industrialization (Appendini, 2001; Warman, 2001). This orientation meant that, far from being a priority sector in itself, agriculture was conceived as a source of resources for other sectors, specially manufacturing, which led to a systematic neglect of its structural and innovative capacities.

During the 1940s and 1950s, agricultural growth was promoted through major hydraulic infrastructure projects, support for strategic crops, and public credit, enabling a significant expansion of production. However, these benefits were concentrated in the most productive regions and among farmers with greater access to land, credit, and technology. Beginning in the 1960s, with the consolidation of the Green Revolution model, the logic of agricultural intervention shifted toward a technocratic approach, with an emphasis on productivity and yield, to the detriment of social equity (Hewitt, 1976).

This functionalist view of agriculture limited the possibility of building a solid foundation for rural development. The Mexican countryside was divided between a technologically advanced, export-oriented corporate agriculture and a backward peasant agriculture with limited access to resources, technical assistance, and technological innovation (Calva, 2001).

The introduction of the high-yield input model, promoted by the Green Revolution programs in partnership with international research centers, marked a radical shift in the logic of agricultural production. This model promoted the intensive use of improved seeds, fertilizers, pesticides, machinery, and technical irrigation, with the goal of significantly increasing productivity per hectare.

Although this approach achieved significant increases in staple grain production, it also generated profound segmentation in access to and utilization of available technologies. Its implementation was largely directed toward areas with high agricultural potential, where infrastructure and capital existed to absorb the costs of technological packages, excluding large sectors of peasants and small-scale producers (Toledo, 1990; Altieri & Toledo, 2011).

The model failed to consider the structural limitations of small producers, such as access to credit, land, or markets. It also failed to offer solutions adapted to diverse agroecological conditions, nor did it value local knowledge. Consequently, the technologies promoted were neither affordable nor relevant to those most in need of improved productivity. This exclusion fueled a cycle of marginalization, loss of autonomy, and rural migration, consolidating a dual pattern of agriculture in the country: on the one hand, agribusiness integrated into international trade; on the other, impoverished peasant agriculture (Calva, 2001; Eakin, 2005).

The technology transfer system in Mexico has been characterized by a centralized and vertical logic (Solleiro *et al.*, 2017). For decades, the main decisions regarding research, development, and technology dissemination were made by national government agencies or international centers, with little participation from local governments, regional universities, or the producers themselves.

This model was based on the idea that technology could be developed in a specialized center and then disseminated to rural areas through extension or training programs. However, this logic failed to consider the cultural, ecological, and socioeconomic diversity of Mexican rural areas. In fact, it has been found that even in rural areas operated under the same program, the effects have been heterogeneous due to the cultivation orientation and the use of certain innovations such as seeds or machinery (Ramírez *et al.*, 2022). The transferred technologies were, in many cases, inadequate for local conditions, both due to their cost and their technical design (Altieri & Nicholls, 2008).

In contrast, a decentralized approach to technological innovation would involve the coordination of local actors such as producers, universities, technicians, and municipal governments in the generation, validation, and adoption of adapted technologies. This participatory model would allow for the development of more relevant, accessible, and sustainable solutions. Successful experiences with agroecological innovation, such as those promoted by peasant organizations or autonomous universities, show that decentralization can significantly improve technological appropriation processes and strengthen productive autonomy (Altieri & Toledo, 2011; Bebbington, 2007).

One of the main weaknesses of Mexico's agricultural development system has been the disjointed nature of the most important components of the innovation process: research, strategic planning, and operational implementation. This fragmentation is reflected in the existence of programs that are technically well-designed but lack connection to local capacities, lack inter-institutional coordination, and have little evaluation of results.

In many cases, research agendas have been defined from a technocratic or commercial perspective, failing to address the real needs of the territories. State planning, for its part, has operated in a sectoral manner and has been insensitive to the heterogeneity of the countryside. Finally, implementation mechanisms, such as rural extension, have suffered from budget cuts, deprofessionalization, or political capture (Boege, 2008; FAO, 2020).

As a result, the knowledge generated by research centers does not effectively reach producers. At the same time, agricultural development plans are often disconnected from local realities, and public policies reproduce a homogeneous and reductionist vision of the rural world.

Rural development planning that seeks to be effective must correct these flaws by creating territorial innovation systems that coherently integrate research capabilities, local demands, and implementation mechanisms with a participatory and multi-stakeholder approach (Schejtman & Berdegué, 2004; CEPAL, 2015).

Towards more effective planning

The analysis of Mexico's experience in agricultural technology development revealed the persistence of structural limitations and institutional practices that limit technological innovation processes among small producers. This scenario raises the need to reorient rural planning toward an inclusive, decentralized, and participatory model capable of recognizing and leveraging the country's agroecological and sociocultural diversity. Within this framework, the proposals seek to strengthen institutional capacities, optimize territorial coordination, and establish differentiated innovation frameworks that respond to the specificities of each region.

Agricultural innovation in Mexico has historically depended on international institutions and organizations that identify the sector's problems and potential solutions. However, these centers operate under global frameworks that prioritize technology standardization. More effective planning requires reorienting efforts toward coordination between national research centers and regional public universities, which possess contextualized knowledge, community collaboration networks, and underutilized technical capabilities (Boege, 2008).

National agricultural universities and research centers possess strategic advantages, such as location, experience, talent, and infrastructure, that enable them to lead the development of rural human capital, essential elements for economic and social development. Through job training systems, innovative models, and learning communities, they can provide the intellectual support necessary to modernize agriculture and boost the local economy (Yun-feng, 2012).

On the other hand, there is evidence suggesting that higher education with a territorial focus is not only relevant at the basic levels, but also at the university level, where it can be articulated with regional networks and innovation systems. This allows institutions to act as development hubs, adapting their teaching and research to the needs of the territory and fostering the transfer of knowledge to producers, entrepreneurs, and communities (Bryden, 2007).

At the same time, higher agricultural education institutions can expand their reach beyond the agricultural sector, strengthening the sustainable management of natural resources and connecting with other educational levels. Through partnerships with local stakeholders and dialogue with public policymakers, they can become beacons of local tradition and knowledge, while integrating global innovations. Thus, these institutions consolidate their position as catalysts for rural development, poverty reduction, and food security (Atchoaréna, 2005).

This coordination could give rise to local innovation systems in which the processes of experimentation, validation, and technological adaptation respond to the specific needs of each territory. Such systems, by incorporating agroecological and sociocultural diversity, would overcome the vertical and homogeneous orientation of technology transfer, favoring the relevance and sustainability of solutions. They would also contribute to strengthening local capacities through training processes, internships, field placements, and knowledge generation with direct participation of producers, strengthening the links between universities, communities, and research centers. Finally, this approach would facilitate multi-stakeholder territorial coordination, integrating public policies, institutional resources, and local knowledge into differentiated innovation schemes aimed at inclusive rural development.

The persistence of institutional barriers in agricultural extension processes is reinforced by cultural factors. One of the main shortcomings of the traditional extension model has been its weak anchoring in the sociocultural realities of the Mexican countryside, evidenced by the implementation of outreach programs that have ignored the linguistic diversity, traditional knowledge, worldviews, and agroecological practices of indigenous and peasant communities. The prevalence of mechanistic and unidirectional approaches, lacking consideration for local ecological conditions, has limited its effectiveness (Altieri & Toledo, 2011).

Rebuilding institutional capacities for technology dissemination, from a culturally and ecologically relevant perspective, requires the training of extension workers with intercultural competencies, active listening skills, pedagogical skills, and agroecological knowledge. It also demands strengthening ties between institutions, communities, and social organizations through the adoption of participatory methodologies that promote the dialogue of knowledge and the co-creation of solutions.

In this context, the implementation of a community outreach program inspired by the rural doctor model appears to be a viable option. This model, based on the incorporation of trained young professionals who spend time in rural communities, live with their residents, and participate in the diagnosis and resolution of productive problems, has proven effective in the field of public health by reducing territorial gaps through proximity, building trust, and personalized care (Guirao-Goris *et al*., 2007).

Translating this approach to the agricultural sector would involve community internships by graduates of agricultural, environmental, or related programs, under institutional support. The constant presence of these professionals, combined with their technical knowledge and integration into the community, would facilitate adaptive diffusion processes aimed at the adoption of innovations and strengthening local capacities. This process could lay the foundation for the development of rural youth leadership, with the potential to revitalize the social fabric of the countryside and reduce forced migration.

The effectiveness of this model requires the provision of institutional incentives, technical monitoring mechanisms, and coordination with universities, research centers, and local governments. Incorporating participatory evaluation components, ongoing training, and generating evidence on the results achieved would be key to its sustainability.

On a broader level, tariff and pricing policies have played a decisive role in structuring Mexican agriculture. However, their design has disproportionately favored certain business sectors, without considering the redistributive impacts on the peasant production base. Equity-oriented planning requires evaluating these policies based on criteria of distributive justice, regional equity, and economic sustainability (Calva, 2001; CEPAL, 2015). A comparison between the Sugarcane Product System and the coffee value chain in Mexico clearly illustrates the resulting asymmetries, (Table 2).

Table 2. Asymmetries of sugarcane and coffee.

Aspect	Cane Product System	Coffee Value Chain
Predominant type of producer	Large agro-industrialists and ejidatarios with contract	Small producers, mostly indigenous
Market orientation	National and industrial (refinery)	Export and promotion of niches (organic, fair trade)
Intermediation	Highly regulated	Highly fragmented
Pricing policy	Negotiated centrally with agribusiness	Fluctuating, dependent on the international market
Government supports	High, focused	Dispersed, with territorial programs

Source: Self-elaborated.

While sugarcane receives concentrated support and preferential tariffs, coffee, with more than 500,000 small producers, suffers from international market volatility and limited institutional support. This disparity highlights the urgent need to design differentiated instruments that recognize the structural conditions of each chain and promote equity in access to the benefits of agricultural trade (SIAP, 2022; SAGARPA, 2018).

Differentiation of planning by type of agriculture

Agricultural planning requires recognition of the structural heterogeneity of the Mexican countryside, characterized by the coexistence of agricultural forms with divergent logics, capabilities, and needs. The imposition of uniform policies has resulted in ineffectiveness and regressive biases, systematically favoring the most established actors.

The differentiation of planning into three axes constitutes a strategy to optimize the allocation of resources and maximize impacts:

Peasant agriculture, whose sustainability demands the strengthening of comprehensive support in access to land, appropriate technologies, short marketing channels, solidarity financing and training, in order to dignify its role as a food producer, custodian of biodiversity and cultural actor (Altieri and Nicholls, 2008).

Corporate agriculture, which requires the establishment of incentives linked to job creation, integration with regional chains, and compliance with socio-environmental standards, based on criteria of sustainability, social responsibility, and environmental compliance.

Export agriculture, for which regulations that prevent social exclusion, water hoarding, and environmental degradation are essential, complemented by fiscal, tariff, and investment policies aimed at comprehensive territorial development.

The implementation of this differentiation scheme would promote a more equitable and efficient distribution of public resources, increasing productivity, social inclusion, and sustainability, and strengthening the resilience and sovereignty of the agri-food system.

Conclusions

The analysis of agricultural development strategies and technological innovation processes in Mexico highlights the need to rethink rural planning from an inclusive, territorially differentiated, and socially just perspective. The research shows that the dominant technology transfer model, focused on vertical and standardized solutions, has limited adoption by small producers by failing to consider the agroecological and sociocultural realities of the territories.

It is observed that the coordination between universities, research centers, government agencies, and community actors is essential for building territorial innovation systems. These systems must integrate applied research, participatory co-innovation, and community outreach, ensuring that knowledge generation responds to local needs and potential.

Likewise, planning must differentiate strategies and instruments for small-scale, corporate, and export agriculture, allocating public resources and regulatory frameworks equitably and efficiently. Only in this way will it be possible to promote a resilient and sustainable agrifood system capable of reducing the structural gaps that persist in the Mexican countryside.

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ANALYSIS OF THE GLOBAL COMPETITIVENESS INDEX: KEY FACTORS FOR MEXICO

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Abstract

The World Economic Forum created the Global Competitiveness Index (GCI) to assess and compare competitiveness among nations, given that a competitive country tends to offer better living conditions to its population. The objective of this study was to identify the factors that influence a country's competitiveness according to the 2019 GCI and to conduct a specific analysis of Mexico. To this end, a cluster analysis was performed to classify all countries into low, medium, and high competitiveness categories. The possible reasons behind Mexico's poor performance in this index were investigated. The results revealed that innovation capacity and ICT adoption are key factors that distinguish the most competitive countries from the least. Although Mexico stands out for its economic stability and significant market size, it has significant deficiencies in areas such as education, innovation, and institutions. However, simply increasing the budget allocated to research and development does not guarantee greater innovative capacity, as adequate infrastructure and trained human capital are required to effectively implement innovation.

Keywords: systemic competitiveness, GDP, institutions, government, innovation.

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Introduction

Addressing competitiveness involves understanding the problems of the development scenario of national economies in a global economic context, and considering the different factors required by different economies, particularly those in the process of development (Suñol, 2006). In this sense, a nation's competitiveness should not be viewed as an increase in investment in certain sectors of a country's economy, but rather as the result of a combination of various factors, such as the productive structure and the formulation of public policies implemented by governments, which lay the foundation for competitiveness in the regions and economic sectors involved.

Competitiveness indicators are useful for comparing one economy with another, and there are institutions specialized in competitiveness analysis. One of them is the World Economic Forum (WEF), which has published the Global Competitiveness Report (GCR) since 1979. This index establishes an international competitiveness ranking using the Global Competitiveness Index (GCI). The WEF (Schwab, 2019) defines competitiveness as "the set of institutions, policies, and factors that determine an economy's level of productivity". The GCI is an information tool when developing and justifying public policy decisions, such as the formation of physical and human capital, investment in innovation, and the development of competition policy (Lall, 2001, p.1505)

The GCI is an information tool when developing and justifying public policy decisions, such as the formation of physical and human capital, investment in innovation, and the development of competition policy (Lall, 2001, p.1505).

The GCI has been criticized for its methodology (Lall, 2001), lack of theoretical support (Dong-Sung & Hwy-Chang, 2000), and the origin of its data (Benítez-Márquez *et al*., 2022). This indicator is characterized by assigning equal weight to the 12 pillars of competitiveness without theoretical justification, using information from official institutions in each country, conducting an opinion survey of the business sector, and considering economic and social variables. However, it omits issues related to the environment and economic specialization. Furthermore, it measures all countries equally, without considering individual characteristics such as size, economic development, preference for certain types of policies, and attractiveness to foreign investment, which are determining factors in the heterogeneity of relations between countries (Kudła *et al*., 2023).

In this exercise, the performance of the GCI was analyzed using information published through 2019, given its importance as a benchmark in systemic competitiveness studies and because it presents the state of the global economy prior to the health emergency and the conflict between Russia and Ukraine. The results are aimed at answering the questions: according to the GCI, what determines a country's competitiveness? or how can a nation with low or medium competitiveness level rise?

Thus, the objective of this study was to analyze the characteristics shared by countries with a similar competitive level according to the Global Competitiveness Index, to identify opportunities for Mexico. The premise of this contribution is that competitiveness is intrinsically linked to a nation's structural elements. Furthermore, this work contributes to the existing debate about what makes countries competitive.

Literature review

Evolution of theories on competitiveness

Smith (1776) laid the foundations for the theory of international trade and absolute advantage. Ricardo (1817) complemented this theory with the theory of comparative advantage, which establishes the choice to produce those goods that make the most efficient use of resources and import those that are cheaper to produce. Both theories were based on resource availability, cheap labor, and climatic conditions; however, the rise of industrialized capitalism motivated the intensive use of science and technology (Chesnais, 1990). Both theories were based on the availability of resources, cheap labor and climatic conditions, however, the emergence of industrialized capitalism motivated the intensive use of science and technology (Chesnais, 1990).

Both absolute and relative advantage emphasize that a competitive country is one that benefits from international trade. Aghion & Howitt (2009) explain that international trade has benefits such as the diffusion of knowledge from more advanced to less developed countries and an increase in each country's domestic productivity. Krugman (1994) and Porter (1991) consider that it is firms, not nations, that compete for market share. The international competitiveness of nations is associated with rivalry, as it refers to their performance relative to other countries (Voinescu & Moisoiu, 2015). Subsequent theories addressed other principles aimed at improving a country's export capacity.

For Krugman (1996), theories that link competitiveness with international trade constitute a mercantilist view that uses the pretext of generating employment to access markets. He also asserts that a country can trade goods thanks to productive and territorial specialization. On the other hand, the Offshoring Theory suggests that territorial specialization is no longer a determining factor of productivity, since activities that require low-skilled labor can be carried out in any territory without falling into diminishing returns, so that a product can be designed in country A but manufactured in country B and increase the GDP of country A (Grossman & Rossi-Hansberg, 2008).

Various definitions of competitiveness suggest that, for companies, it simply implies a sustained increase in investment and trade ties that maintain them in the global market. However, a current review of the concept clarifies that competitiveness is much more complex if we want to understand the behavior of economies that compete internationally. Thus, it is necessary to recognize that achieving true, sustained competitiveness over time will require the implementation of various policies to address the obstacles that may hinder its attainment.

In this sense, Porter (1991) states that the competitiveness of a country is achieved through the productivity of companies, in turn productivity is achieved through innovation and the efficiency of the workforce, thus the factors that induce the generation of competitive advantages of a nation are born, fundamentally, from improvement, innovation and change. Moon and Peery (1995) cited by Bhawsar and Chattopadhyay (2015) explain that while competitiveness is the position compared to competitors, productivity is the ability to obtain that position.

Both Porter (1990) and the Economic Commission for Latin America and the Caribbean [CEPAL by its acronym in Spanish] (Velásquez, 1995) suggest increasing labor productivity to reduce costs. While the overexploitation of labor, the exchange rate favoring developed economies, and trade barriers provide comparative advantages (Guzmán, 1997) and the objective of remaining in the market is met, there is no real effect on improving the population's standard of living.

A broader approach is structural competitiveness, which considers innovation a key factor, but for it to be achieved, it must be supported by the institutional capacity to foster it (Esser *et al*., 1996; Otero *et al*., 2006). Thus, the competitiveness of economies is an effect of the development of business modernization policies: technology, workforce and labor relations, equipment, and reorganization of work processes.

Based on structural competitiveness, Esser *et al*. (1994) propose the concept of systemic competitiveness, which is based on a set of interrelated measures aimed at specific objectives at four analytical levels of the system (meta, macro, meso, and micro). Thus, the objective of a country's competitiveness is to create the conditions for companies, sectors, and regions to be more productive and efficient, as this will result in better living conditions for the population (Birnie *et al*., 2019; Parola *et al*., 2016; Romo & Abdel, 2005; Velásquez, 1995).

Competitiveness according to the Global Competitiveness Index

According to Sala-I-Martin (2004), the GCI was created to complement the Growth Competitiveness Index developed by Jeffrey D. Sachs and John W. McArthur, and the Business Competitiveness Index developed by Michael Porter, under the premise that the macroeconomic and microeconomic determinants of competitiveness should not be separated, since the ability of companies to prosper depends on institutional effectiveness (Sala-I-Martin & Artadi, 2005).

Sala-I-Martin (2004) explains that the economic process depends on the macroeconomic environment, the quality of public institutions, and technology. Sala-I-Martin & Artadi (2005) defined competitiveness, for the GCI, as "the set of institutions, policies, and factors that determine a country's level of productivity; the level of productivity, in turn, establishes the sustainable level of prosperity that a country can achieve". The World Economic Forum (WEF) (Schwab, 2019: 2) updated the previous definition, identifying competitiveness as "the attributes and qualities of an economy that enable more efficient use of production factors".

The GCI was updated in 2018. Previously, each pillar had a different weight without a theoretical justification; after the update, all pillars had the same weight, since the WEF considered that economies should perceive the pillars that measure the degree of competitiveness of an economy from a holistic approach, being able to focus on their competitiveness without focusing on a single factor in particular and thus a good performance in one pillar does not compensate for a weak performance in another (Schwab, 2018).

Methodology

To accomplish the objective of this study, the analysis was conducted using a quantitative approach, as it is the most appropriate for comparing and processing the GCI database. The study has a correlational scope, as it seeks to understand the behavior of the competitiveness pillars that comprise the index and how they specifically affect Mexico.

It should be noted that until 2017, the GCI consisted of three sub-indexes: 1) Core Requirements, 2) Efficiency-Enhancing Factors, and 3) Innovation and Factor Sophistication. Beginning in 2018, with the Fourth Industrial Revolution (4IR), the new Global 4.0 index was introduced. This index emphasizes human capital, innovation, resilience, and agility as hallmarks of economic success in the 4IR. The index covers 141 economies, representing 99% of global GDP.

The GCI 4.0 is the aggregate product of 103 individual indicators, derived from a combination of data from individual organizations as well as the WEF Executive Opinion Survey. The indicators are organized into 12 pillars (Table 1). The GCI presents the results of each of its components as a "progress score" on a scale of 0 to 100, with 100 representing the "frontier," an ideal state in which the problem no longer hinders productivity growth. Each country should aim to approach the frontier in each component of the index. This approach underscores that competitiveness is not a zero-sum game between countries: it is achievable for all countries (Schwab, 2019).

In the initial phase of the analysis, a database was created using Excel software based on the 12 pillars of the GCI applied to 141 countries. 2019 was considered as it was the last year with complete data available. Furthermore, this period reflects the economic situation prevailing before the health emergency.

Using the database, the overall performance of the indicator and the performance of each country were examined using descriptive statistics using IBM SPSS Statistics (version 24). A cluster analysis was then performed to group countries with similar competitiveness to identify and compare the factors determining each

Table 1. The 12 pillars of the Global Competitiveness Index.

Pillar	Weight %	Number of variables		
		N	Quantitative	Qualitative
1. Institutions	8.30	26	11	15
2. Infraestructure	8.30	12	6	6
3. ICT adoption	8.30	5	5	0
4. Macroeconomic stability	8.30	2	2	0
5. Health	8.30	1	1	0
6. Skills	8.30	9	3	6
7. Product market	8.30	7	4	3
8. Labor market	8.30	12	3	9
9. Financial system	8.30	9	6	3
10. Market size	8.30	2	2	0
11. Dynamism in business	8.30	8	4	4
12. Innovation capacity	8.30	10	6	4
Total variables		**103**	**53**	**50**

Source: Self-elaborated based on Schwab (2018).

group's competitiveness. The clustering was carried out using the 12 pillars of competitiveness as variables to group 141 countries.

The hierarchical clustering method was used, applying the squared Euclidean distance and Ward's method (Mendenhall *et al.*, 2010). Tests were conducted with 3, 4, and 5 groups; three groups were selected because they showed the greatest difference with the other groups. To test for differences, the ANOVA test was performed to compare the means of each group, which revealed statistically significant differences.

The analysis for Mexico was conducted by comparing the country's performance with the results of its respective group and with the overall results. Mexico's ranking of the pillars of competitiveness was ordered from highest to lowest to identify the factors in which Mexico is least competitive.

Results and Discussion

Analysis of international competitiveness

The Global Competitiveness Index (GCI) for 2019 ranks Singapore as the most competitive country, with a population of 5.6 million in 2019, scoring above 70% across all competitiveness pillars. According to the World Bank (2023), for that year, 89% of its population had access to the internet, 100% had access to electricity, and its literacy rate was 97%.

In 2019, the Singaporean government allocated 19% of its total spending to education, compared to around 30% from 2011 to 2013. In contrast, the least competitive country was Chad, Africa, with a score below 45% in 11 of 12 pillars. The GCI top ten is consistent with the World Competitiveness Report (WCR) in seven countries and with the International Competitiveness Index (ICI) in six (Table 2).

Table 2. Most competitive countries according to each indicator.

GCI			WCR		ICI	
Range	Country	Sc	Range	Country	Range	Contry
1	Singapore	84.8	1	Singapore	1	Finland
2	USA	83.7	2	Hong Kong	2	Norway
3	Hong Kong	83.1	3	USA	3	Swiss
4	Holland	82.4	4	Swiss	4	Holland
5	Swiss	82.3	5	United Arab Emirates	5	Denmark
6	Japan	82.3	6	Holland	6	Ireland
7	Germany	81.8	7	Ireland	7	United Kingdom
8	Sweden	81.2	8	Denmark	8	Sweden
9	United Kingdom	81.2	9	Sweden	9	Japan
10	Denmark	81.2	10	Qatar	10	Canada
46 of 141	Mexico	64.9	50 of 63	Mexico	39 of 43	Mexico

Source: Self-elaboration based on the Mexican Institute for Competitiveness (2019), Schwab (2019), and the Mexican Institute for Competitiveness (2019).

Each index uses a different methodology and measures a different number of economies, so a country's advantageous position in one ranking does not mean it is more competitive than a country in a lower position in another ranking. In other words, a direct comparison between indicators is not possible. However, all three indexes highlight the importance of education, institutions, and economic policies in achieving competitiveness.

Figure 1 shows the descriptive statistics of the GCI, and it is observed that the distance between countries is most evident in innovation capacity, in which Germany is a leader. Some of the criteria considered in this pillar are research and development (R&D) expenditure, patents, scientific publications, and the prominence of institutions. In this regard, R&D World (2022) reported that in monetary terms, China is the country that invests the most in research, investing more than 2.1% of its GDP in 2022. On the other hand, in relative terms, Israel is the one that invests the highest percentage of its GDP, with 4.8% in 2022.

The same figure shows that Asian countries lead in several competitiveness factors: Singapore leads in the infrastructure and labor market pillars, while Hong Kong leads in goods and financial markets, China leads in market size, and Korea leads in ICT adoption. On the other hand, European countries are more efficient in institutions, education, and innovation capacity.

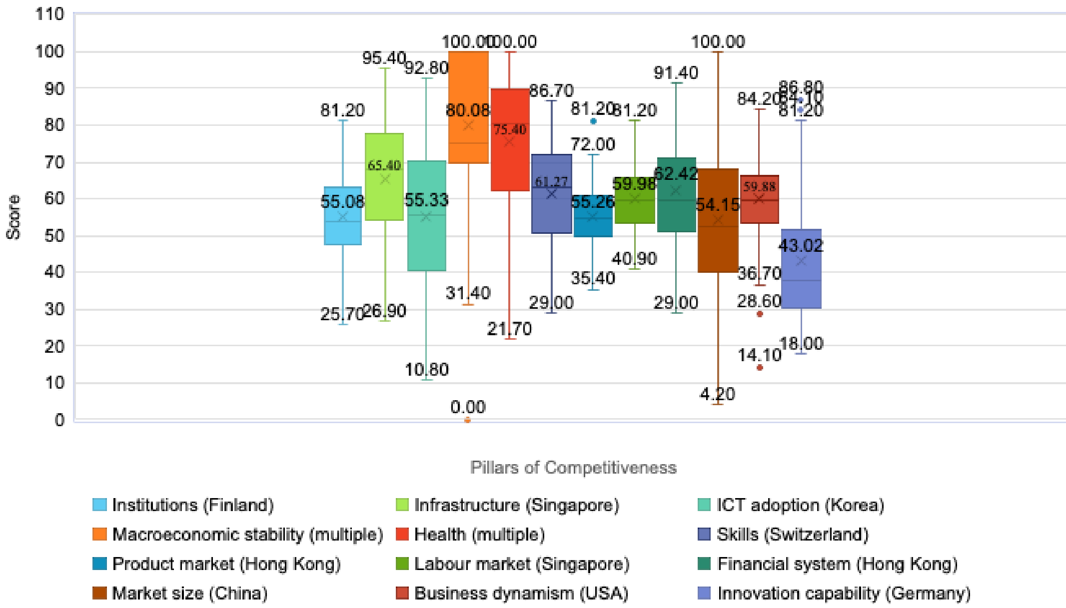

Figure 1. GCI–WEF descriptive statistics.
The leading country in each pillar is indicated in parentheses.
Source: Self-elaborated based on Schwab (2019).

Likewise, the Global Competitiveness Index showed that, at one extreme, there are countries with macroeconomic stability and market size scores of 100%, and at the other, countries with scores between 0% and 4.20% in the same pillars, indicating the disparity between economies (Figure 1). Macroeconomic stability depends on a country's control over its inflation levels. For example, Venezuela is the country that reported a score of zero in this pillar due to its uncontrolled inflation.

Figure 2, which reports countries with high inflation, shows that the inflation rates recorded by Argentina and Turkey are substantially higher. The other three economies remain at constant inflation rates, except for 2022. However, inflation had a global impact in that year, with consequences for all countries. For Mexico, these effects were smaller compared to the rest of the world.

Based on the twelve pillars of competitiveness, a hierarchical cluster analysis was conducted, allowing countries that share similarities across the GCI pillars of competitiveness to be grouped together. It was found that segmentation into three groups showed the greatest differences among them. Each group was named according to its level of competitiveness (Table 3). The three groups scored highest on the macroeconomic stability pillar and the lowest on innovation capacity.

There is a smaller gap between the three groups in the pillars of the goods market and the labor market (Figure 3). The variables considered within these pillars are

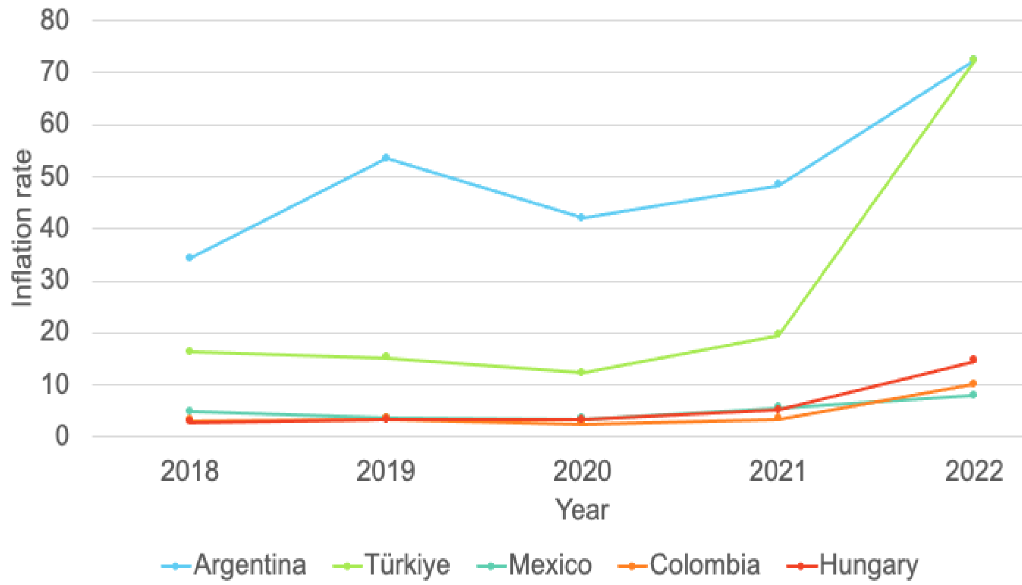

Figure 2. OECD countries with the highest inflation.
Source: Self-elaborated based on OECD (2023b).

Table 3. Cluster analysis of the 141 economies considering the 12 pillars of competitiveness.

Pillar of competitiveness	High (n=47)	Average (n= 63)	Low (n=31)	F	P
Institutions	67.82 ± 6.3[a]	51.86 ±7.90[b]	42.3 ± 6.71[c]	137.9	.000
Infrastructure	82.42 ± 7.14[a]	64.66 ± 6.95[b]	41.08 ± 7.47[c]	312.8	.000
ICT adoption	75.46 ± 11[a]	52.73 ± 8.03[b]	30.08 ± 9.82[c]	202.49	.000
Macroeconomic stability	97.6 ± 12.17[a]	75.35 ± 4.7[b]	63.13 ± 16.9[c]	90.91	.000
Health	89.80 ± 10.68[a]	77.59 ± 8.6[b]	49.14 ± 11.76[c]	148.35	.000
Education and skills	75.92 ± 7.43[a]	60.15 ± 6.15[b]	41.34 ± 7.91[c]	220.29	.000
goods market	63.29 ± 5.49[a]	53.52 ± 6.48[b]	46.62 ± 5.78[c]	79.5	.000
Labor market	68.26 ± 6.03[a]	57.9 ± 6.5[b]	51.65 ± 5.43[c]	76.68	.000
Financial system	75.66 ± 8.25[a]	60.61 ± 11.6[b]	46.02 ± 5.6[c]	102.08	.000
Market size	66.23 ± 16.33[a]	51.27 ± 14.79[b]	41.68 ±14.4[c]	25.64	.000
Business dynamisms	70.34 ± 6.73[a]	57.94 ± 6.93[b]	47.96 ±10.33[c]	82.13	.000
Innovation capacity	62.90 ± 6.05[a]	35.81 ± 13.8[b]	27.55 ± 4.44[c]	173.79	.000

Different literals represent statistically significant differences at 0.05%.
Source: Self-elaborated.

related to labor and economic policies such as labor rights, dismissal costs, economic barriers, and taxes and subsidies.

Some of these policies can generate advantages for countries, as they encourage other nations seeking to reduce production costs to relocate manufacturing operations

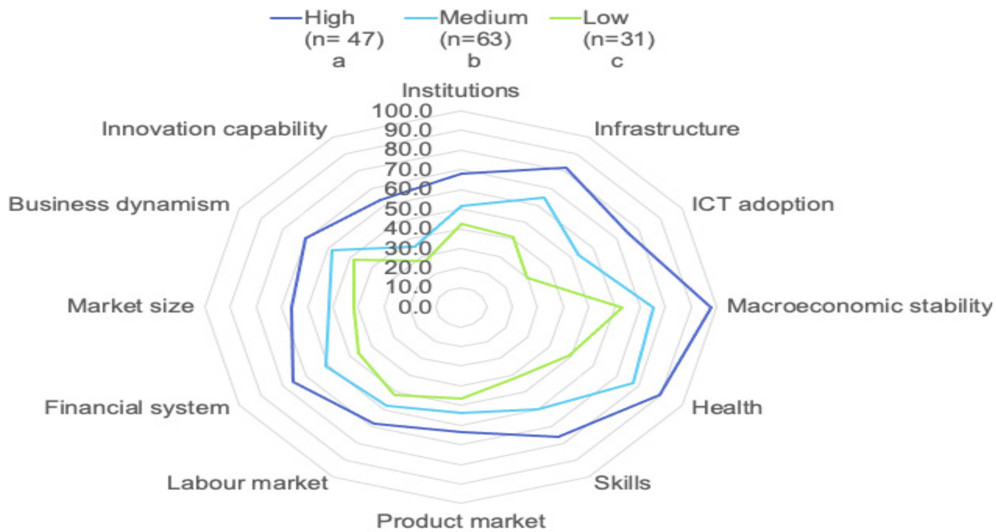

Figure 3. Comparison of the three groups with different levels of competitiveness. Different literals represent statistically significant differences at 0.05%.
Source: Self-elaborated.

to countries with labor flexibility. Roldan (2000) describes this type of competitiveness as "spurious" or passive and explains that it occurs when a government overexploits natural and human resources or implements tariff or subsidy policies solely to reduce the cost of domestic production.

The greatest gap between groups is observed in ICT adoption, health, and innovation capacity. The first two relate to a country's infrastructure and service capacity, that is, access to and availability of telecommunications and health services. Innovation capacity focuses on each country's ability to invest in the generation of skills and knowledge. Arredondo *et al*. (2016) determined that for Latin America, the variables that have the greatest influence on the innovation pillar are: capacity to innovate, quality of research institutions, government acquisition of advanced technology, and availability of scientists and engineers. Figure 4 shows the countries that comprise each cluster.

The high competitiveness group reflects the policy and resource orientation of advanced economies. On the one hand, their institutions are more transparent; on the other, their pillars of education, health, and infrastructure demonstrate that they provide basic services to their populations. These economies can afford to increase the quality of their teaching and research institutions and allocate more resources to the latter. However, this premise does not apply to all countries in the group, as China's competitiveness is determined by the size of its market (GDP in terms of purchasing power and imports of goods and services) and macroeconomic stability (inflation percentage and debt dynamics), not by the components.

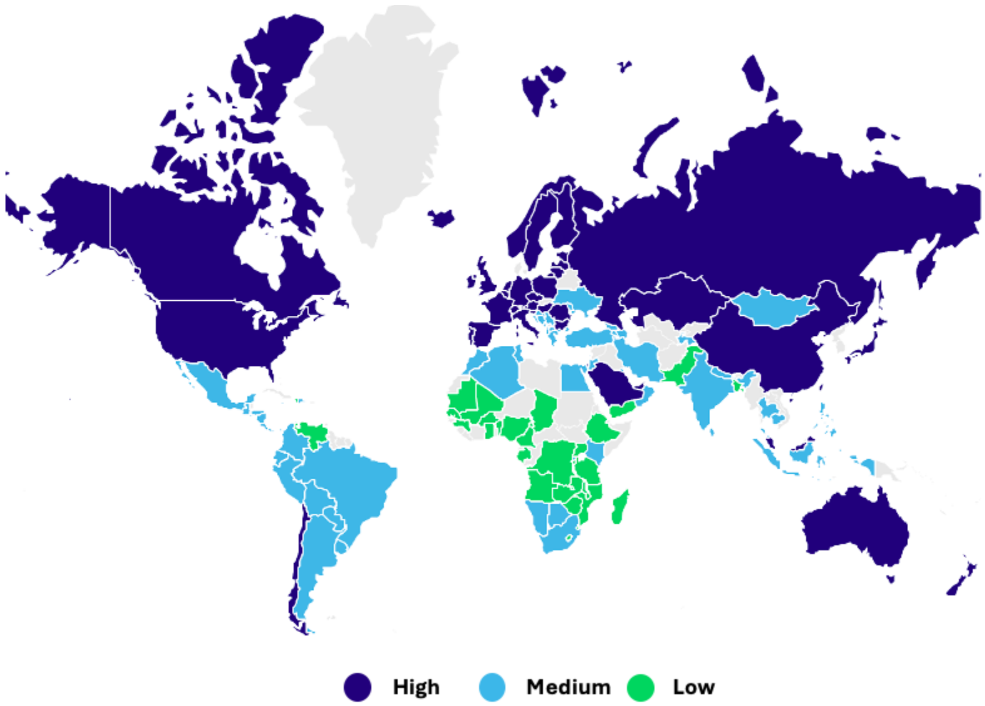

Figure 4. Countries that make up the clusters.
Source: Self-elaborated.

The medium competitiveness group has its highest scores in macroeconomic stability and health, while its lowest scores were in innovation capacity and ICT adoption. This group shows that policies are geared toward promoting the economy and meeting the basic needs of its population. In this regard, Melara-Gálvez & Morales-Fernández (2022) in the GCI analysis they made for the countries belonging to Central America, reported that the governments in the countries they analyzed should prioritize their intervention in the pillars of macroeconomic stability, infrastructure, health, ICT adoption and financial system.

The low competitiveness group is made up of 31 predominantly African countries. Ten of the 12 pillars in this cluster have scores below 50%. This indicates that these countries lack the capacity to meet their population's needs, such as health, education, and employment, and therefore focus their supply on cheap labor.

Although the indicator addresses social variables, its focus is on improving business sector productivity as the driving force of the economy. Environmental legislation is not considered, nor is it criticized for countries that maintain illegitimate competitiveness through export subsidies and import tariffs.

Finally, the labor market pillar is composed of 12 variables, three quantitative and nine qualitative, that indicate that to be competitive in this area, one must be flexible in hiring and firing practices, salary allocation, and the hiring of foreign labor, among others. This suggests a discrepancy between what the business sector considers competitive and labor rights.

Outlook for Mexico

Figure 5 presents Mexico's score and ranking position, the group to which the country belongs, and the overall scores for each of the GCI pillars. Although the country has higher scores than the global average in seven pillars, it is not among the top performers in the ranking. Mexico is ranked 11th thanks to its GDP performance and the proportion of imported goods and services relative to GDP.

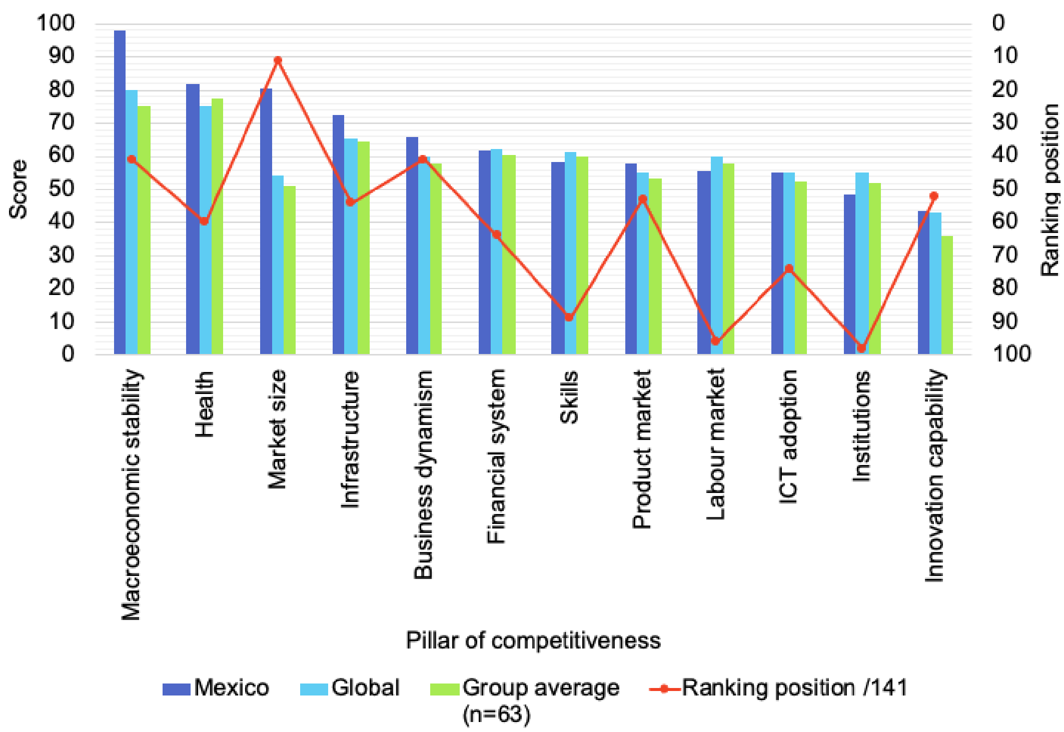

Figure 5. Comparison of Mexico's GCI score with respect to the global score and its group.
Source: Self-elaborated.

The country showed positive performance in macroeconomic stability, which, for GCI purposes, depends on inflation and debt dynamics. Over the last decade, GDP has remained steady; however, Figure 6 shows a decrease between 2019 and 2020 compared to the previous year, as did imports and exports. However, imports decreased more than exports, thanks to Mexico's continued exports of fruit and vegetable products to the United States.

Figure 6. Changes in Mexico's GDP and its components, 2010-2020.
Source: Self-elaborated with data of the International Monetary Fund (2020).

Mexico ranks lowest in the Institutions (98), Labor Market (96), and Education and Skills (89) pillars (Figure 5). The results in the Institutions pillar are driven by the business sector's perceptions of security, judicial independence, government efficiency, corruption, and government vision, among others. According to Transparency International (2021), Mexico has one of the highest corruption perception indices (Figure 7). In 2021, it was ranked 130 out of 180 countries with a score of 29 out of 100 (0 being high corruption and 100 being no corruption). At the other extreme is Denmark, the country with the lowest perception of corruption with a score of 88/100.

Trust in government is another indicator related to institutions and refers to the proportion of people who report having confidence in the national government. The data shown in Figure 7 reflect the proportion of respondents who answered yes to the question: In this country, do you have confidence in the national government? Unlike the previous indicator, Mexico shows an increase in confidence in its government since 2018.

Regarding the labor market pillar, the result is due to the low scores it received in the following areas: how much it costs to fire a worker; hiring and firing practices; and active labor market policies. Regarding the education and skills pillar, Mexico's results are based on average years of schooling, graduates' skills, and the ease of finding qualified employees. As mentioned above, most of this data comes from the executive opinion survey conducted with the business sector.

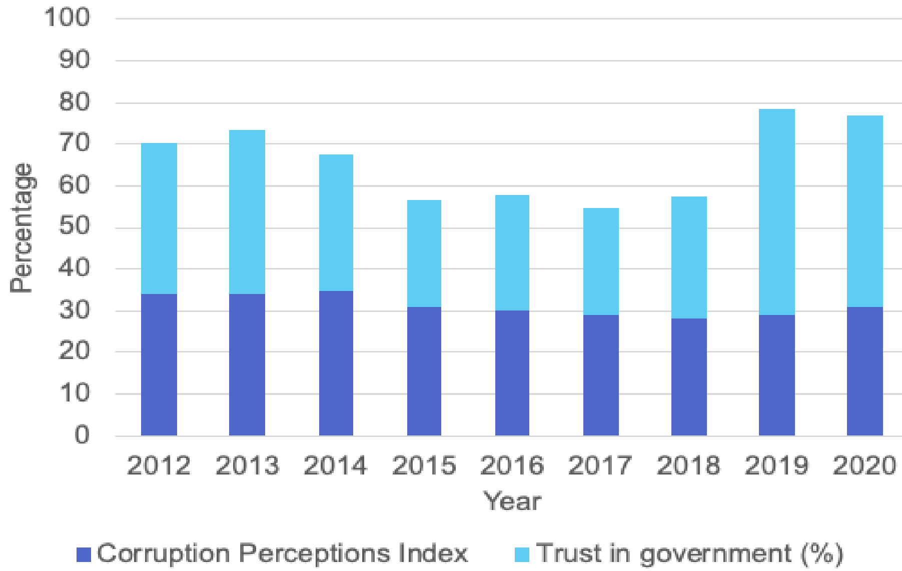

Figure 7. Confidence in government and corruption perception index.
Source: Self-elaborated with data the Transparency International (2021) and OCDE (2022).

In addition to implementing public policy interventions in these three pillars, it is important to emphasize the pillar with the lowest score: innovation capacity. Similarly, Gocłowska-Bolek (2022), in the comparison she makes between Mexico and Poland based on the GCI, recommends that to increase the competitiveness of both economies, innovation should be stimulated.

Like the countries in the medium and low competitiveness groups, Mexico showed weaknesses in the areas related to innovation: ICT adoption and innovation capacity (Figure 5). The innovation capacity pillar refers to workforce diversity, investment in research and development, buyer sophistication, and trademark applications. Figure 8 shows the countries that allocate the largest percentage of their GDP to research; Mexico allocates less than 0.5%.

Regarding ICT adoption, the variable considers access to telecommunications. According to the International Telecommunication Union (2020), in 2000, while Mexico had six percent of internet users, the US was approaching half of its population using this technology. This gap widened over the following decade, but by 2020 the gap was much smaller: 71.97% of Mexicans used the internet compared to 90.9% in the USA. Mobile phones and television are the most widely used technologies (Table 4), which can be used as tools for disseminating knowledge.

Furthermore, it was identified that Mexico's competitive position is limited by the results of the executive opinion survey and by the lack of variables related to social and environmental aspects. However, this analysis provides a framework for action to

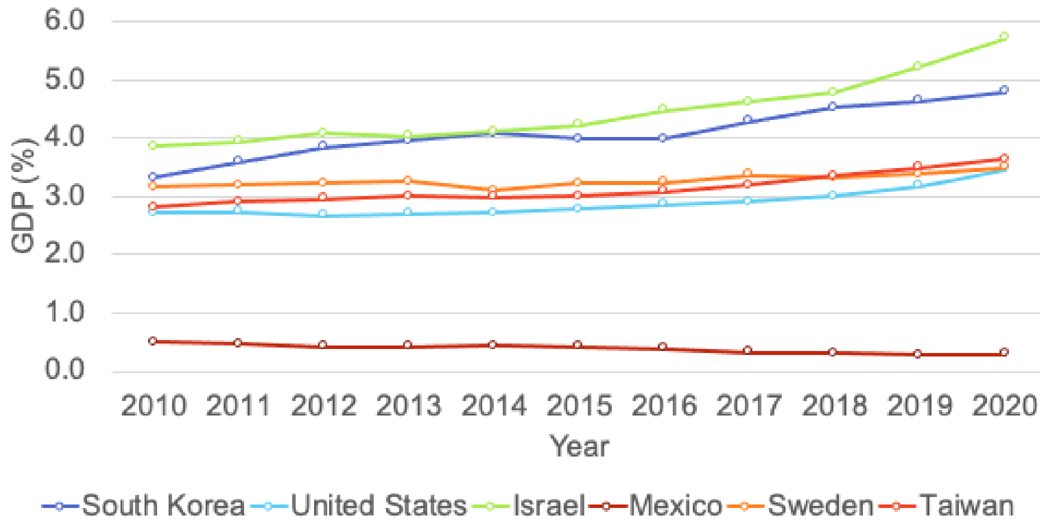

Figure 8. Research and development (R&D) expenditures.
Source: Self-elaborated with data the OCDE (2023a).

Table 4. Access of the Mexican urban population to telecommunications.

Technology	Percentage of households with:	Percentage of people who use:
Radio	53.9	
Television	92.5	
Landline telephone	39.5	
Cellular mobile phone	89.	75.1
Computer	44.2	43
Internet access	60.6	72

Source: Self-elaborated with data from the International Telecommunication Union (2020).

improve business productivity in the long term. The need to improve the quality of institutions, increase investment in research, and intervene in the current educational model to train professionals with more digital skills is highlighted. Addressing these aspects could allow Mexico to improve its position in the GCI competitiveness ranking, although in practice this would not guarantee greater real competitiveness.

Technological development in Mexico faces significant challenges, as increased investment in research does not guarantee technological progress. To achieve positive results, it is necessary to combine access to knowledge with adequate infrastructure and qualified social capital (Fagerberg *et al.*, 2007). Furthermore, domestic technological development may lag that of developed countries. According to Aghion and Howitt (2009), there is a monopoly on technological development that can limit the impact of national efforts in this area. Likewise, there is little coordination between key players such as universities, the government, and the private sector (Moreno-Brid *et al*., 2018).

Conclusions

The most common definition of competitiveness relates to market positioning, but a broader definition requires considering other elements such as institutions, policies, and technological development for a country to be considered competitive. The Global Competitiveness Index, in addition to comparing the efficiency of governments across nations, also identified deficiencies in each country's policies and administration.

In this way, the most competitive countries, once their population's basic needs are met, use their resources for technological development, which will give them an advantage in the long term, in addition to providing other countries with the technology they cannot produce. Medium-competitive countries have policies geared toward providing services, but they do not promote industrial development. Low-competitiveness countries find themselves in a paradox regarding the efficient use of their resources, as they must decide which of their population's demands they can address first: health, education, infrastructure, etc.

It's worth noting that innovation capacity is the factor that separates advanced economies from emerging ones; it's a tangible and promising outcome, as the fourth industrial revolution demands countries, companies, and workers with different types of capabilities. In the case of Mexico, actions aimed at improving productivity through innovation must be carried out with a long-term vision, since at present it is not possible to achieve the technological development of developed countries. Therefore, resources must be directed toward improving the population's educational levels and their capacity to adopt new technologies. This requires an institutional component with a renewed development vision.

In summary, the limitation of this work is that the most recent information available is for 2019, so it is recommended to compare it with the next GCI publication to determine the effects of the pandemic. It is also recommended to apply other methodologies for competitiveness analysis and include other variables such as environmental policies to conclude whether a country is competitive or not.

Finally, given that the most recent information available corresponds to 2019, which may be a limitation for a broader understanding of the Mexican economy's competitiveness in the global context, it is recommended to compare it with the next GCI publication to determine the effects of concurrent, non-continuous phenomena such as the COVID-19 pandemic. Future analyses recommend including other variables, such as environmental policies, to determine the degree of competitiveness of the national economy.

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EVALUATION OF PUBLIC POLICIES IN MEXICO: AN ANALYSIS OF THE INSTITUTIONALIZATION OF EVALUATION

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Abstract

This review article analyzes the role of the National Council for the Evaluation of Social Development Policy (CONEVAL) in the institutionalization of public policy evaluation in Mexico. Twenty years after its creation, CONEVAL has established itself as a technical benchmark in the generation of information and methodologies for measuring poverty and evaluating social programs. However, its history was also marked by political tensions, institutional limitations, and debates about its autonomy and usefulness. Through a systematic documentary review of 35 key sources, including official reports, academic articles, external evaluations, and national and international technical literature, we examined CONEVAL's achievements, challenges, and dilemmas from 2004 to 2024. However, its history was also marked by political tensions, institutional limitations, and debates about its autonomy and usefulness. Through a systematic documentary review of 35 key sources, including official reports, academic articles, external evaluations, and national and international technical literature, we examined CONEVAL's achievements, challenges, and dilemmas from 2004 to 2024. An analytical matrix was used to classify and compare documents according to criteria of relevance, institutional impact, and timeliness. The main findings reveal a central paradox: CONEVAL developed robust technical capabilities but faced structural obstacles to effectively influencing public policy decisions. Furthermore, its limited involvement in participatory mechanisms and its exposure to political changes weakened its legitimacy. Furthermore, its limited connection to participatory mechanisms and its exposure to political changes weakened its legitimacy. It is concluded that strengthening evaluation activities, which will be carried out by INEGI starting in 2025, requires incorporating participatory and deliberative approaches, as well as ensuring the use of methodologies developed by CONEVAL to enable comparability of evaluations. To be effective and democratic, public evaluation must be technical, inclusive, and participatory to serve social rights and distributive justice.

Keywords: accountability, CONEVAL, social development, policy evaluation, institutionalization

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Introduction

In the Latin American context, the institutionalization of public policy evaluation has faced a trajectory marked by tension between technical autonomy and centralized political decisions. In Mexico, the National Council for the Evaluation of Social Development Policy (CONEVAL) was key in advancing a culture of evaluation to improve government decisions, strengthen accountability, and, above all, positively impact the lives of people living in poverty and vulnerability.

However, in recent decades, and particularly after the change of government in 2018, there has been growing pressure to weaken autonomous bodies. This raises critical questions about the viability of maintaining independent evaluation mechanisms in contexts of high concentration of power. Therefore, it is urgent to reflect on the role played by CONEVAL, its achievements, limitations, and potential for strengthening.

The evaluation of public policies has gained increasing importance in recent decades, especially in countries with consolidating democratic systems like Mexico. In this context, the need for institutions capable of generating objective, transparent, and timely information for decision-making has become an imperative of modern governance (OCDE, 2020). This demand intensifies when it comes to policies targeting vulnerable populations, such as social programs that aim to reduce poverty and inequality.

The creation of CONEVAL in 2004 marked a turning point in the institutionalization of evaluation in Mexico. For the first time, the Mexican State was provided with a technical and formally autonomous agency responsible for coordinating poverty measurement and evaluating the federal government's social programs (CONEVAL, 2006). This institution emerged in a context of democratic transition and international pressure to improve accountability mechanisms, within the framework of reforms inspired by new public management models (Santiso, 2007).

However, the history of CONEVAL also reflects the structural and political limitations that evaluation institutions face in contexts of high centralization of power. Despite its national and international recognition, the organization was subject to recurring tensions, particularly when its findings did not coincide with the political priorities of the governments in power (Moreno-Brid & Pérez-Benavides, 2021). An example of this was the controversy generated by the change in general management in 2019 and the proposal to merge CONEVAL with the Ministry of Welfare, which raised concerns about the possible loss of its technical autonomy.

From a critical perspective, this article proposes a review of the role played by CONEVAL in strengthening the national evaluation system. To do so, it starts from the premise that evaluation cannot be understood exclusively as a technical or methodological practice, but rather must be analyzed based on its capacity to influence power structures, budgetary decisions, and the democratic quality of the State (Bovens, 2007; Chelimsky, 2006).

It is also argued that the future of evaluation in Mexico will depend not only on robust regulatory frameworks, but also on an active citizenry and a political class committed to transparency and the continuous improvement of public interventions. In times of political polarization and the weakening of autonomous organizations, it is essential to defend evaluation as a collective right to knowledge and to participate in the construction of more just policies.

Theoretical framework

To understand CONEVAL's role in policy evaluation, we started from a theoretical articulation that incorporated three key dimensions: 1) governance and democratic accountability, understood as the State's capacity to respond to citizen demands in a transparent, efficient and participatory manner (Bovens, 2007; Behn, 2001); 2) organizational learning and the use of evaluation as a tool to continuously improve public interventions (Chelimsky, 2006; Weiss, 1999); and 3) the theory of change, which allows us to understand how public policies can transform realities when they are built from an evidence-based approach and with social participation (Funnell & Rogers, 2011). From this perspective, evaluation is considered a dynamic process that contributes to the development of public institutions serving the people, rather than an isolated act of oversight.

In the first dimension, governance and democratic accountability have entailed an institutional redesign geared toward transparency, citizen participation, and effectiveness. Thus, accountability is not limited to a hierarchical relationship between superiors and subordinates but is configured as a network of public responsibilities involving citizens, social actors, and technical institutions (Bovens, 2007).

Democratic accountability proposes that oversight and control mechanisms should be geared toward ensuring that government decisions respond to the public interest, rather than to partisan or clientelist logic (Behn, 2001). In this context, public policy evaluation is a key tool for supporting institutional performance and the effects of public interventions with evidence.

In the second dimension, evaluation, organizational learning, and decision-making, it is considered that evaluation is more than a measurement technique; it represents an institutional practice that enables organizational learning and continuous policy feedback (Weiss, 1999). In this sense, evaluation generates critical knowledge about what works, why, and under what conditions, allowing for error correction, resource optimization, and strategy redesign.

Chelimsky (2006) distinguishes three fundamental purposes of evaluation in modern democracies: knowledge (understanding whether policies are working), improvement (suggesting adjustments or transformations), and oversight (preventing abuses or deviations). From this perspective, CONEVAL played an intermediate role by acting as a bridge between technical knowledge and political decisions, which placed it in a strategic, but also vulnerable, position.

Finally, the theory of change, the use of evidence, and evaluation models allow us to understand how public interventions aim to generate social transformations and the necessary conditions for this (Funnell & Rogers, 2011). Evaluation, within this framework, is not only about verifying outcome indicators, but also about reconstructing the intervention's logic, its assumptions, and its intended or unintended effects.

In Mexico, CONEVAL developed a robust methodology for evaluating consistency and results, which articulated program theory with quantitative and qualitative indicators. This model has been recognized by multilateral organizations as a leading evidence-based evaluation practice (OCDE, 2020).

Based on these dimensions, the analytical framework of this review positioned CONEVAL as an intermediary actor between evaluative technocracy and democratic accountability mechanisms. On the one hand, it possessed specialized technical expertise and developed highly complex measurement and evaluation instruments; on the other, its legitimacy depended on its ability to translate these results into understandable and useful decisions for citizens and decision-makers.

This intermediary role is inherently tense: when evaluation confirms official discourse, it is institutionally strengthened; but when it questions or contradicts government priorities, it becomes a target for pressure, cutbacks, or delegitimization. This ambivalence requires a sufficiently autonomous evaluation body with regulatory and institutional protection that allows it to act independently and responsibly in the public interest.

Thus, the theoretical framework allows us to understand that evaluation should not be disconnected from power structures or disputes over the direction of policies. Consequently, having a strengthened autonomous body implies strengthening the democratic capacities of the State to be accountable, learn from its mistakes, and act fairly.

Methodology

This study followed a qualitative documentary methodology and a systematic review of primary and secondary sources. An interpretive approach was adopted to reconstruct CONEVAL's institutional history from its creation in 2004 to 2024 and identify its methodological contributions, its institutional role, and the political tensions it faced. This methodology allowed for the systematization of disparate information, generating a critical analysis from a contextual perspective.

Thirty-five key documents were analyzed, selected for their thematic relevance, timeliness, and impact on public policy. These documents were grouped into five broad categories:

CONEVAL annual and special reports (2006-2023).
External evaluations of social programs coordinated by CONEVAL.
Academic articles indexed in Redalyc, Scielo and Scopus.
Reports from multilateral organizations (OECD, World Bank, ECLAC).
Grey literature: technical notes, expert editorials, official communications, and popular essays.

Key documents include: the Social Development Policy Evaluation Report (CONEVAL, 2008, 2012, 2018, 2022), Multidimensional Poverty Measurement Methodology (CONEVAL, 2019), the evaluation of the consistency and results of the Prospera Program (2014), and the document The Future of Evaluation in Mexico (CONEVAL, 2020).

For document analysis, an analytical matrix was constructed based on categories derived from the theoretical framework and refined through an exploratory reading of the selected documents. This systematization allowed us to identify patterns and trends relevant to the discussion, as shown in Table 1.

Table 1. Description of the analysis categories.

Category	Description	Subcategories
Institutional autonomy	Degree of technical and financial independence of CONEVAL	Financing, Management Appointment, Relationship with the Executive
Methodological capacity	Technical rigor and development of evaluation instruments	Methodologies, Indicators, Data Transparency
Political advocacy	Ability to influence public policy decisions	Derivative reforms, Impact on program design, Legislative use
Social participation	Inclusion of social actors in the evaluation process	Consultative mechanisms, Hearings, Accessible disclosure
Tensions and conflicts	Critical institutional or political moments	Regulatory changes, Media controversies, Political pressures

Source: Self-elaborated.

Each document was examined through critical reading to identify relevant information according to these categories, recording findings, key quotes, and assessments in analytical sheets. Qualitative content analysis techniques were used (Bardin, 2002). The period selected (2004–2024) for the study spans from the legal creation of CONEVAL until before its dissolution. This was done with the aim of observing three key moments: 1) the stage of institutional consolidation (2004-2012), characterized by the development of methodologies and growing technical legitimacy; 2) the stage of stabilization and recognition (2012-2018), with CONEVAL's positioning as a national and international reference; and 3) the stage of institutional tension and vulnerability (2019-2024), marked by attempts at political weakening and redefinition of its role. These periods were triangulated with institutional events, regulatory reforms, and changes in government, in order to contextualize the findings and provide elements for their historical interpretation.

Given the documentary analysis nature of the study, it is recognized that the findings are determined by the availability of public sources of information and the document selection process. However, these biases were mitigated through source triangulation, transparency of criteria, and comparative analysis. In short, the methodology used allowed for a systematic, rigorous, and critical approach to CONEVAL's institutional performance, from a comprehensive perspective that recognizes its technical, political, and social dimensions.

Results

A diverse documentary database was compiled, comprising 35 sources selected based on three criteria: (a) thematic relevance to the object of study, (b) level of institutional impact (such as influence on the design, reform, or elimination of policies), and (c) the document's relevance to the period of analysis (2004–2024). This selection made it possible to identify not only the technical evolution of CONEVAL but also the social and political contexts in which it developed. Each document contributed key pieces to reconstruct the tensions, strengths, and challenges that have accompanied this organization from its creation in 2004 to 2024.

These documents were grouped into five categories: 1) CONEVAL reports, which provided an overview of methodological developments and institutional positions in response to political situations; 2) external evaluations, which provided insights into the uses and effects of CONEVAL's diagnostics; 3) indexed academic articles, which provided a critical and theoretical perspective on CONEVAL's role; 4) international technical literature (OECD, World Bank, ECLAC), which provided comparative insights into evaluation institutions; and 5) gray literature and opinion papers, which contributed to understanding the social and political perceptions of CONEVAL at different historical moments.

This analysis identified patterns, ruptures, and continuities in the process of institutionalizing evaluation in Mexico. The matrix presented below systematizes this interpretation, articulating the selection criteria with the information extracted and their contribution to the findings of this analysis (Table 2).

Table 2. Concentrated analytical matrix of the documents analyzed.

Nº	Title	Selection criteria*	Information that provides	Main finding
1	Social Development Policy Evaluation Report 2008 (CONEVAL, 2008)	Thematic relevance, impact	Consolidation of indicators and multidimensional measurement	First important technical institutional positioning
2	Report 2012 (CONEVAL, 2012)	Relevance, impact	Methodological monitoring and expansion of evaluations	Greater interinstitutional integration
3	Report 2018 (CONEVAL, 2018)	Current events, impact	Pre-evaluation for change of government	Evidence of structural lags in priority programs
4	Report 2022 (CONEVAL)	Current events, impact	Evaluation of new federal programs	Difficulties in evaluating without clear operating rules
5	The future of evaluation in Mexico (CONEVAL, 2020)	Relevance, current events	Positioning in the face of institutional tensions	Call to defend technical autonomy
6	Consistency and Results Evaluation: Prospera 2014 (CONEVAL, 2014)	Relevance, impact	Application of the CONEVAL evaluation model	Linking theory of change and measurement
7	Multidimensional Measurement Methodology (CONEVAL, 2019)	Relevance	Technical bases of the measurement system	International recognition of the Mexican model
8	Building Capacity for evidence (OCDE 2020).	Comparative, current	Regional diagnosis of evaluation capacities	Lack of link between evaluation and decisions
9	Evaluation and Management for Results, Banco Mundial (2021)	Comparative, current	Latin American experiences	Evaluation without institutionalization, ineffective
10	Social Panorama (CEPAL, 2022)	Comparative	Structural inequalities	Lack of distributive impact in evaluations
11	Moreno-Brid y Pérez-Benavides (2021)	Relevance, current events	Criticism of institutional dismantling	The assessment has not prevented setbacks
12–25	Indexed articles (cited in the Text)	Relevance, impact	Case analysis, conceptual debates	Reinforce critical and contextual reading
26–30	External program evaluations (SEDESOL, 2009–2017)	Relevance, impact	Application data of the CONEVAL model	Variability in quality and incidence
31–35	Grey literature (opinion articles, interviews, press releases)	Present	Public narratives about CONEVAL	Social perception depends on the political climate

*Selection criteria: a) thematic relevance, b) level of institutional impact, and c) relevance of the document.

Source: Self-elaborated.

This collection of documents provides empirical support for the interpretations presented in the following sections. The evidence collected allows us to identify a series of milestones, tensions, and institutional lessons learned that illustrate the dynamic role played by CONEVAL in shaping the national evaluation system. The results presented below are the product of the intersection of this evidence and the developed theoretical framework, allowing for a structured and critical reading of the role of evaluation in contemporary Mexican public policy.

The findings derived from the analysis reveal that public policy evaluation in Mexico, carried out by CONEVAL, is a deeply political field, in which values, priorities, and visions of social development are negotiated. Identifying how and when technical evidence influences real-world decisions, and when it is neutralized or ignored, allows us to understand the necessary conditions for a democratically informed public evaluation. In this context, the findings of this research not only document what CONEVAL has been, but also raise fundamental questions about what it can and should become.

The systematic documentary analysis reveals a complex and nuanced picture of the role played by CONEVAL in the institutionalization of public policy evaluation in Mexico. Based on the analytical matrix constructed, the findings are presented grouped into five key areas: 1) institutional autonomy, 2) methodological capacity, 3) political influence, 4) social participation, and 5) institutional tensions.

Institutional autonomy

CONEVAL was designed as a technically autonomous, though not constitutionally autonomous, body budgeted by the Ministry of Finance and Public Credit (SHCP) and with a collegial board composed of academics and government representatives. This configuration allowed it to operate with a degree of independence during its initial years (CONEVAL, 2008) but proved insufficient in the face of subsequent political challenges, especially after the removal of its executive director in 2019 due to criticism of the elimination of social programs without prior evaluation (Moreno-Brid & Pérez-Benavides, 2021).

This finding aligns with Bovens's (2007) theory, which argues that accountability is effective only when responsible actors have the real capacity to act independently and enforce their recommendations. The lack of full legal guarantees calls into question the effectiveness of their evaluative role.

Methodological capacity

CONEVAL has been recognized by international organizations for its methodological rigor. Its multidimensional measurement of poverty, the types of evaluations (design, processes, outcomes, and, to a lesser extent, impact), and the methodological guides published annually demonstrate a technically sound institution (CONEVAL, 2018; OECD, 2020).

The analysis of the reports reveals a sustained effort to translate the theory of change into operational logic applicable to social programs, with an emphasis on the coordination of objectives, activities, and expected results. This is in line with the perspective of Funnell & Rogers (2011), who highlight the usefulness of logic models as comprehensive planning and evaluation tools.

Political influence

One of the most significant results of the analysis is the observation of a gap between the generation of evaluative knowledge and its effective use in public policy decisions. Despite robust findings, CONEVAL lacked the authority to modify or condition budgets, nor to force agencies to redesign failed programs (CONEVAL, 2020). However, through the Areas Susceptible to Improvement (ASM by its acronym in Spanish), which generated commitments assumed by the agencies or entities of the Federal Public Administration (APF), recommendations or findings from external evaluations were issued with the aim of implementing improvement processes in the programs, which were regularly addressed when the APF was the one who sent the recommendations.

This finding is consistent with Weiss's (1999) thesis, who warns that the use of evaluation is often symbolic or politically selective, especially when the findings contradict institutional interests. In this regard, CONEVAL was empowered to issue more prescriptive recommendations related to the lack of institutional independence.

Social participation

Despite its technical advances, CONEVAL demonstrated a systematic weakness in incorporating participatory mechanisms into its evaluation processes. Most evaluations were conducted from an expert perspective, without involving beneficiaries or user communities, which limits the social appropriation of the results and perpetuates a technocratic logic (Santiso, 2007).

This limitation has been pointed out by ECLAC (2022), which warned that the legitimacy of evaluation also depends on its capacity to generate processes of dialogue and social deliberation. Although CONEVAL has published citizen versions of its reports, such as memoirs, infographics, and documentation on mobile applications, these efforts were insufficient in the face of the need to democratize the evaluation process.

Institutional tensions

The 2019-2024 period is marked by an increase in tensions between CONEVAL and the federal government. These tensions are expressed at three levels: (a) discursive, with the public discrediting of its reports; (b) budgetary, through the reduction of resources; and (c) institutional, with proposals to eliminate it or merge it with other agencies (CONEVAL, 2020).

According to Chelimsky's (2006) theory, these conflicts are indicative of a clash between the logic of political control and technical autonomy. Evaluation then becomes a field of symbolic dispute where the question of who has the right to say what works and what doesn't is decided.

Discussion

The results show that, while CONEVAL has been a benchmark in the institutionalization of evaluation, its existence and effectiveness are closely tied to the political context. Unlike agencies such as the National Planning Department in Colombia or the National Evaluation Council in Chile, CONEVAL, from its inception, lacked sufficient legal guarantees to ensure its independence from the executive branch.

In a country with deep structural inequalities, it is essential that evaluation instruments not only generate information but also effectively influence the allocation of resources and the redesign of interventions. CONEVAL's experience demonstrates that technology alone is not enough: political will and an active citizenry are required to sustain a culture of critical and transformative evaluation.

These results allow us to delve deeper into the role that CONEVAL played as an institution that operated on an intermediate level between technical and political rationality. As argued in the theoretical framework, its status as an intermediary actor placed it in a strategic but also vulnerable position, especially in contexts of concentrated power and limited participatory institutionality.

CONEVAL confirms that the institutionalization of evaluation in Mexico was not accompanied by legal and budgetary mechanisms that ensured its functional independence. This represents a central contradiction for democratic accountability, since citizen oversight requires agencies capable of issuing technical judgments, without the results being taken as political positions and impacting the functioning of evaluation activities (Behn, 2001; Bovens, 2007).

The tension between the evaluative mandate and political subordination thus becomes a constant that not only affects CONEVAL but is common to other evaluation agencies in Latin America, as documented by CEPAL (2022) in its comparative analysis. In this sense, the institutionalization of evaluation should be understood not as a fait accompli, but as a contested political process.

Second, the methodological capacity developed by CONEVAL enabled the consolidation of a robust evaluation infrastructure, which contributed to strengthening transparency and access to disaggregated information. However, as Chelimsky (2006) points out, the knowledge generated by evaluation only has a democratic meaning if it becomes an input for improving public policies and is not locked into technocratic circles.

From this perspective, although CONEVAL offered the opportunity for those responsible for the evaluated programs or public policies to express their opinions regarding the evaluations, decision-makers observed limited effective use of its recommendations. This demonstrates a weak connection between evaluation and political planning. This not only limits the evaluation's effectiveness but also reduces its transformative function. As Weiss (1999) warns, when evaluation is not used, the system loses its capacity for institutional learning.

Third, the limited social participation in CONEVAL's evaluation processes demonstrates that the evaluation culture in Mexico continues to be dominated by top-down logic. Despite efforts to socialize results, mechanisms for deliberation and peer evaluation remain marginal. This situation reinforces Santiso's (2007) argument about the predominance of an evaluation technocracy in the region, which risks depoliticizing the debate on public affairs.

Finally, the recent political tensions faced by CONEVAL should be interpreted as symptoms of a broader conflict over the role of knowledge in public management. When evidence contradicts official discourse, a reaction is triggered that seeks to undermine the legitimacy of evaluation bodies. This dynamic confirms the hypothesis that evaluation, far from being a neutral field, is embedded in power relations and symbolic disputes (Bovens, 2007; Chelimsky, 2006).

In summary, the findings highlight the need to strengthen CONEVAL, on the one hand, to protect its institutional autonomy through legal and budgetary reforms, and on the other, to move toward a more participatory, deliberative, and social justice-oriented evaluation, in terms of the effective exercise of social rights. To achieve this, it is necessary to generate interest and willingness among political actors to address the construction of a comprehensive vision of evaluation policy in Mexico on government agendas (López, 2020).

Prospective analysis

The focus of this research is on the institutional history of CONEVAL, from its creation in 2004 to 2024, as an experience in the construction of an autonomous body specialized in social evaluation. This process, under a collegial logic and with academic and technical participation, allowed it to position itself as a national and international benchmark in the multidimensional measurement of poverty, the monitoring of social programs, and the generation of useful evidence for public decision-making (Scartascini & Chuaire, 2014; OCDE, 2020). However, in the evening edition of July 16, 2025, the Official Gazette of the Federation published the reform decree to extinguish CONEVAL and transfer its functions to INEGI, which entered into force on July 17, 2025.

This research adds a perspective that assumes the institutional closure of the agency as a turning point. From this perspective, the transfer of evaluation functions to INEGI, an institution with high technical recognition but no track record in deliberative or normatively oriented evaluation, could mark a technocratic reconfiguration of the evaluation system.

In this regard, Scartascini & Chuaire (2014) pointed out that an effective evaluation policy cannot be reduced to the production of indicators but must be integrated into the entire public policy cycle, promoting institutional learning, plural deliberation, and the redesign of social intervention strategies. In this sense, the new functions granted to INEGI open two possible scenarios.

First, the dismantling of CONEVAL constitutes a risk to the technical accountability model, with implications that extend to the evaluative autonomy of the Mexican State (Moreno-Brid & Pérez-Benavides, 2021). Furthermore, it poses a risk of vertical rather than horizontal execution, an aspect that jeopardizes the production of knowledge derived from the evaluated actions, government transparency, and citizens' capacity to participate in the debate on the effectiveness of public policies (Behn, 2001; Santiso, 2007).

Second, this transfer of functions opens an unprecedented institutional scenario in Mexico. While this transfer has raised concerns about the potential loss of evaluative autonomy and the depoliticization of accountability, it also represents an opportunity to reflect on the progress made by CONEVAL and its potential compatibility with the functions historically performed by INEGI.

From an institutional perspective, CONEVAL provided a normative approach to evaluation, linked to social rights, multidimensional poverty, and distributive justice. Its evaluations not only produced data but also contextualized interpretations based on criteria of equity, effectiveness, and sustainability. Furthermore, it developed innovative methodologies for measuring poverty and monitoring social programs based on the theory of change and consistency and results models (CONEVAL, 2020).

For its part, INEGI is an autonomous constitutional institution specialized in statistical, geographic, and census production. It has consolidated experience generating reliable and systematic information useful for multiple sectors, including public administration. Its technical strength decentralized national structure, and institutional legitimacy could facilitate efficient technical implementation of the measurements inherited from CONEVAL (INEGI, 2024).

However, the real challenge of this institutional merger lies not in the technical compatibility between the two institutions, but in their epistemological and political compatibility. INEGI has not historically been a social policy evaluation body, nor does it have a collegial tradition of normative interpretation of information. While CONEVAL valued academic deliberation, critical evaluation, and the use of evidence to influence public decisions, INEGI has favored a logic of producing neutral data, without engaging in the debate over the direction or impact of public policies.

Considering these institutional characteristics, this merger can build functional convergence, ensuring that the transferred functions retain a normative and participatory approach and creating a specialized evaluation unit with technical staff from the defunct CONEVAL. This unit could operate as a collegial core within INEGI, coordinating its statistical capabilities with qualitative and social impact assessment frameworks. Likewise, it will be necessary to strengthen the link between statistical products and the cycles of public policy formulation, monitoring, and redesign through new legal or regulatory provisions that guarantee the independent, transversal, and deliberative nature of evaluation.

In short, while the dissolution of CONEVAL represents a potential decline in terms of autonomous evaluation institutions, integrating its functions into INEGI may be functionally viable, recognizing the need to maintain its critical focus and its connection to social rights. The future of evaluation in Mexico will depend not only on the technical capacity of institutions, but also on their political will to be accountable, learn institutionally, and build more transparent and inclusive governance.

Conclusions

CONEVAL represented a significant effort to institutionalize public policy evaluation in Mexico. Its methodological contributions and rights-based approach have been fundamental in highlighting social gaps and demanding better results from government policies. This review revealed significant progress in building a culture of public policy evaluation. Its creation formalized an institutional framework for measuring poverty and evaluating social programs, providing the State with technical tools to monitor, adjust, and report on its interventions.

Among its most significant contributions are: the multidimensional poverty measurement methodology, adopted as a national standard; the design of technical guides and guidelines for the evaluation of federal programs; the generation and dissemination of disaggregated and publicly accessible information; and the promotion of good evaluation practices at the national and international levels.

These actions strengthened transparency and placed evaluation on the public agenda, a fundamental contribution to strengthening the democratic state. However, despite the institution's efforts to develop tools to facilitate decision-making for improving public policy and authorizing budgets for its operation, there has been a gap between the production of evaluative knowledge and its effective use for decision-making. CONEVAL's recommendations lacked binding force. Furthermore, a limited inclusion of social stakeholders in the evaluation processes was identified, which limited citizen appropriation of the evaluation and diminished its transformative potential. This lack of participatory action reinforces the perception that evaluation responds to a technocratic rather than democratic logic. In other words, evaluations became bureaucratic exercises rather than instruments for continuous improvement.

While the study also revealed the institutional fragility of CONEVAL in the face of political ups and downs, as well as the lack of sufficient legal safeguards, which made it particularly vulnerable to pressure from the executive branch and budget cuts, the fact is that, with its dissolution authorized by the legislature and published in the Official Gazette of the Federation, its functions have been fully absorbed by INEGI.

The above reveals an urgent need to move toward evaluation models that combine technical rigor with citizen inclusion, effective advocacy, and non-political use. This will require citizen observation to understand how the transition is carried out and how the knowledge and information generated by CONEVAL is adopted.

Finally, it is important to clarify that this research does not aim to highlight or criticize a political position, but rather to highlight the progress made in the institutionalization of evaluation in the analysis for the development of a strong, participatory, and impactful public evaluation, undoubtedly a commitment to democracy.

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EVALUATION OF THE PRODUCTIVITY, EFFICIENCY AND RESILIENCE OF FOOD PRODUCTION SYSTEMS DURING THE COVID 19 PERIOD (2020-2022): A CASE STUDY FOR GLOBAL REGIONS

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Abstract

To operationalize the term resilience in food systems, it is necessary to indirectly quantify this attribute, so that the impact caused by external phenomena can be measured. One way to think of resilience is in terms of maintaining productive efficiency over time. It is assumed that resilience is an intrinsic property of complex adaptive systems, which should be measured as a comparison across time of the behavior of the system under study (time series) and comparing similar cases (data panels). This paper integrates the concepts and results of econometric analyses based on total agricultural production (TFP), data envelope analysis (DEA) and Malmquist index to identify nations that in the period from 2020 to 2022 serve as an example in terms of maintaining their productive efficiency under adverse contexts such as the COVID pandemic. The results are discussed with a complex adaptive systems approach.

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Introduction

There are global phenomena whose aggregate effects on decision-making units are more frequent and imminent, such as extreme weather events, aggressive and unpredictable economic policies and pandemics, among others. These risks of different natures have an asymmetrical impact across organizational scales and ecological, economic and social dimensions on complex systems, this includes food production and distribution systems.

To analyze the effect of global phenomena on agrifood systems and their resilience, this paper proposes to analyze the productivity of nations and discuss the results from a complex systems approach. Resilience is then considered in terms of productive efficiency and the ability to maintain such efficiency after an external phenomenon that disrupted the usual plans and behaviors of food chains, such as the COVID 19 pandemic.

Resilience is assumed to be an intrinsic attribute of systems that, in this case, reflects the continuity of aggregate behavior. However, since there is no universal approach to this concept, the present work suggests a way to indirectly quantify this attribute of systems by integrating econometric analysis tools.

The general objective of this work is to analyze from a national scale, the productivity efficiency of agricultural sector activities in different regions of the world, with emphasis on the Latin American region, but integrating North America, Asia, Europe and Oceania into the study, during the period 2020 to 2022, through three econometric analysis tools: first, an overview of the Total Agricultural Productivity (TFP) indicator, second, a data envelope analysis (DEA) and finally, a Malmquist analysis, in order to identify the regions and countries that show greater resilience post-COVID-19.

Methodology

Next, a brief description of the conceptual tools used for the analysis of productivity and efficiency is made, as well as a reference to the database where the information of the different nations has been compiled that has been used for the research. The literary sources used as a reference for the discussion of the results are also mentioned.

The International Agricultural Productivity report measures agricultural productivity using the Total Agricultural Productivity (TPF) indicator. It compares the proportion of the total products of agricultural activities with the combined inputs used in their production of land, human labor, capital, and material resources used in field production. Most of the information used to develop the indicators comes from FAOSTAT, also integrating information from multiple other databases (Department of Agriculture, U.S., 2025). In (a) describes the calculation of the indicator, defined as a proportion of outputs (outputs) and inputs (inputs):

$$TFP = \frac{Y}{X} \quad 1)$$

Total Factor Productivity (Department of Agriculture, U.S., 2025).

$$ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \sum_i R_i ln\left(\frac{Y_{it}}{Y_{it-1}}\right) - \sum_j S_j ln\left(\frac{X_{jt}}{X_{jt-1}}\right) \quad 2)$$

Weighted difference of value (costs)-share between total product growth and total input growth (Department of Agriculture, U.S., 2025).

Y= Total products
X = Total inputs
Ri = revenue share of the i-th product
Sj = share of the costs of the j-th input

Total output growth is estimated by adding the growth rates of each output, weighted by its revenue share, represented in (b), is the weighted value-share difference between total output growth and total input growth. These growth rates are used to estimate the annual index, where the base year *t* has a value of 0. If total outputs grow faster than total inputs, it is called an improvement in productivity per total factor (Department of Agriculture, U.S., 2025).

Now, there are multiple products and inputs that make up agricultural activities as a whole, also, competitive markets in equilibrium are assumed, where the underlying technology is represented by production functions of constant returns to scale, so technological improvements have a "positive" effect on yield, it is also assumed that an agricultural product *i* will have its elasticity defined by the participation of an input *j* in its cost for each input present. (Department of Agriculture, U.S., 2025).

These growth rates of Total Agricultural Productivity (TPF) are compared to generate the TPF Index, which is based on the year 2015, since its last update in 2024, assigned a value of 100, so a value of 115 in the year 2020 would be an increase of 15% in the TFP in relation to 2015. This increase in technical efficiency is driven by changes in the set of available technologies, extension and education, market access and institutional reforms, derived from public policies.

In this context, and to provide a valid analysis and interpretation, the TFP values are referenced to 2020, therefore, it is assumed that:

$$\text{TFP Index}_t^{\text{base 2020}} = \frac{\text{TFP}_t}{\text{TFP}_{2020}} \times 100 \quad 3)$$

Value of the index in year t, assigning a score of 100 to the year 2020.

and

$$\text{TFP}_t = \text{TFP Index}_t^{\text{base 2015}} \times \left(\frac{\text{TFP}_{2015}}{100} \right) \quad 4)$$

Value in year t, assigning a score of 100 to the year 2015 to the index.
then

$$\text{TFP Index}_t^{\text{base 2020}} = \frac{\text{TFP Index}_t^{\text{base 2015}}}{\text{TFP Index}_{2020}^{\text{base 2015}}} \times 100$$

5)

Clearing of the Total Agricultural Productivity index for the year 2020 with a value of 100.

In such a way that new TFP values are generated, by region, based on the year 2020, given in (c), (d) and (e), these are structured as a data panel for a descriptive statistical analysis.

Subsequently, a data envelope analysis (DEA) was performed to evaluate and identify those countries in the Americas, Oceania, Europe and Asia that define an efficiency frontier by having a score of =1, which serves as a reference for "inefficient" countries (*Coelli, et al.*, 2005), the score is obtained by estimating the minimum distance to get as close as possible to its virtual efficient versions, *theta*. This procedure was carried out for the year 2020, 2021 and 2022. Broadly speaking, it consists of defining inputs (inputs) and outputs (profitable products) to generate an efficiency frontier established by decision-making units (in this case countries), for each year, by means of a linear optimization approach. An input-oriented analysis was performed, with a constant return-to-scale (CRS) approach, also with variable return-to-scale (VRS) to finally estimate the efficiency at scale (SE).

$$\begin{aligned} \min_{\theta,\, \lambda} \quad & \theta \\ \text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io}, && i = 1, \ldots, m, \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}, && r = 1, \ldots, s, \\ & \lambda_j \geq 0, && j = 1, \ldots, n. \end{aligned}$$

6)

Approach to the linear DEA problem, with constant return of scale, oriented to outputs (Coelli, *et al.*, 2005).

Where *x* is the quantity of inputs, *y* the quantity of outputs, *i* is the index of inputs, *r* is the index of outputs, *j* is the index of decision-making units, in this case countries. Theta(θ) is the efficiency score, it refers to the total percentage of inputs that are necessary to generate the same amount of outputs, while the percentage of possible reduction (improvement in processes) of inputs for each decision-making unit is *1-θ*. Lambda(λ) is the weight assigned to each decision unit *j* that serves as a reference for the most inefficient decision units and that have similar values in terms of scale/efficiency (Coelli*, et al.*, 2005).

For the model with variable return to scale (VRS) one more limitation is added to the optimization problem, which forces the reference values when generating the boundary to have as 1 the value of the total sum (figure 7), this controls the size at scale unlike CRS according to Thanassoulis, 2001, who also describes scale efficiency as:

$$\sum_{j=1}^{n} \lambda_j = 1$$

7)

Limitation added to the linear problem to propose a variable return of scale (VRS)

"... measures the divergence between the efficiency score (θ) of a DMU under CRS and VRS respectively... the greater the divergence between the efficiency ratings of VRS and CRS, the lower the value of scale efficiency and the more adverse the impact of scale size on productivity" (Thanassoulis, 2001:140) (h).

$$\mathbf{SE}_o = \frac{\theta_o^{\mathrm{CRS}}}{\theta_o^{\mathrm{VRS}}}$$

8)

Calculation of Scale Efficiency.

The linear optimization problem is solved in *RStudio*, using the *Benchmark* package, which in turn uses the *lpsolve* package to solve the problem, using a simplex algorithm.

The variable established as the total product (*y*) is defined as the gross value of agricultural production of crops, livestock and aquaculture multiplied by $1000 at constant 2015 prices. The following are the variables used (Table 1) as inputs (*J*), this information is part of the database with which the TFP was calculated, in it you can consult the sources of information and explanation of the units.

The final component of the present work consists of a Malmquist analysis (i) for adjacent periods, which *"measures productivity changes over time and can be decomposed with a non-parametric approach like DEA... it represents changes in efficiency and technological changes"* (Lee, 2011:1). A variable return scale model was used to consider differences around the countries.

$$\mathrm{MPI}^I_{t,t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \underbrace{\frac{D^I_{t+1}(x_{t+1}, y_{t+1})}{D^I_t(x_t, y_t)}}_{Efficiencychange(EC)} \times \underbrace{\left[\frac{D^I_t(x_{t+1}, y_{t+1})}{D^I_{t+1}(x_{t+1}, y_{t+1})} \cdot \frac{D^I_t(x_t, y_t)}{D^I_{t+1}(x_t, y_t)}\right]^{1/2}}_{Technicalchange(TC)}.$$

9)

Table 1. Description of the variables used as inputs for the data envelope analysis (DEA) and the Malmquist analysis, source: Department of Agriculture, U.S., 2025.

Input	Description
Earth	Agricultural area adjusted for quality; cropland irrigated with rainfall.
Farmland	Total cropland (including arable land and land with permanent crops)
Irrigated land	Total Area with Irrigation Equipment
Grasslands	Total area of permanent pasture
Work	Number of workers in agricultural sectors
Capital	Net Equity Stock Value, $1000 at constant 2015 prices
Fertilizer	Total nitrogen (N), phosphate (P2O5) and potassium/potash (K2O) nutrients from inorganic fertilizers and N from organic fertilizers applied to soils
Feed for animal production	Total metabolizable energy from animal feed, M Cal

Source: Self-elaborated.

Estimation of the Malmquist index, proposed as a change in efficiency between two adjoining periods (Färe *et al.,* 1994).

Where D_t^I is a function that results in the distance of a decision-making unit (countries in this exercise) in period *t,* to the efficiency frontier, given a set of technologies, inputs and outputs, (Färe *et al*., 1994), this value is a score like theta, where it takes the value of 1 if it is at the efficiency frontier.

$$\mathrm{EC} = \frac{\hat{\theta}_t + 1(x_t + 1, y_t + 1)}{\hat{\theta}_t(x_t, y_t)}, \qquad \mathrm{TC} = \sqrt{\frac{\hat{\theta}_{t+1}(x_t, y_t)}{\hat{\theta}_t(x_t, y_t)} \cdot \frac{\hat{\theta}_t(x_{t+1}, y_{t+1})}{\hat{\theta}_{t+1}(x_{t+1}, y_{t+1})}}, \qquad 10)$$

Definition of efficiency change and technological frontier change (Färe *et al*., 1994).

The change in efficiency between these two adjacent periods is driven by two components, efficiency change, which refers to the resources and technologies available, and that is how far or close one is to the efficiency frontier. The change of the technological frontier refers to the sets of technologies available in each year and can be understood as a contraction or expansion of the frontier (Chang & Ross, 2024, Färe *et al*., 1994). In this approach, an improvement in efficiency can be explained by the fact that there were more technologies available or that it was more efficient with the available technologies, which allowed better results in terms of quantities of proportions of inputs and outputs obtained.

$$\mathrm{MPI} = \mathrm{EC} \times \mathrm{TC}. \qquad 11)$$

Simplification of the Malmquist index defined by the change in efficiency and the change in the technological frontier

In (k) simplifies the index, where values >1 indicate growth in productivity while values <1 indicate a decrease; The formal definition and breakdown of the method used as a reference are by Färe et al., 1994 and Chang & Ross, 2024. To visualize the contribution of each component of the index, the multiplication is decomposed to generate an additive visualization.

$$\underbrace{\mathrm{MPI}-1}_{totalchange} = \underbrace{(\mathrm{EC}-1)}_{catch-up} + \underbrace{(\mathrm{TC}-1)}_{frontiershift} + \underbrace{(\mathrm{EC}-1)(\mathrm{TC}-1)}_{interaction}. \qquad 12)$$

Additive visualization of the contribution of each component to the indicator.

For Malmquist's analysis, a set with all countries with data available in the selected regions was used in the regional comparison, for the intraregional comparison subsets by region were used.

In order to discuss the final results within an already established and broader context of analysis with applicable theoretical approaches on resilience of complex adaptive systems, concepts established in the assessment framework for food systems ABCD (Agency, Buffer, Connectivity and Diversity) (Fonteijn et al., 2022), Analysis of Complex Adaptive Systems (Carmichael & Hadzikadic, 2019, Cumming, 2011, Adger *et al*., 2005), Resilience of socio-ecosystems (Folke, 2006), Adaptive cycles and Panarchy (*Resilience Alliance - Panarchy*, n.d., Meuwissen *et al*., 2019) are used as a framework of analysis.

Results and Discussion

The section is semi-structured, comparing the interregional and intraregional data, first, of the values of Total Agricultural Productivity, then the results of the analysis by data envelope, the results of the Malmquist analysis and finally a correlation between the three.

In terms of the change in the gross value of agricultural crop, livestock and aquaculture production in 2020, Oceania has the best yields, followed by Latin America and Asia (Figure 1).

Given that in a complex system there are variables of rapid and slow qualitative change, the variability in behavior in a relatively short period of time (2020 to 2022) can be attributed to rapidly changing variables and interactions, and to the fact that the

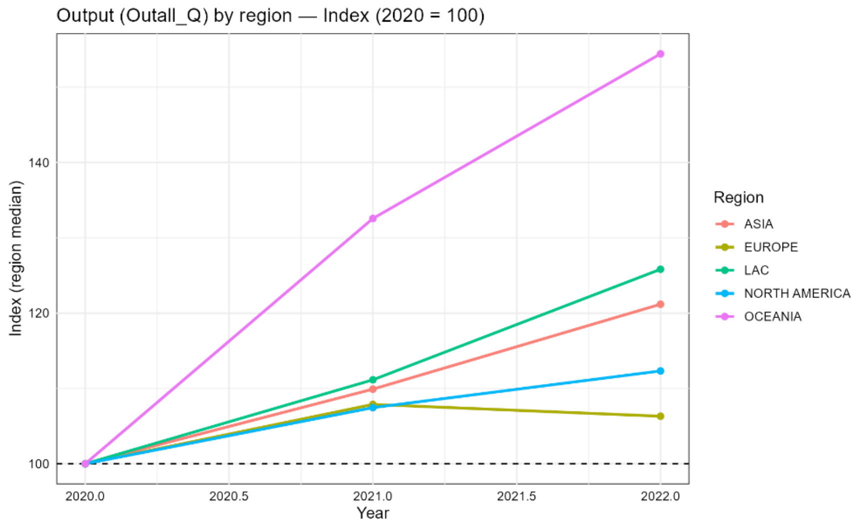

Figure 1. Values of the Output variable (gross value of total agricultural production base 2020).

response of institutions is usually when phenomena impact the daily life of society (*Resilience Alliance - Panarchy*, n.d., Folke, 2006) for example, assuming that there have been more changes in the quantities and/or prices of fertilizers, livestock feed, and capital value, their effect on process efficiency, both in the uncertainty for strategic planning and operational issues in shorter periods of action, will have a greater impact on the set of available technology and possibly on technical efficiency in the use of resources, than the sizes or holdings of production areas, as well as drastic institutional changes.

In this case, "Total Factor Productivity (TFP) growth reflects the ability to produce more with less: higher production with a given set of inputs" (Bureau & Antón, 2022: p. 4) because, in this case, the indicator uses a reference year to assess change over time, It is interesting to see the changes before and after 2020; in this sense, the impact on the trend of efficiency behavior is observed at the regional scale, where Oceania initially stands out with high values in the indicator both before and after 2020. Latin America and North America have TFP values lower than the reference year, both before and after, without recovering (Figure 2).

In reference to inputs, although it is usually presented as second place, Oceania does not stand out for having values as high as North America, only in the total area of permanent pastures (Pasture_Q), however, its gross value of total production (Output_Q) and value in Total Agricultural Productivity show resilience in terms of maintaining its efficient productive capacities or technological improvement through the process of managing COVID-19, given that by 2022, they approached their maximum values in 2017, even though there was a decline prior to 2020.

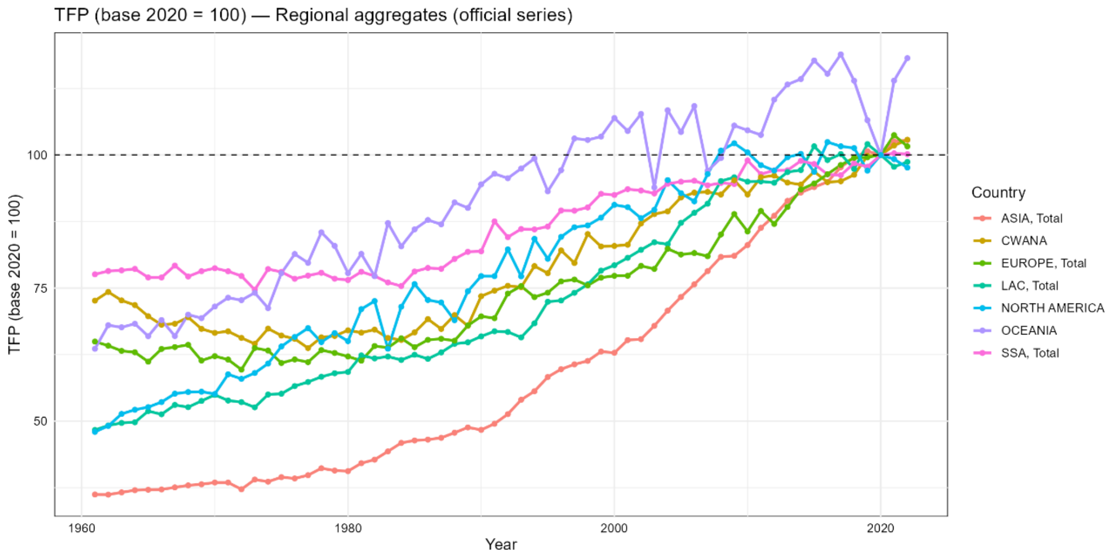

Figure 2. Time series from 1961 to 2022 with Total Agricultural Productivity (TFP) values base 2020.

As can be seen in Figure 3, some countries increased their values of the indicator. In Latin America, it is observed that Peru had an increase of 110.15 in 2021 and 118.66 in 2022, being the highest value in the total agricultural productivity

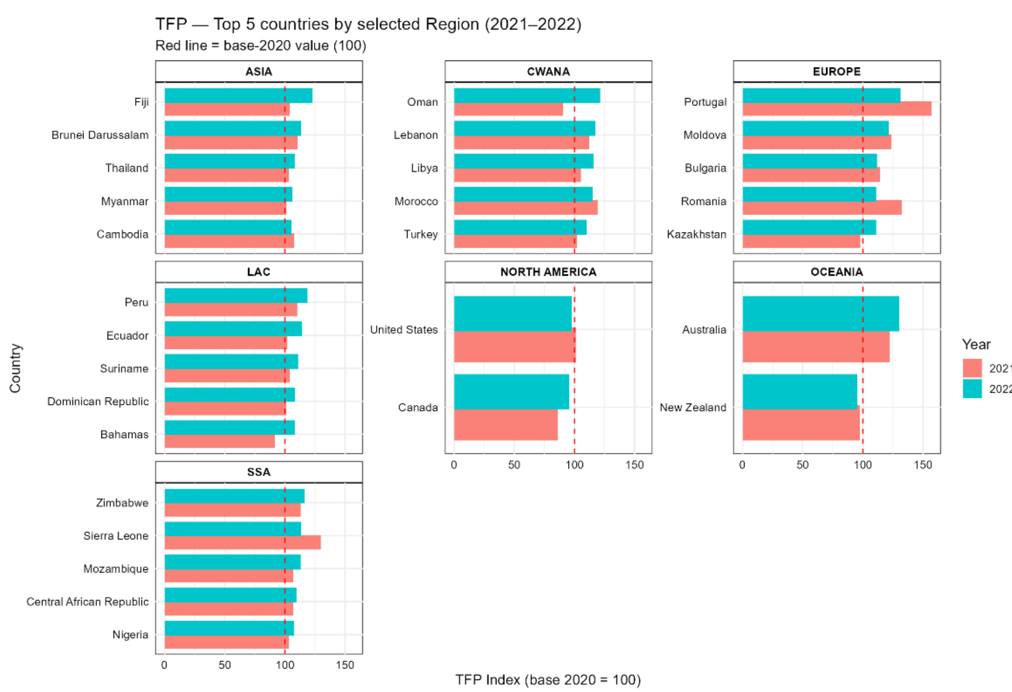

Figure 3. The 5 countries with the highest values in Total Agricultural Productivity 2021 and 2022.

index during the two years of the analysis, with Ecuador, the Dominican Republic and Suriname remaining in the top 5 during the two years of analysis.

Brunei, Fiji, Oman, Morocco, Portugal, Moldova, Romania, Peru, Sierra Leone and Zimbabwe are the best references for their respective regions in terms of reducing production costs, because their growth in the indicator implies either an improvement in the efficiency of the processes or an improvement in the set of technologies (or both). which results in less quantity or costs than those of inputs (Bureau & Antón, 2022).

Oceania and North America represent, in this database, large areas, but only two governments, however, both have low values, indicating an impact on their ability to maintain post-COVID-19 processes. When contrasting with the results of the additive decomposition of the MPI (Figure 20), we observe that there is a negative change in the technological frontier, it may be due to the loss of labor or other available inputs that the total set of possible inputs was reduced.

The following are results of the data envelope analysis, particularly the scale efficiency values. The average presented in Figure 4 is the result of the technological and process efficiency differences between countries in these regions, in Latin America,

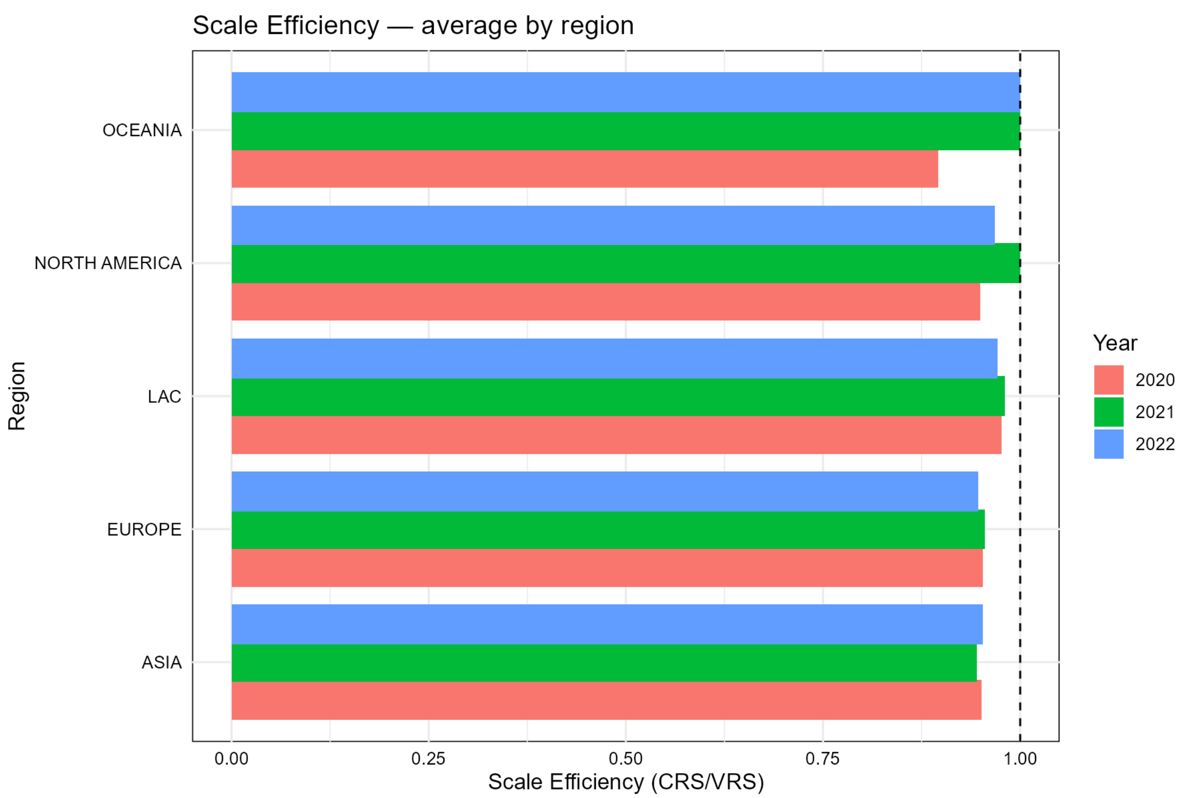

Figure 4. Average of the scale efficiency (SE) score of the countries that make up each region.

Asia and Europe, the number of countries is greater and therefore the average is more sensitive to extreme values.

In terms of efficiency of scale (SE), Oceania is part of the set that defines the border in 2021 and 2022, during this period the countries of this region operated optimally on their most productive scale (Aparicio & Santín, 2025), which reinforces the interpretation of a return to their production capacity and efficiency prior to 2020. given the production technology sets available in each year considering returns to scale as well as North America in 2021.

For those nations that have <1 values, this implies the possibility of improvement in the use of their resources (Figure 5). Values =1 coincide with the countries identified in the TFP ranking in the regions analyzed, however, Peru presents values less than 1 in the three years, not operating on an optimal scale, it was able to improve its capacity to produce the same amount with fewer inputs in the following years.

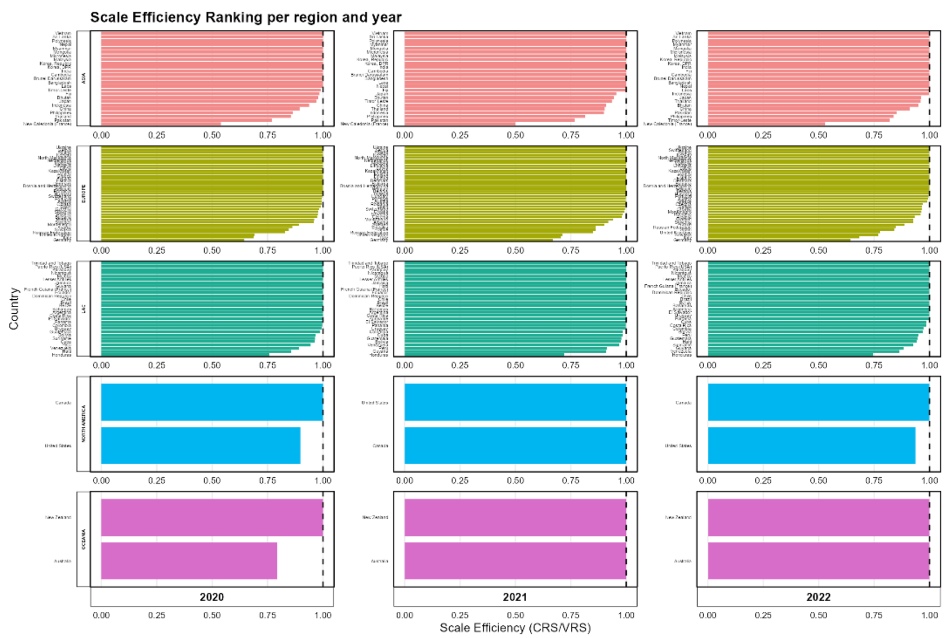

Figure 5. Score obtained by country in scale efficiency (SE).

Malmquist's analysis results:

The ranking presented in Figure 6 was made with all the mean of all the countries per region. Latin America and Europe take the 1 ranking in the period 2020 to 2021 and 2021 to 2022 respectively, Asia has number 2 in the year 2020 to 2021 and LAC in the second period. This narrative indicates the presence of feedback mechanisms between organizational scales that managed asymmetric changes and impacts on the variables of "rapid" change in supply chains, particularly those linear and nonlinear

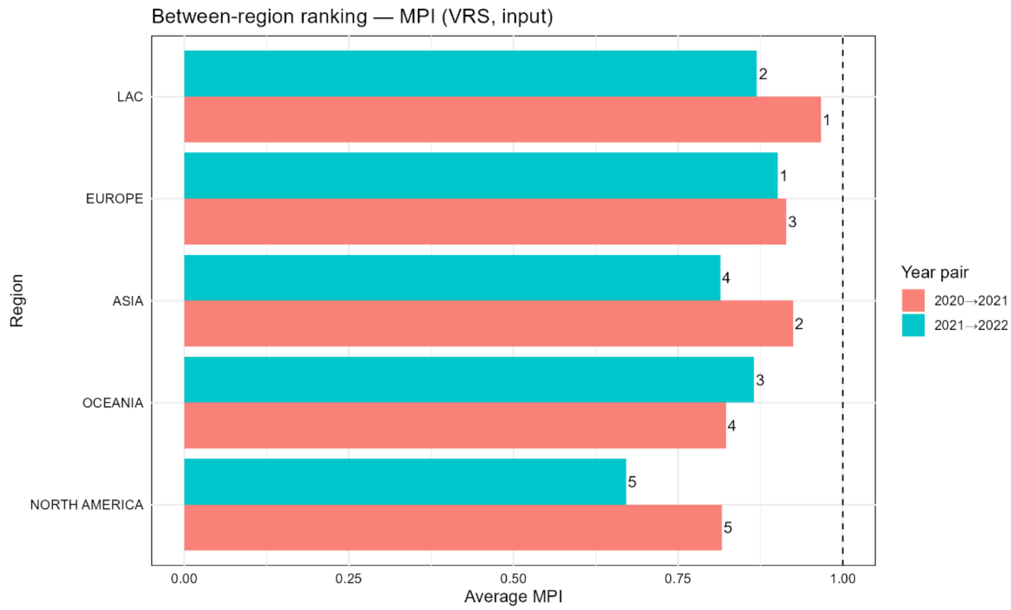

Figure 6. Average score of the Malmquist indicator of the countries that make up each region.

processes that impacted production and price levels on the farm, managing to increase efficiency in their total production after the impact produced in 2020.

This ranking was made with subsets by region (Figure 7). In Latin America, the Bahamas, Cuba and Guana stand out in the period 2020 to 2021, Honduras and Paraguay in the period 2021 to 2022. The other countries have values lower than 1, according to the indicator, that is, a decrease in the efficiency of their total agricultural productivity, after 2020, which may have previously had high values and there was a reduction in the set of available technologies, or a possible decline in the technical efficiency of the use of resources. illustrated as a distancing from the efficiency frontier.

In North America, only Canada in the period 2020 to 2021 has a value greater than 1, with a value less than 1 in both periods in the United States and the countries of Oceania. In Asia, Mongolia, Micronesia, Timos Leste and Bangladesh present values greater than 1 in the period 2020 to 2021, in the following period, this is the case only for Sri Lanka and Bhutan, which maintained their values at 1 during both periods.

In Europe, during the period 2020 to 2021, Croatia, Estonia and Slovenia have values greater than 1, Slovakia and Finland maintain a value equal to 1. In the following period, many more countries show improvements in the efficiency of their total agricultural production, including Hungary, Spain, Sweden, Ukraine and Romania, with Albania maintaining its value equal to 1.

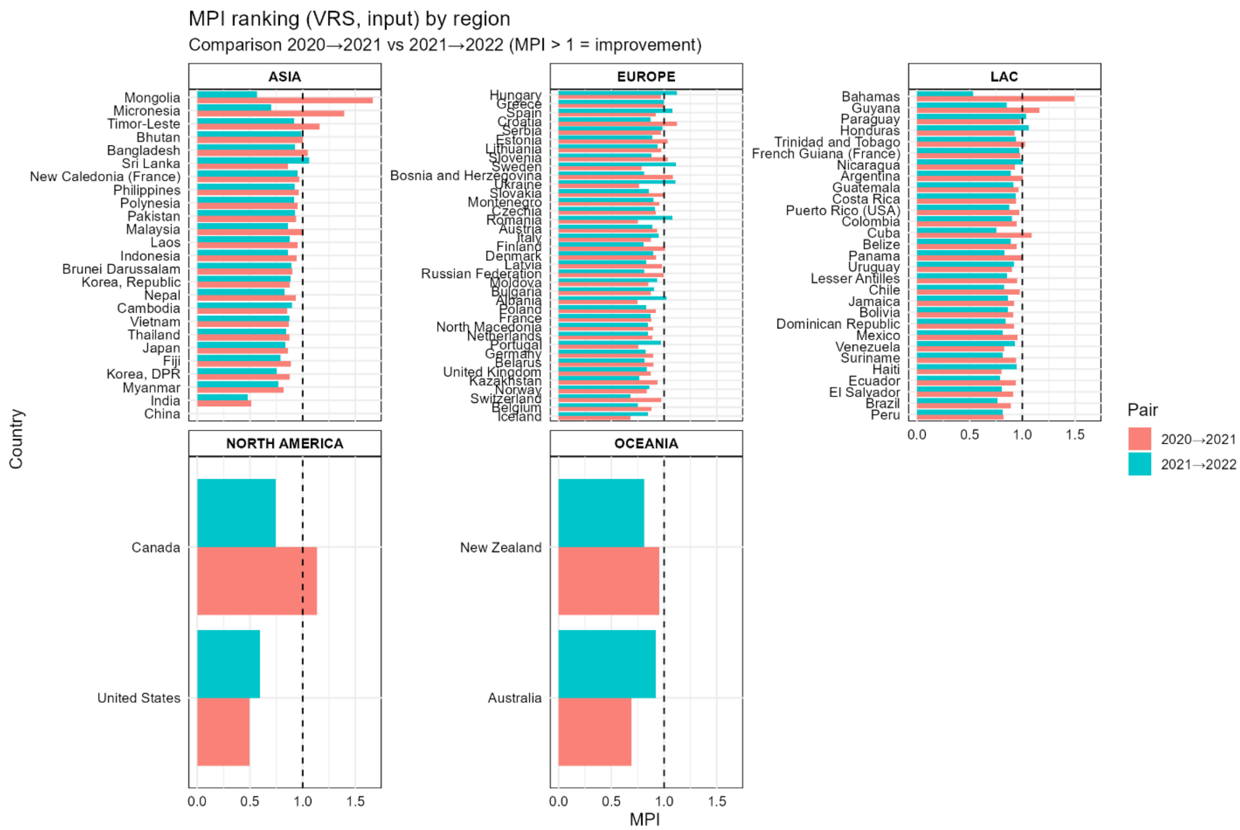

Figure 7. Score obtained from each country in the Malmquist index.

Figure 8 shows the countries with the highest value in the Malmquist indicator, this ranking being particularly useful for Latin America, Asia and Europe, and is broken down by attributing growth to a component determined by a set of available technologies and another by technical efficiency.

In the case of Latin America, the greatest growth was during the period 2020 to 2021, attributed mainly in the Bahamas and Guyana to an increase in the technological frontier and therefore a greater availability of technologies that allowed for more efficient production (with greater cost-benefit). Cuba's increase is mostly attributed to being more efficient with the same set of technologies, getting closer to the efficiency frontier. In the period 2021 to 2022 there were few changes related to the additive contribution, all related to the availability and use of sets of technologies, which may be due to an interruption in supply chains that contracted the frontier as there was less technology available (e.g. types of agrochemicals, industrial parts, workers, etc...).

Similarly in Asia, in the period 2020 to 2021, the increase in the countries is attributed to greater availability and use of technologies in the period 2020 to 2021,

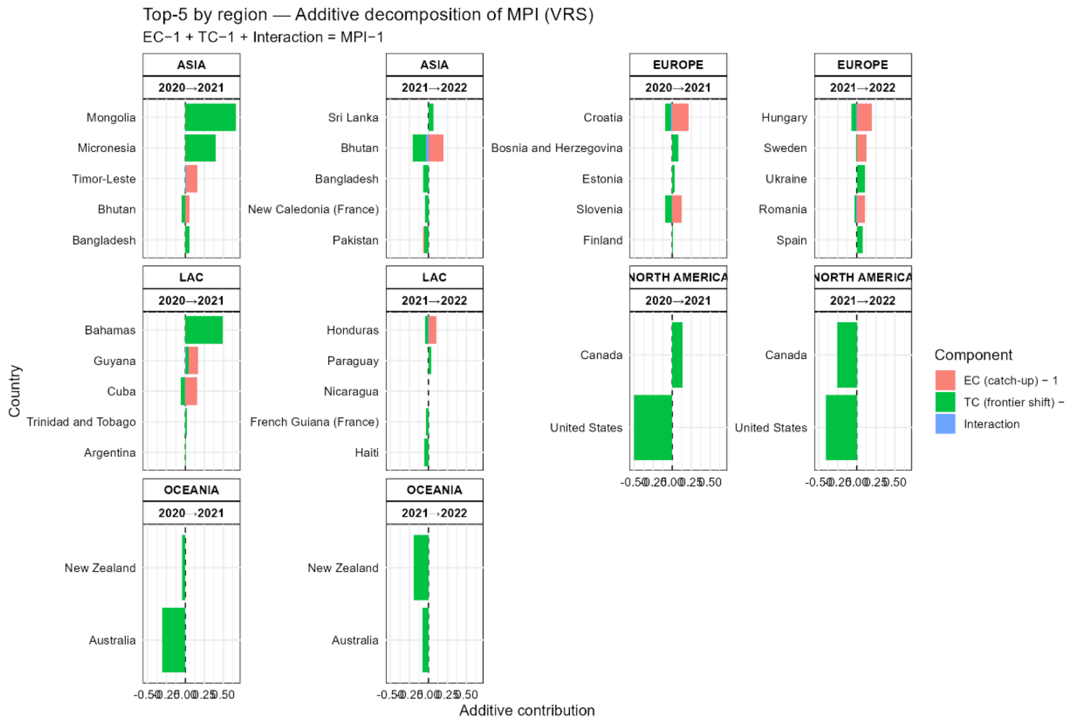

Figure 8. Additive decomposition of the Malmquist index

particularly for Mongolia and Micronesia, during the following period the largest increase is attributed to an improvement in the efficiency of the use of available resources and technologies.

In Europe, the largest increase in the period 2020 to 2021 is mostly attributed to an improvement in efficiency, particularly in Croatia, while in the following period 2021 to 2022, Ukraine stands out for an increase attributed to the subset of technologies, being this lower in Spain, while in Sweden and Hungary the increase is attributed to improving efficiency.

These analyses are performed with regional boundaries generated by the data subsets, so when these efficiency frontiers and the relative change in them are defined, by the set of available technologies, it is in relation to the countries that make up that region, "*these measures capture performance in terms of the best practices defined by the sample" (Färe et al., 1994:78).*

Consistency in the results obtained by the 3 analysis tools:

One possibility of the negative correlation (Figure 9) between TFP and MPI (also in Efficiency of Scale and MPI to a lesser extent) is that countries with high

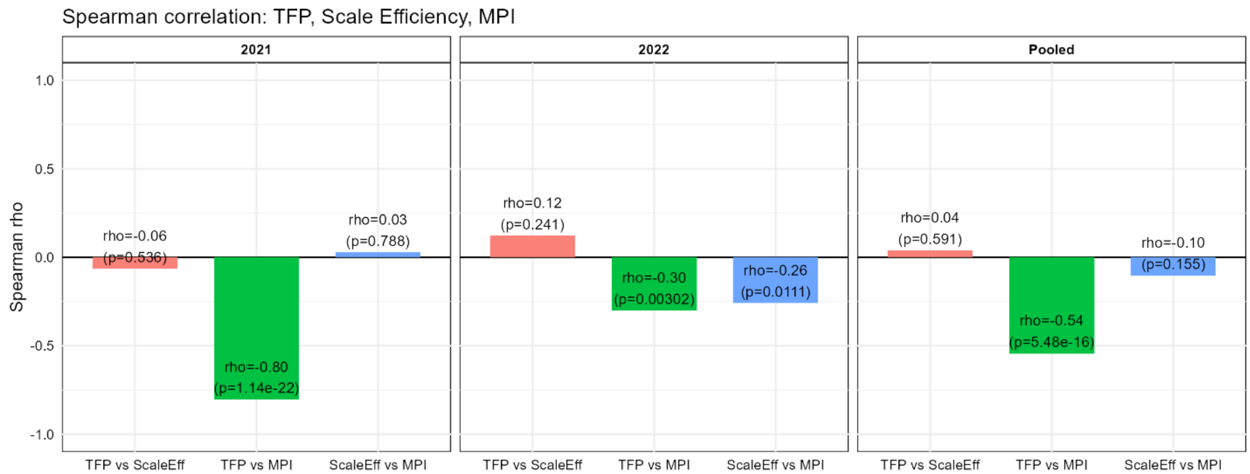

Figure 9. Results of Spearman's correlation.

total agricultural productivity and that tend to produce at their optimal scale have relatively small increases, coherent with Farnoukdia, 2023: *" can be attributed to the fact that, if a country has achieved development in a given year, it becomes increasingly difficult to achieve further development in the following year... If a country has experienced a deterioration in a given year, it is comparatively easier to achieve development in the following year through minor changes." (Farnoukdia, 2023: 3070)*

The positive correlation presented between TFP and efficiency scale, particularly in the year 2022, coincides in a monotonic relationship between operating at an optimal scale and increasing total agricultural productivity, being that it seeks to get closer to using the optimal possible amount of available resources and technologies in an efficient way (SE), there could be a more punctual correlation with an increase in technical efficiency.

Factors that determine the increase in TFP refer to the components of the Malmquist index, directly such as the change in the set of available technologies (frontier expansion) or in extension and education and market access, which indirectly refers to technical efficiency (approach to the frontier) (Depårment of Agriculture, 2025, Färe et al., 1994). These have impacts on operational processes and strategic planning, but still on the scope of actors directly related to the agricultural sector, while institutional reforms derived from public policies, which are not necessarily related to the sector, can have a broader, more asymmetrical and non-linear effect on the productivity of agricultural sectors

The Latin American region is then described in detail by comparing the values of the countries that presented the highest scores in Total Agricultural Productivity (Table 2) and the Malmquist (Table 3) index during the year 2021 and 2020, this to

Table 2. Comparison of the results for the top 5 in Total Agricultural Productivity (TFP) values.

Rank	Country	TFP 2021	SE 2021	MPI 2020-2021	Country	TFP 2022	SE 2022	MPI 2021-2022
1	Peru	110.15	0.91	0.79	Peru	118.66	0.95	0.77
2	Haiti	109.67	1	0.79	Ecuador	114.06	1	0.71
3	Bolivia	105.86	0.97	0.91	Suriname	110.87	0.92	0.84
4	El Salvador	105.63	0.99	0.90	Dominican Republic	108.39	1	0.79
5	Belize	104.51	1	0.90	Bahamas	108.06	1	0.51

Source: Self-elaborated.

Table 3. Comparison of the results for the top 5 in Malmquist index score.

Rank	Country	TFP 2021	SE 2021	MPI 2020-2021	Country	TFP 2022	SE 2022	MPI 2021-2022
1	Bahamas	91.88	1	1.44	Nicaragua	98.73	1	1.00
2	Guyana	85.09	0.90	1.27	Paraguay	76.62	1	0.98
3	Cuba	95.9	0.98	1.09	Honduras	95.21	0.71	0.95
4	Argentina	92.06	1	1.00	Haiti	107.67	1	0.94
5	Paraguay	92.69	1	0.99	French Guiana	99.09	1	0.93

Source: Self-elaborated.

highlight examples of resilience in terms of increasing and/or maintaining their TFP and the change in productivity between the periods 2020 to 2021 and 2021 to 2022.

Since the database used for this analysis aggregates the information at a national level, nations can then be defined as complex adaptive systems, with a behavior of the condition of the system (in this case TFP, SE and MPI) within a regime of attraction that involves interactions across public and private scales of organization. in economic dimensions (agriculture as an economic activity), social (given the impacts of COVID-19 on health) and ecological (considering soil management and inputs of renewable resources), these interactions are non-linear but generate dependence on paths, capturing processes and mechanisms with distinguishable and characterizable patterns. While the data directly reference inputs and outputs in terms of masses and costs, the implicit interactions warrant an approach of complex adaptive systems for their analysis (Folke, 2006, Carmichael & Hadzikadic, 2019).

It is intuitive to want to identify the public policies and practices (or identifiable processes and patterns) carried out at the multiple organizational scales that allowed these countries to be resilient and maintain or increase their productivity and efficiency through this period of health crisis, not only with primary producers but also with the industrial and marketing sector. Largely affected, by institutional structures, regulations and power interactions, as well as the monitoring and action capacity of the multiple actors, both small producers and large public companies that direct the direction of adaptation, since an improvement in econometric terms does not necessarily imply a fair distribution of profits or sustainable management of the resources involved in production. "*A management system for a natural resource has multiple scales and must be managed at different scales simultaneously" (Adger et al., 2005:1)*

One approach is to characterize the demographic groups, actors, and systems that make up the agricultural sector and identify the formal (and informal) feedback mechanisms across scales of organization present related to gender, social status, level of education and educational opportunity (Agency), savings capacity, amount of savings, statistical parameters related to financial capabilities (Buffer), merchant networks, distances to markets, percentage of inputs exchanged between whom (Connectivity), non-agricultural economic activities, type of production system or industrialization (Diversity). These variables and properties of Agency, Buffer, Connectivity, and Diversity are proposed in the ABCD approach to assess food systems resilience and can be integrated by categorizing or defining mechanisms as adaptative, transformative or robustness driving (Meuwissen et al., 2019, Fonteijn et al., 2022).

The presence of these feedback mechanisms, quantifying them over time and in horizontal and vertical interactions at the public and private organizational scales, can help to identify the designs and configurations of policies, infrastructure, and capacities of agents that, in non-linear interactions but with a recordable dependence on paths, correlate with resilience. In this way, with a reliable record, changes in domain regimes derived from external phenomena at the national level can be integrated as the decisions or selection criteria of the decision-making units to these options (or unplanned emergent behaviors, and therefore importance of having Agency in the agricultural sector). which, in a correlated change, generate adaptations that allow the efficiency of the agricultural sector to be maintained, the coherent limitation of this category of analysis being key (Folke, 2006, Carmichael & Hadzikadic, 2019, Cumming, 2011).

In this way, resilience is proposed in this paper as quantifiable indirectly in terms of maintaining or increasing efficiency; Because this attribute is intrinsic to systems, being efficient is first defined by the technological capabilities of the system and then how optimally those resources are used, this latter optimization characterization requires comparison with systems with similar capabilities and scales.

Methodologically, the presence of agency, diversity, connectivity and buffer properties can be correlated with total agricultural productivity or the Malmquist index, both individually and/or in multiple configurations and values, especially after an external event that negatively affects and threatens a change in the dominance regime. A characterization of this type is justified in a nation like Mexico, where there are great differences in the scales and production capacities of the actors that make up the agricultural sector and its entire production and value chain.

Limitations of the study

The database used for the analysis has subsets of country data that were estimated due to lack of information (Department of Agriculture, U.S. 2025), as well as multiple changes and revisions that make it subject to bias and errors. The information is highly aggregated and incorporates multiple sectors, so the results should be taken with criticism.

The efficiency scale (ES) DEA analysis such as Malquemist (MPI) was input-oriented, it was assumed that countries sought to maintain productivity levels with the same or fewer inputs due to supply chain disruptions. For the analysis of regional Malquemist, regional sets were used, while the efficiency scale used the total set of countries to make a comparison that considers interregional examples, which limits their comparison and opens up a comparative analysis of subsets of data.

The difference in complexity in terms of decision-making is evident between regions and countries of the world, with there being, for example, more countries and therefore more administrative boundaries in Latin America than in Oceania or North America; this point is not explicitly considered in the analysis, a subsequent review of the correlation between productivity, number of government regimes and participation is proposed, to identify institutional mechanisms and public policies that provide resilience in terms of agency, connectivity and diversity (Fonteijn et al., 2022) abstracted into variables and indicators of a social nature.

Conclusions

The most resilient regions and countries by region have been identified, in terms of maintaining and/or increasing their capacity to convert inputs (efficiency) into procedures and improve the set of technologies available during the period 2020 to 2022, obtaining different results depending on the analysis tool.

In Latin America, according to total agricultural production (TFP), Peru stands out for being the country that was present in the 2 years, with El Salvador and the Dominican Republic, Bolivia, Haiti and Belize in the first places during 2021 and 2022. In terms of the Malmquist index, Paraguay remained in the ranking for the analysis of both periods, in which the Bahamas, Cuba, Argentina and Nicaragua, Honduras and Haiti were also in 2021.

A negative correlation between total agricultural production (TFP) and the Malmquist index, a negative correlation between scale efficiency (SE) and the Malmquist index and a positive correlation between total agricultural production

(TFP) and scale efficiency (SE) were estimated, being consistent with the bibliographic references consulted.

Concepts, approaches, and possible methodologies that integrate multiple disciplines to characterize and quantify resilience were identified and discussed, highlighting the approach of complex adaptive systems and ABCD, which are coherently structured for integration with econometric approaches.

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REMeVAL

HIGH-VALUE CROPS AS A DEVELOPMENT STRATEGY: EVALUATION OF FIG CULTIVATION WITHIN THE FRAMEWORK OF THE SEMBRANDO VIDA PROGRAM

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Abstract

Protected agriculture has established itself as a viable strategic alternative for diversifying peasant production in rural areas. This study evaluated the cultivation of fig (*Ficus carica* cv. Neza) a high-value fruit, within the framework of the Sembrando Vida program. The objective was to analyze its technical, economic, and institutional viability. The analysis was based on a theoretical framework for public policy evaluation, incorporating the concepts of differentiated policies and entry and exit strategies geared toward the implementation and scaling of productive projects. To this end, a 50 m² pilot module with 60 greenhouse plants was designed at the Chapingo Experimental Field, operated in two staggered cycles per year. Yields of up to 76 t ha^{-1} were obtained, with soluble solids above 17° Brix and firmness greater than 5 Newtons: meeting export quality standards. The economic analysis projected gross revenues of $14,000.00 MXN per module annually, with net margins of $3,500.00 MXN and a benefit-cost ratio of 1.2. The territorial analysis identified the states of Morelos, Puebla, Hidalgo, and the State of Mexico as highly suitable due to their agroclimatic vocation, levels of marginalization, and the institutional presence of the program. It is concluded that the proposed module is technically viable, economically profitable, and institutionally compatible with the guiding principles of Sembrando Vida, particularly those of food self-sufficiency, environmental regeneration, and social inclusion. Consequently, it is recommended to promote their adoption through modular micro-lots to maximize

economic benefits for rural communities and strengthen the national strategy for inclusive rural development.

Keywords: protected agriculture, differentiated policies, fig, entry strategy, rural development.

Introduction

Rural development in Mexico faces structural challenges expressed in high levels of poverty and marginalization, low agricultural productivity, and increasing vulnerability to climate change (CONEVAL, 2023; FAO, 2021). Faced with this situation, public policy has sought to reestablish intervention schemes that go beyond addressing insufficient peasant income and, at the same time, strengthen the social fabric and promote environmental regeneration processes. Within this framework, the Sembrando Vida program constitutes one of the most ambitious social and productive policy initiatives in the country, aimed at linking the promotion of agroforestry systems with community inclusion and local capacity building (Secretaría del Bienestar, 2024).

The effectiveness of these rural policies, however, depends on their ability to recognize the heterogeneity of the Mexican countryside. In this sense, the literature on public management emphasizes the relevance of designing differentiated policies, understood as those that adapt their instruments and strategies to the conditions of each social and territorial group (Ortegón, 2008a; Sen, 2000). From this perspective, the contemporary peasantry is characterized by pluriactivity and the need to diversify risks, so any productive innovation must be integrated into modular schemes compatible with local social and economic dynamics (Kay, 2009). In this context, the analysis of high-value crops such as fig (*Ficus carica* cv. Neza) under protected agriculture should not be limited to technical productivity criteria but should also consider their institutional and social compatibility within programs such as Sembrando Vida.

Public policy evaluation provides an appropriate analytical framework for examining such integration, as it distinguishes three key stages: the entry strategy, which refers to crop selection and the design of pilot modules consistent with the program's resources and capabilities; the validation phase, which focuses on measuring technical, social, and economic variables under real-world adoption conditions; and the exit strategy, which defines criteria for territorial scalability and long-term sustainability (Weiss, 1998; Ortegón, 2005). These phases should not be understood as linear processes, but rather as cyclical ones, as feedback is essential for continuously adjusting the technical and social components of the policy.

Within this framework, protected agriculture is defined as a differentiated strategy for productive diversification, combining technical innovation—microclimate control, increased yield and quality—with social relevance—small-scale modules, transferable training within one year, inclusion of women and youth—and environmental advantages—efficient water use, reduced application of agrochemicals. In particular, the cultivation of fig (*Ficus carica* cv. Neza) is emerging as a fruit with high nutraceutical potential, with growing demand in national and international markets and notable adaptability to marginalized contexts (Mendoza *et al*., 2017). These characteristics make it a strategic crop for evaluation within the Sembrando Vida production catalog.

The objective of this study was to evaluate the viability of fig cultivation under protected agriculture as a fruit diversification strategy within the framework of the Sembrando Vida program. To this end, we considered technology transfer, the use of existing community resources and structures—Peasant Learning Centers (PECs), bio factories, and community nurseries—as well as their technical and productive compatibility in marginalized regions with agroclimatic potential. Based on this analysis, we seek to generate evidence that will contribute to the design of differentiated public policies aimed at promoting peasant innovation and strengthening the national strategy for sustainable rural development.

Theoretical framework

The field of public policy evaluation has shifted from approaches focused on regulatory compliance and administrative control to perspectives oriented toward organizational learning, continuous improvement, and strengthening territorial development. This paper adopts an evaluation-for-development approach that integrates three core dimensions: 1) public relevance, 2) territoriality, and 3) policy improvement. Three analytical references are articulated within this framework: i) policy guidelines and cycle (design, implementation, monitoring, and evaluation); ii) evaluative models and criteria; and iii) the territorial and institutional dimension. Ortegón's (2008b) Guide to Public Policy Design and Management, developed within the framework of ILPES/ECLAC, is a seminal reference in Latin America, as it links state capacities, inter-institutional networks, incentives, and evaluation methods throughout the policy cycle (design, negotiation, implementation, monitoring, and evaluation), while emphasizing the importance of performance indicators and cost-benefit analysis in public decision-making.

This framework posits that the quality of a policy depends on its internal coherence—expressed in the theory of change, means-ends congruence, and implementation arrangements—and its external coherence, relative to its alignment with the territorial context, actors, and institutional capacities. Consequently, evaluation transcends the measurement of outcomes to become an explanatory process of how and why an intervention works (or not) in specific territories, and an indispensable feedback mechanism for policy design.

The notion of differentiated policy refers to designs that recognize the socioeconomic, environmental, and cultural heterogeneity of territories and adjust instruments, goals, and implementation paths based on these specificities. In rural Mexico, factors such as peasant pluriactivity, asset diversity (land, water, social capital), gender gaps, and climate variability require policy to be tailored to different contexts (semi-arid, irrigated, rainfed; with and without experience in protected agriculture) to maximize its relevance and effectiveness. In Sembrando Vida, this differentiation is reflected in components such as Agroforestry Systems (AFS), the Milpa Intercropped with Fruit Trees System (MIAF), community nurseries, bio factories, and Peasant Learning Centers (CAC). Within this framework, the compatibility of the protected fig with these components was evaluated, as well as with the inclusion and scalability criteria already defined by the program.

From the perspective of public policy design, the entry strategy involves defining the target population, pilot territories, initial instruments, governance arrangements, and critical assumptions of the theory of change. Ortegón (2005) emphasizes that this phase must explicitly articulate the cause-effect relationship, the coherence of ends and means, and the definition of incentives and institutional capacities necessary for implementation and monitoring, such as agency roles, coordination mechanisms, and learning models, which determine subsequent effectiveness. In some cases, evidence shows attempts to intensify fig cultivation where a lack of experience in technical management or marketing aspects has discouraged adoption and continued cultivation. Hence the importance of validating production processes through applied research before moving toward a scaling strategy.

Applied to this case, the entry strategy was conceived in four components: i) technological validation in small, scalable modules; ii) territorial selection based on agroclimatic criteria, social backwardness, and institutional presence (CAC, technicians, bio-factories); iii) technological and social transfer arrangements (training, nurseries, inputs, technical-social support); and iv) definition of a market strategy (short circuits and collective schemes) that makes economic sense for adoption. These guidelines derive from both the institutional analysis of Sembrando Vida and the documented evidence in the file of the compatibility of fig cultivation with the program.

The exit strategy establishes "graduation" conditions in three dimensions: a) technical efficiency, expressed in the consolidation of standardized management protocols and the achievement of consistent quality; b) economic efficiency, measured by a benefit-cost ratio greater than one, compliance with the break-even point, and access to marketing channels; and c) social and environmental sustainability, reflected in the use of bio-inputs, community organization through CACs, and the inclusion of women and youth in production processes. The technical evaluation report for the protected fig tree reports positive net margins on small areas and effective integration with nurseries and bio factories. These elements allow for a responsible transition from intensive support to a phase of light accompaniment and monitoring, a necessary condition to ensure both sustainability and territorial scalability.

OCDE-DAC and CIPP Criteria

The classic evaluation criteria—relevance, coherence, effectiveness, efficiency, impact, and sustainability—allow for an assessment of the extent to which the innovation package associated with fig cultivation under protected agriculture responds to territorial needs, is aligned with the Sembrando Vida Program, generates the expected results and changes with appropriate use of resources, and demonstrates long-term viability. Additionally, the CIPP (Context-Input-Process-Output) model offers an analytical framework that guides the assessment in four dimensions: Context (conditions of social backwardness and agroclimatic characteristics); Inputs (productive infrastructure such as nurseries, bio factories, and technicians); Process (technology transfer and collective learning in the CACs); Output (yield, production quality, and income generated).

Realist evaluation, based on the mechanisms-contexts-outcomes framework, provides an explanatory approach to what works, for whom, and under what conditions. For example, the combination of high planting density with plastic covers and the organizational expertise of a CAC can favor substantial increases in productivity and quality; while the presence of water limitations, accompanied by insufficient assistance, is associated with risks to productive performance. In turn, contribution analysis allows connecting the intervention (the protected fig module) with the observed outcomes, without requiring a perfect counterfactual, which is particularly useful in multi-component programs such as Sembrando Vida.

The territorial approach conceives development as an endogenous process, in which the coordination of local actors, knowledge, and resources generates added value and social cohesion. According to Ortegón (2005), governance—understood as the capacity for coordination, the existence of networks, and adequate incentives—along with the connection with science and technology, are fundamental conditions for transforming productive structures. This reinforces the importance of institutional capacities and social learning as pillars for sustaining innovations in rural areas.

This territorial assessment analyzed three dimensions: i) agroclimatic conditions; ii) social backwardness; and iii) the institutional presence of Sembrando Vida. Based on this, pilot municipalities were selected, and the innovation module (planting densities, water management, and training framework) was tailored to each context.

Effective technology transfer for fruit crops under protected agriculture requires the integration of four elements: a) modular technology packages compatible with peasant pluriactivity; b) social learning through CAC (Cooperation and Development Cooperation), field schools, and peer mentoring; c) endogenous provision of inputs, such as stake nurseries and local bio-inputs; and d) linkages to markets through short circuits or collective purchases. Evidence from the technical file indicates that greenhouse-grown figs achieve higher yields (≈76 t ha-1) and high levels of quality, which enables attractive incomes for small-scale modules, an essential condition for their adoption.

Compatibility of the protected fig with Sembrando Vida

The cultivation of fig (*Ficus carica* cv. Neza) under protected agriculture shows high compatibility with the program components:

SAF/MIAF: It is integrated as a perennial fruit tree that diversifies income, contributes to carbon capture, and can be harmonized with the milpa calendar through pruning and fertigation adjustments.

Nurseries and bio factories: propagation by cuttings and management with bio-inputs reduce costs and strengthen local technological sovereignty.

CAC and gender approach: The demand for skilled labor in pruning, sorting, and packing opens opportunities for women and young people, provided it is accompanied by gender-sensitive strategies and equitable marketing schemes.

Inclusion and scalability criteria: The modular design (e.g., 50 m^2) allows for starting with small units and expanding as demand grows and capacities strengthen, a critical aspect in territories with water and capital limitations.

Indicators and evaluative hypotheses

For the specific case of fig evaluation in protected agriculture, four types of indicators were considered:

Economic: yield ($kg \cdot m^{-2}$), quality (° Brix, firmness), production costs, benefit-cost ratio (B/C) and break-even point.

Social: participation of women and youth, training hours, CAC governance, marketing agreements.

Environmental: water consumption per kg produced, use of bio-inputs and soil health indicators.

Institutional: coverage of technicians, operation of nurseries and bio-factories, and coordination with the program's Operating Rules.

The central hypothesis holds that, in municipalities with favorable agroclimatic conditions, high social backwardness, and a strong institutional presence, the adoption of protected figs with the support of CACs generates significant improvements in productivity, income, and social organization. These results translate into B/C ratios > 1 and stable commercial quality, conditions that reinforce the viability of this crop as a distinct strategy for Sembrando Vida.

Methodology

This research was designed using a mixed-methodological approach, integrating the technical-experimental validation of fig (*Ficus carica* cv. Neza) cultivation under protected agriculture conditions with an economic, institutional, and territorial analysis aimed at assessing its compatibility and viability as a productive alternative within the Sembrando Vida program. This approach allowed, on the one hand, to examine the yield and quality of the crop in a controlled environment and, on the other, to analyze the feasibility of its adoption in rural communities, considering public policy arrangements and schemes.

Pilot module

A 50 m² pilot module was designed, consisting of 60 fig plants (*Ficus carica* cv. Neza), at the Chapingo Experimental Field, under multi-tunnel greenhouse conditions. The modular design responded to the principle of farmer adaptability, considering small areas that could be integrated into diversified production units without displacing staple crops intended for subsistence and dietary supplementation.

The experimental management was structured with a phased production schedule that included two annual cycles of approximately six months each, with the goal of ensuring income continuity. During each cycle, agronomic and quality variables were recorded, including:

Yield per plant and per surface ($kg{\cdot}m^{-2}$ and $t{\cdot}ha^{-1}$).

Fruit quality parameters, such as total soluble solids (° Brix), firmness, size and uniformity.

Plant health, measured through the incidence of pests and diseases, as well as the effectiveness of local bio-inputs in phytosanitary management.

The analysis of these parameters validated the hypothesis that fig cultivation under protected agriculture can achieve higher yields than those reported in rainfed systems, while maintaining quality standards compatible with the demands of the fresh fruit market.

Training and technology transfer

A 12-month support protocol was designed, aimed at the comprehensive transfer of knowledge and production practices to participating producers. This program included various training and organizational components, including:

Practical training in pruning, fertilization, and phytosanitary management using bio-inputs.

Specialized harvest and post-harvest workshops, focused on preserving fruit quality and reducing losses.

Community management and organization sessions, coordinated with the Peasant Learning Committees (CAC) as spaces for collective strengthening.

The methodological approach adopted was based on building local capacity, based on the principle that, at the end of the mentoring period, producers will have the necessary skills to independently manage their production module. This strategy responds to the technology transfer objectives set forth in the Sembrando Vida program by promoting social learning, self-management, and sustainability processes at the community level.

Financial analysis

A financial feasibility analysis of the pilot module was conducted to determine its economic viability under small-scale conditions. The study included three main components:

Initial investment, which included the installation of greenhouse infrastructure (metal structure, plastic cover, anti-aphid mesh), the drip irrigation system, as well as the acquisition of seedlings and propagation materials.

Production costs, including labor, acquisition and application of bio-inputs, infrastructure maintenance, and electricity consumption associated with the irrigation system.

Projected income, calculated from the marketable volume per production cycle, considering local and regional market prices.

The module's profitability was assessed using standard economic analysis indicators, such as the benefit-to-cost (B/C) ratio, net margin, and revenue per unit of surface area. A B/C value greater than 1.1 was established as a viability criterion, in line with recommendations for high-value, small-scale crops (FAO, 2021; Mendoza *et al*., 2017).

Institutional evaluation

A documentary analysis of the current guidelines and Operating Rules of the Sembrando Vida program (Secretaría del Bienestar, 2024) was carried out, with the purpose of identifying the degree of compatibility of the protected fig module with its strategic components:

Agroforestry Systems (SAF)

Milpa Intercropped with Fruit Trees (MIAF).

Community nurseries.

Bio-factories of organic inputs.

Peasant Learning Committees (CAC).

The profitability of the module was assessed using standard financial analysis indicators, such as the benefit-cost (B/C) ratio over a 15-year period, the Net Present Value (NPV), the Internal Rate of Return (IRR), and the payback period. A B/C value > 1 was established as a viability criterion, consistent with recommendations for high-value, small-scale crops (FAO, 2021; Mendoza *et al*., 2017).

Territorial evaluation

Finally, a territorial assessment was conducted to identify priority areas for pilot implementation of fig cultivation under protected agriculture, applying an approach based on climate and social compatibility. To this end, three main sources of information were used:

CONEVAL (2023): index of social backwardness at the municipal level, used to prioritize territories with high levels of marginalization.

SIAP (2023): information on water availability, agricultural land use and complementary crops in the regions considered.

INIFAP Agroclimatic Atlas (2019): identification of semi-arid zones with potential for the establishment of fruit trees under protected agriculture conditions.

The territorial analysis made it possible to guide the incorporation of figs as a sustainable fruit alternative into the program's technical catalog, particularly in semi-arid and agricultural transition regions. In this process, potential municipalities for module validation were evaluated based on three key categories, defined based on public policy objectives and the production system's adoption potential: agroclimatic conditions, level of marginalization, and institutional presence. These categories are presented systematically in Table 1 to support the selection of pilot territories and ensure the relevance of the intervention.

Calculating the score of potential municipalities/states

The score calculation for determining the suitability of a municipality/state is first performed for each category, as shown in Table 2. As a final step in calculating suitability, the three categories are summed. This result should be placed within the range according to the interpretation scale, which will indicate the interpretation of the municipality/state's suitability.

Based on these categories, the impact was focused on those communities with the greatest need for innovative production alternatives. The categories were weighted using an institutional compatibility approach, which not only considers the agronomic suitability for cultivation, but also the existence of a favorable environment for

Table 1. Evaluation of potential municipalities for fig cultivation under protected agriculture.

Evaluated category	Variables considered	Evaluation criteria (score)	Maximum score
1. Agroclimatic conditions **(agro_cond)**	- Average annual solar radiation (kcal/cm²/año)	≥ 450…………………(10) 430–449………………(8) 410–429………………(7) 390–409………………(6) 370–389………………(5) 350–369………………(4) 330–349………………(3) 310–329………………(2) <310…………….....…...(1)	10
	- Taverage annual temperature (16-36°C)	20–28 °C…………….(10) 18–19.9 o 28.1–30…..(8) 16–17.9 o 30.1–32…..(6) 14–15.9 o 32.1–34…..(4) <14 o >34…………….(1)	
	- Water availability (irrigation or treated wastewater: planting, 4 l/day 60 days; development, 6 l/day 30-45 days; fruit emission, setting and ripening 8 l/day per plant) the variation in moisture retention depends on the substrate.	- Abundant and reliable [legal well, irrigation and/or treated wastewater]………..……………(10) Good [well or seasonal irrigation with management possibilities]...(8) Partial [seasonal source, limited catchments]………………………(6) Low [rain dependence]………….(3) Criticism [no viable sources]……(1)	
	- Previous experience in protected fruit growing	Multiple projects/greenhouses operating with trained technicians………………………(10) Specific experiences/producers with a track record……………..…(8) Recent initiatives in piloting.……(6) No local experience……………..(2)	
2. Marginalization level **(marg_lev)**	- Social Backwardness Index (CONEVAL)	Very high - national top quartile.......................................(10) High -2nd upper quartile………...(8) Medium high..……………………(6) Half…………...…………………....(4) Low/very low…...………………….(1)	10
	- Percentage of rural population	70% rural ………………………(10) 50–70% …………………………(8) 30–49% …………………………(6) 10–29% …………………………(4) <10% ……………………………(1)	
	- Lack of basic services (water, electricity, drainage)	60% lack………..………………(10) 40–59% …………………………(8) 20–39% …………………………(6) 5–19% …………………………..(4) <5% ……………………………..(1)	

Table 1. Continued.

Evaluated category	Variables considered	Evaluation criteria (score)	Maximum score
3. Institutional presence of Sembrando Vida (inst_pres)	- Number of active CACs	consolidated CAC with documented regular activities…………..…….(10) Active CACs with regular activities….……………..…………(8) CAC in training…….….…...…….(6) CAC planned, but not active……………………………...(3) Without CAC……………………..(1)	10
	- Presence of productive and social technicians	≥1 technician per 50–100 families [fam] with ongoing training…...……………………….(10) 1 technician per 100–200 fam.....(8) 1 per 200–500 fam ……………...(6) <1 per 500 fam ………………..…(3) No technician…...…………………(1)	
	- Existence of community bio-factories	Bio-factory(ies) operating and supplying inputs…………………(10) Bio-factory(ies) in the implementation phase………..…..(7) Plans for a bio-factory without operation………………………….(4) They do not exist…………...……(1)	
	- Experience with previous fruit crops	Several successful fruit projects [documented]……………………(10) Pilot projects with partial results……………………………..(8) Limited experiences…………….(5) No experience…………………...(1)	

Source: Selft-elaborated.

Table 2. Interpretation scale.

Score by category *	Escala de interpretación (Rango)	Aptitud
agro_cond = (A + B + C + D) / 4	25–30 puntos	Alta aptitud, alta prioridad para implementación piloto
marg_ lev = (A + B + C) / 3	18–24 puntos	Aptitud media, requiere fortalecimiento de capacidades antes de implementación
Inst_pres = (A + B + C + D) / 4	10–17 puntos	Aptitud baja, no recomendable en la fase inicial del proyecto
Municipality/State = cond_agro + marg_lev + inst_pres (search range)	<10 puntos	No apto, condiciones técnicas, sociales o institucionales insuficientes.

* Round the result to the nearest integer (min. 1, max. 10).

Source: Selft-elaborated.

cultivation from an agronomic perspective, in a social and institutional context capable of fostering its adoption, scalability, and sustainability. This analysis also allows for the identification of initial intervention areas where fig cultivation can be evaluated as a scalable fruit alternative, with technical support and territorial relevance.

By cross-referencing this information, four states were selected that contain municipalities with potential for community validation, considering their favorable agroclimatic conditions, the institutional presence of the Sembrando Vida program, and the organizational capacity of the communities.

Results

Productivity and fruit quality

The cultivation of fig (*Ficus carica* cv. Neza) under protected agriculture and high planting density (1.25 plants m^{-2}) reached an annual yield of up to 76 t ha^{-1}, far exceeding the national open-air averages (5–6 t ha^{-1}; SIAP, 2023).

Regarding fruit quality, the average soluble solids content was 17.2° Brix, firmness between 5.1 and 5.8 Newtons, and uniformity in color and size were recorded, meeting fresh market and export standards (Piga *et al*., 2008; Mendoza *et al*., 2017). These results confirm the technical and commercial viability of the system under agroecological management.

The proposed pilot modules (50 m², with a density of 1.5 plants m^{-2}) allow for estimated yields of 1,000 kg per year. This production level makes it possible to recover the initial investment and generate a surplus of $60,000.00 MXN, with an IRR of 19% and a B/C ratio > 1, which increases to 1.22 in 100 m² modules and to 1.85 in 500 m² modules. The 50 m² module can multiply producers' minimum income up to five times. Integration with community bio-factories and the use of local materials reduce costs and facilitate the model's replicability under collective marketing schemes, strengthening community networks and boosting local economies (Table 3).

Table 3. Financial profitability indicators.

Fig cultivation	VAN ($ M. N.)*	TIR (%)*	R (B/C) *	PR (Years)
50 m^2 module	60 026.38	19	1.12	7.8
** 100 m^2 module	133,504.77	20	1.22	7.4
**500 m^2 module	793,541.45	23	1.85	6.5

*Project planning horizon: 15 years, with a 12% update rate and a fig sales area of $30.00 MXN per kg1
**Scalable modules with suitable conditions and knowledge appropriation. Source: Prepared by the authors.

The consistency of quality and health across staggered cycles supports the adoption of protected fig as a scalable fruit alternative in rural communities. Overall, the results validate the hypothesis that protected agriculture offers an effective strategy for overcoming productivity and quality limitations associated with rainfed systems, ensuring income stability and socioeconomic relevance within the framework of the Sembrando Vida program.

Documentary analysis of compatibility with the program

In the documentary analysis of compatibility between the protected agriculture fig production model and the public policy guidelines established by the Sembrando Vida program (Secretaría del Bienestar, 2024), a systematic comparison was made between the program's regulatory criteria and the technical, social, and economic characteristics of the protected fig production system. The proposed model aligns with the program's strategic objectives and opportunities for adapting it to the Sembrando Vida production portfolio. The results of this comparison are presented in Table 4.

The findings obtained demonstrate a high degree of congruence between the proposed fig cultivation system under protected agriculture and the structural components of the Sembrando Vida program, considering four key aspects.

First, in terms of productive self-sufficiency, fig cultivation can complement the family food system through its fresh consumption and its processing into derivatives, such as jams and dried fruits, while generating marketable surpluses.

Secondly, regarding the strengthening of the CACs, the introduction of a novel crop, with a high demand for technical learning and possibilities for continuous improvement, which encourages collective work, horizontal transfer of knowledge and peasant experimentation, fundamental principles of the CACs (Sembrando Vida, 2024).

Third, regarding the production of bio-inputs and agroecology, the system adapts to the use of compost, leachates, mycorrhizae, and microorganisms produced in community bio-factories. Since the fig is a rural crop with potential for research and validation under these conditions, it contributes to reducing dependence on external inputs and strengthening local technological sovereignty (Toledo & Barrera-Bassols, 2015).

Finally, regarding family participation and inclusion, crop management is compatible with the participation of women and youth, since it does not require heavy machinery and adjusts to community schedules and rhythms, thus promoting greater productive equity (Secretaría del Bienestar, 2023).

Table 4. Compatibility of the protected fig model with the Sowing Life guidelines.

Public Policy Guidelines (Sembrando Vida)	Description in official documents	Compatibility of the protected fig model	Observations for scalability
Operating rules 2023–2024	They define participation criteria, productive components and obligations of the beneficiaries.	Meets eligibility criteria: family production, technical support, and collective work in CAC.	Requires formal validation in the program's technical catalog.
SAF (Agroforestry Systems)	Association of fruit/timber trees with annual crops for soil diversification and regeneration.	Integrating fig as a perennial fruit tree in SAF for diversification and carbon capture.	Establish integrated fig management in mixed systems to minimize competition for resources.
MIAF (Milpa Intercropped with Fruit Trees)	Agroecological design that combines corn, fruit trees and short-cycle crops.	Incorporating fig as a fruit tree in MIAF under limited irrigation, improving family income.	Adapt pruning and fertigation to the cornfield calendar.
Community nurseries	Produce plants for agroforestry systems managed by CACs.	Propagation of fig by cuttings in community nurseries and reduces the spread of disease.	Train community nursery workers in propagation and sanitary management of cuttings.
Biofactories	Community production of biofertilizers, biofungicides and microorganisms.	Using bio-inputs in bio-factories reduces agrochemicals and costs.	Prepare specific technical sheets for bio-inputs for application in fig cultivation.
Inclusion criteria	Prioritize communities with high and very high marginalization and beneficiaries in the CACs.	Implementable in municipalities with social backwardness and experience in protected agriculture.	Conduct territorial diagnosis for water availability and optimal climate.
Scalability	Replicate the model in territories with technical and social supervision.	Modular and scalable system: start at 50 m^2, grow according to demand.	Scalability conditioned by local inputs, markets and technical capabilities.
Environmental regeneration	Soil restoration, increased biodiversity, and carbon capture.	The evergreen fig promotes ground cover and can be integrated with pollinating plants and hedges.	Incorporate landscape design that combines production and conservation.
Common welfare	Increased income, community strengthening, and reduced inequalities.	Protected fig increases income and improves social cohesion in CACs.	Ensure equitable access to benefits and fair distribution of profits.
Social inclusion	Participation of women, youth and groups in vulnerable situations.	The fig promotes equal participation and leadership of women and youth.	Incorporate leadership, marketing, and product transformation workshops for participating groups.

Source: Selft-elaborated.

Institutional compatibility

The protected fig production model demonstrates a high degree of congruence with the operational guidelines and guiding principles of the Sembrando Vida program

(Secretaría del Bienestar, 2024). In terms of institutional alignment, its affiliation is reflected in various strategic components:

Food self-sufficiency: by complementing basic crops with high-value fruit crops that contribute to the diversification of family income.

Environmental regeneration: supported using bio-inputs from community bio-factories, the reduction of agrochemical use, and the efficient use of water.

Social inclusion: Since its design in small-scale modules facilitates the participation of rural women and youth in both production and marketing.

Common well-being: By integrating into collective work schemes through the CACs, it strengthens the processes of peasant organization and the generation of community learning.

Overall, the protected fig model not only meets technical and economic criteria but also aligns harmoniously with the institutional logic of Sembrando Vida. In this way, it expands the fruit-producing and innovative component of the program and offers a feasible path for scaling up in regions with high levels of marginalization.

Territorial compatibility

The territorial analysis identified priority areas for the validation and adoption of the protected fig model in four states: Morelos, Puebla, Hidalgo, and the State of Mexico. These states meet three strategic conditions that justify their selection:

Favorable agroclimatic vocation, characterized by high solar radiation, availability of water—including sources of treated wastewater—and semi-arid climates conducive to the cultivation of protected figs (INIFAP, 2019).

Significant social backwardness, with highly marginalized municipalities in which the introduction of this crop can serve as a strategic alternative within social inclusion programs (CONEVAL, 2023).

Institutional presence of Sembrando Vida, which is expressed in the coverage of productive technicians, CAC, bio-factories and community nurseries, which provides an institutional platform for the implementation of agricultural innovations.

Based on these criteria, municipalities with ideal agroclimatic conditions, high levels of marginalization, and the institutional presence of the Sembrando Vida program were delimited, which promotes the adoption of this system as a diversification strategy. These factors, together, enhance the adoption of the system as a fruit diversification strategy. For the delimitation, the following were considered: i) the social backwardness index criteria (CONEVAL, 2023), ii) agricultural vocation and agroclimatic potential (INIFAP Agroclimatic Atlas, 2019), and iii) the territorial coverage of the program in terms of CAC, production technicians, and bio-factories (Secretaría del Bienestar, 2024).

Based on the above, four priority regions were identified (Figure 1). In Morelos, the municipalities of Ayala, Jantetelco, and Tepalcingo are most suitable for productive

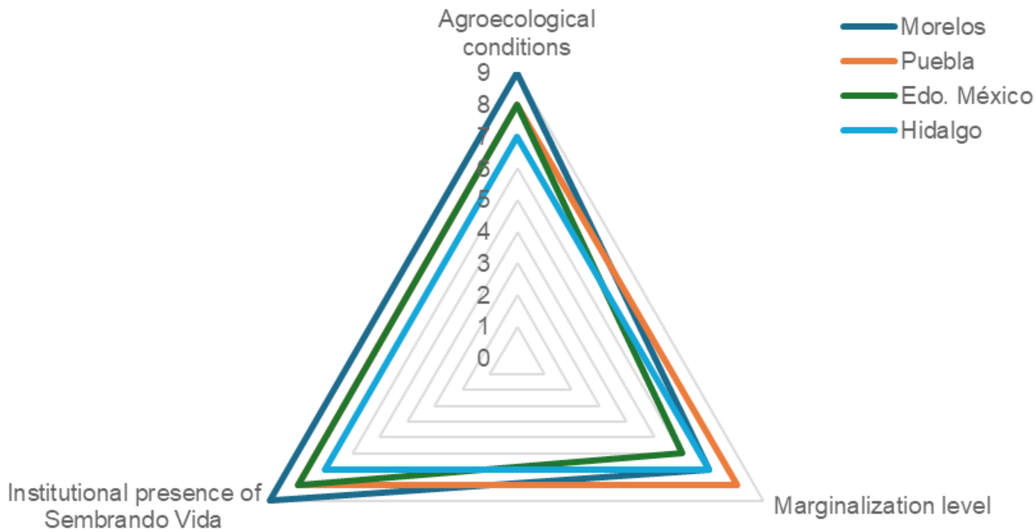

Figure 1. Evaluation of potential states for fig cultivation.

validation of the protected fig, supported by high solar radiation and the availability of treated wastewater (SIAP, 2023; CONEVAL, 2023). In Puebla, the municipalities of Chiautla, Huehuetlán El Grande, and Tehuacán stand out for their dry semi-arid climate, the active institutional presence of social programs, and a nascent fruit-growing vocation, which opens opportunities for the incorporation of productive innovations. In the rural south of the State of Mexico, the municipalities of Tenancingo, Malinalco, and Zumpahuacán are strategic due to their previous experience with protected agriculture and the organization of youth in agricultural activities. In the Mezquital Valley of the state of Hidalgo, the municipalities of Ixmiquilpan, Chilcuautla, and Cardonal constitute territories with a resilient agricultural culture, irrigation infrastructure, and articulated peasant organizations, which favor the incorporation of protected figs into socially inclusive agricultural schemes.

The diversity of identified conditions constitutes a key input for guiding the pilot phase of implementing the fig production system in territories where technical, social, and institutional factors converge to promote a positive and sustainable impact. Initial validation in these areas will generate solid empirical references to support its subsequent scaling to other regional contexts with similar characteristics.

Within this framework, the municipalities of Ayala and Tepalcingo in Morelos; Tehuacán and Huehuetlán El Grande (Puebla); Tenancingo and Zumpahuacán (State of Mexico); and Ixmiquilpan and Chilcuautla (Hidalgo) were recognized as highly suitable areas for establishing pilot modules for protected figs, given the convergence of technical, social, and institutional factors.

Discussion

Entry strategy: technical validation with a sense of development

The agronomic and economic findings of the fig (*Ficus carica* cv. Neza) under protected agriculture, characterized by high potential yields and exportable quality, justify an income for families through pilot modules and pre-defined targeting criteria. In this approach, validation is conceived as a "bridge" between the evidence generated under controlled conditions and its adoption in real-life small-scale contexts, articulating three strategic axes: i) proven technology, supported by high densities, microclimate management, and a controlled environment; ii) territories with enabling conditions, defined by their agroclimatic suitability, high social lag, and the institutional presence of the Sembrando Vida program; and iii) a pre-existing organizational structure (CAC, nurseries, bio-factories, and technical-social support), which reduces coordination costs and accelerates the learning curve.

The relevance of this strategy is documented in the institutional and territorial compatibility analysis, which demonstrated synergies with the SAF/MIAF systems, biofactories, and CACs, in addition to its consistency with the 2023–2024 operating rules and the principles of environmental regeneration and common well-being. In terms of public policy, the design is based on classic management criteria: inter-institutional coordination, reduction of information asymmetries, and provision of appropriate incentives throughout the design, implementation, and evaluation cycle. Latin American public management literature emphasizes that coordination failures and principal-agent problems increase implementation costs and erode effectiveness if not addressed with appropriate governance arrangements. Under this approach, territorial integration expands into existing organizational structures, which reduces these failures and increases the likelihood of adoption.

In operational terms, the validation process was designed to allow technical evidence (productivity, quality, health, costs) to interact with policy criteria (social inclusion, territorial relevance, and scalability). Hence, the municipal selection was based on agroclimatic conditions, levels of marginalization, and institutional presence, as well as the adoption of modules compatible with peasant logic (limited spaces, family labor, and progressive learning). The proven compatibility with Sembrando Vida grants an institutional license for a pilot with rapid replication capacity in areas with active CCS and operating bio factories.

Technology transfer

The agricultural innovation literature agrees that technological adoption is neither linear nor automatic, but rather depends on factors such as contextual suitability, installed capacity, trust, and support (Rogers, 2003; Hall, 2006; Rivera & Alex, 2004). Previous experiences with top-down diffusionist extension have shown low levels of appropriation, misalignment with local timelines and resources, and early abandonment of innovations (Chambers, 1983; Pretty, 1995). To avoid such limitations, transfer here was proposed under a systemic innovation and social learning approach, which articulates co-design of protocols, field demonstration practices, and peer learning in the CACs, integrating bio-inputs from bio-factories and propagation in community nurseries to reduce costs and strengthen local technological sovereignty.

A crucial point lies in the transfer agent. Implementation requires tacit knowledge—fine-grained decisions about pruning, fertigation, ventilation, harvesting, and post-harvest—which can only be effectively transmitted when the technology creators (research/validation teams) coordinate directly with program technicians. This approach reduces information asymmetries, aligns incentives, and shortens the adoption curve, in addition to being consistent with policy-cycle approaches and early-stage technical risk management.

Exit strategy: value addition and micro-batches

The exit strategy is not limited to the marketing of fresh fruit. Adding value at source (size selection, differentiated packaging, dehydration, artisanal confectionery, and jams) allows for higher margins, stabilizes revenue, and reduces exposure to price fluctuations. The intrinsic quality observed (°Brix > 17 and firmness > 5 N) facilitates differentiation processes and the construction of territorial narratives (origin, agroecological practices, traceability), which can be integrated into short marketing channels and, when feasible, into collaborative export schemes.

The micro-lot approach—production and packaging units clearly traceable by CAC, module, or family team—strengthens quality control, comparative learning, and the capture of consistency premiums. International experiences with differentiated products such as coffee show that this model strengthens reputation, enables repeat contracts, and maintains prices above the commodity level (Daviron & Ponte, 2005). In the case of protected figs, consistency in quality parameters represents the main asset for negotiating better commercial conditions, while the aggregation of volumes between CACs guarantees compliance with minimum delivery requirements without sacrificing traceability.

Contributions and challenges

The strategy integrates three pillars of the Sembrando Vida program:

Economical: higher productivity and quality, staggered revenues across two harvest windows, and positive margins in small modules; modularity and use of bio-inputs reduce costs and facilitate organic scaling.

Social: Coordination with CAC, horizontal learning, community savings, and associative processes; participation of women and youth in labor-intensive work, with an impact on empowerment and leadership.

Environmental: perennial management in SAF/MIAF, use of bio-inputs, reduction of agrochemicals, and water efficiency through drip irrigation, with less pressure on the soil.

However, critical challenges remain: i) water availability and management (local sources, reuse of treated water, capture and efficiency); ii) asset security (discrete modular designs, mutual insurance, community monitoring); iii) technical capacity (sequential training, skills certification, on-site mentoring); and iv) marketing (market intelligence, standards, framework contracts, and cold-storage logistics). Evidence indicates that these bottlenecks are mitigated with clear operating rules, institutional coordination, and educational evaluation schemes.

In short, an assessment such as this serves a dual purpose: (1) technical, by demonstrating the system's viability and risks in target contexts; and (2) political, by providing evidence for adjusting existing instruments (catalogs).

Conclusions

The analysis confirms that fig cultivation under protected agriculture represents a viable alternative for diversifying peasant production systems within the framework of the Sembrando Vida program. Experimental validation demonstrated higher yields and quality than open-air systems, along with a favorable benefit-cost ratio even at small scales. This provides evidence that high-value fruit trees can be introduced into marginalized territories as a differentiated production strategy, compatible with the logic of peasant pluriactivity.

The modular design and technology transfer strategy allow innovation to be adapted to heterogeneous contexts, avoiding uniform application and recognizing the agroecological, social, and institutional conditions of each region. This differentiated nature is essential for public policies to generate legitimate and sustainable impacts on the territories (Ortegón, 2005; OECD DAC, 2019).

Likewise, the importance of applied evaluation exercises that identify compatibility and areas for improvement between technological innovations and public programs is highlighted. Evaluation and monitoring not only serve a control function, but also constitute an institutional learning tool that guides investment, scaling, and transfer decisions toward more suitable beneficiaries.

This study shows that public investment in modular schemes can generate more widely distributed economic benefits, in contrast to models concentrated in large areas. The modular approach maximizes social inclusion, strengthens local economies, and contributes to environmental regeneration. The validation of greenhouse figs confirms the relevance of differentiated rural innovation policies: evidence-based entry strategies, technology transfer led by technology developers, and value-added exit strategies with community organization. Only under these principles is it possible to ensure that high-value protected agriculture consolidates itself as an engine of inclusive, sustainable, and territorially differentiated rural development.

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