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Leveraging Biofactories to Promote Sustainable Agricultural Development in Michoacán, Mexico

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Resumen

Este trabajo analiza los factores que inciden en la innovación de biofertilizantes producidos y comercializados por biofábricas en el sector agrícola de Michoacán, México. Se empleó modelado de ecuaciones estructurales por mínimos cuadrados parciales (PLS-SEM) con 129 cuestionarios aplicados a productores de aguacate y zarzamora, complementados con entrevistas y visitas a biofábricas. Los resultados muestran que la rentabilidad es el factor más influyente en la innovación, seguida por la sustentabilidad y la productividad. El uso de biofertilizantes contribuye a mejorar la fertilidad del suelo, reducir costos de producción y favorecer el acceso a mercados orgánicos de exportación. Se concluye que las biofábricas son una estrategia viable para impulsar el desarrollo agrícola sustentable en la región.

Palabras clave: biofábricas, biofertilizantes, sustentabilidad, innovación, desarrollo agrícola

Abstract

This study examines the factors influencing biofertilizer innovation produced and marketed by biofactories in Michoacán's agricultural sector. Partial least squares structural equation modeling (PLS-SEM) was applied to 129 surveys administered to avocado and blackberry producers, complemented by interviews and biofactory visits. Results indicate that profitability is the most influential factor in innovation, followed by sustainability and productivity. The use of biofertilizers improves soil fertility, reduces production costs, and facilitates access to organic export markets. Findings suggest that biofactories are a viable strategy to promote sustainable agricultural development in the region.

Keywords: biofactories, biofertilizers, sustainability, innovation, agricultural development

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Contextualization

Mexico is ranked as the 11th largest agricultural producer globally, largely due to its open trade policies and the signing of 12 free trade agreements with more than 44 countries (SIAP-SAGARPA, 2018). The agricultural sector plays a strategic role in national exports, and within it, fruit production stands out. Berries—including strawberries, blackberries, blueberries, and raspberries—rank third in export value, following beer and avocado, and represent 10.6% of the country's agricultural export earnings (SIAP-SAGARPA, 2018).

Despite this economic importance, the development of agriculture in Mexico has been environmentally unsustainable. Agrifood activity has been characterized as predatory, generating serious pollution in soils, groundwater, rivers, oceans, and the atmosphere. Agriculture is estimated to account for 15% of Mexico's GDP when environmental depletion and degradation are considered (Morales Ibarra, 2014).

Fertilizer use exemplifies these unsustainable practices. Producing one hectare of corn requires approximately 4,000 pesos in chemical fertilizers, compared to just 400 pesos when using biofertilizers. Substituting biofertilizers could increase producers' net income by 2,000 pesos per hectare, with potential benefits for nearly 400,000 small-scale farmers nationwide (Andrade, 2018).

The case of nitrogen fertilizers highlights the severity of the problem. Nitrogen fertilizers are the most consumed and produced type globally, yet their prices in Mexico rose by 500% during the first decade of the 21st century (Secretaría de Economía, 2012). They are highly inefficient, with less than 20% absorbed by plants. In practice, out of 100 kilos of nitrogen fertilizer applied, only 20 are utilized by crops, while the remaining 80 pollute soils, groundwater, and the atmosphere. Beyond economic loss, these inefficiencies contribute to water contamination, biodiversity damage, and nitrous oxide emissions, a greenhouse gas far more potent than carbon dioxide in driving climate change.

Mexico has played an important role in advancing biofertilizer science. In 1980, the Nitrogen Fixation Research Center was created at the National Autonomous University of Mexico (UNAM), today known as the Genomic Sciences Center. This institution positioned Mexico at the forefront of international biofertilizer research (Morales Ibarra, 2014). Later studies by the National Institute of Forestry, Agricultural, and Livestock Research (INIFAP) demonstrated that biofertilizers applied to high-yield corn could reduce nitrogen fertilizer use by 30% while maintaining or even improving yields (Guzmán, 2018).

Data on the exact extension of biofertilizer use in Mexico remains incomplete, but estimates indicate that more than four million hectares were cultivated with biofertilizers in 2018. Coffee represents one of the most important crops where biofertilizers are applied. Only 34% of coffee production relies on chemical fertilizers, making it the second perennial crop with the largest planted area under alternative management. The decline in subsidies for synthetic fertilizers, combined with outbreaks of coffee leaf rust, encouraged producers to adopt biofertilizers. Farmers found that these not only reduced costs but also facilitated access to premium organic markets, while improving plantation health and productivity.

Biofertilizers in Michoacán

Michoacán has become a key region for the promotion of sustainable agricultural practices and biofertilizer use. In 2019, the state government launched the Sustainable Agriculture Program, initially covering three crops and about 6,000 hectares. Based on positive outcomes—including yield increases of 40% to 80%—the program's budget was tripled in 2020 to 45 million pesos, expanding coverage to 20,000 hectares and 12 different crops (SEDRUA, 2019).

The crops supported under this program include corn, strawberries, guava, mango, grapefruit, hibiscus, lentils, and rice. The program's approach emphasizes reducing production costs, eliminating agrochemicals, regenerating soils, and producing healthier food for both local consumption and export.

Michoacán is particularly relevant for the biofertilizer transition because of its dominance in fruit exports. The state contributes 96% of national blackberry production and 10.7% of the state GDP comes from agriculture. Within the state, municipalities such as Los Reyes and Peribán lead agricultural production, representing nearly 18% of the state's total value.

At the federal level, Mexico's Ministry of Agriculture and Rural Development (SADER) has promoted biofertilizer adoption through the AGROSANO Program, which distributed 22,000 tons of biofertilizers to farmers in 2022. According to the state secretary of agriculture, this program is part of an agroecological transition that seeks to increase profitability, improve soil fertility, and maintain productivity while reducing production costs (SADER, 2022).

Alongside financial support, training and education have been central to state and federal strategies. In 2022, fourteen workshops were held to teach high school and university students techniques for producing biofertilizers, composts, and beneficial soil microorganisms. These initiatives were designed to build a network of 25 biofactories co-financed by federal and state resources. By the same year, 113 municipalities were participating in biofertilizer production through local biofactories, with the goal of expanding to 50 municipalities.

The strategy aims not only to promote soil care and reduce input costs but also to foster autonomy in fertilizer production. This is particularly relevant in the context of the Russia-Ukraine conflict, which caused global spikes in the price of synthetic fertilizers, increasing dependency risks for Mexico (Mendoza, 2022).

Despite these policy advances, adoption remains uneven. Surveys and interviews conducted with avocado and blackberry producers in Michoacán indicate that many farmers still rely heavily on chemical fertilizers. While some recognize the long-term benefits of biofertilizers, cultural habits, risk aversion, and the perception of immediate profitability continue to act as barriers.

Sustainable Agriculture

Sustainable agriculture is defined as an agricultural system that maintains long-term productivity while conserving natural resources and minimizing environmental harm. It is also referred to as regenerative, alternative, biological, organic, or agroecological agriculture. Its main objective is to reduce or eliminate the problems associated with conventional agriculture by relying on natural processes such as nutrient cycling, nitrogen fixation, and biological pest control.

Pretty (2003) identifies several objectives of sustainable agriculture:

1. Increasing the use of natural ecological processes in farming.
2. Reducing dependence on external, non-renewable inputs.
3. Ensuring equitable access to resources.
4. Promoting the intensive use of local biological and genetic resources.
5. Ensuring environmental and economic sustainability.
6. Improving the integrated management of soil, water, and energy.

Organic agriculture, considered a subset of sustainable agriculture, explicitly avoids the use of synthetic fertilizers and pesticides. Instead, it depends on natural processes such as composting, soil formation, biological control, and nutrient recycling.

In Michoacán, adoption of sustainable agriculture is still low. Less than 30% of avocado growers and fewer than 20% of blackberry producers apply sustainable practices. Several barriers explain this limited uptake:

- Soil regeneration takes years, making it unattractive for producers of short-cycle crops such as strawberries.
- Transition requires training, soil monitoring, and upfront investment.
- Biofertilizers have shorter lifespans compared to synthetic fertilizers.
- Producers fear economic losses if pests or diseases appear and sustainable methods fail to contain them.

The adoption of sustainable practices is, therefore, uneven and fragile. Some producers initially experiment with biofertilizers to access organic markets but revert to conventional agrochemicals when threatened by production risks.

Biofertilizers: Definition and Functions

Biofertilizers are generally defined as natural organic substances or microbial preparations that enhance soil fertility and crop productivity by partially or completely substituting chemical fertilizers (Vela et al., 2018). The FAO (2018) describes them as products that improve soil quality by fostering microbiological environments. They are also known as bioinoculants, microbial inoculants, or soil inoculants.

Biofertilizers supply essential nutrients, promote plant growth, and improve soil health. Their benefits include:

- Nitrogen fixation: Converting atmospheric nitrogen into forms usable by plants.
- Phosphorus solubilization: Making phosphorus available for root absorption.
- Synthesis of growth hormones and enzymes: Enhancing root development and nutrient uptake.
- Biocontrol of pathogens: Suppressing soil-borne diseases.
- Restoration of soil fertility: Improving organic matter and microbial activity.

Common microorganisms used in biofertilizers include Rhizobium, Azotobacter, Azospirillum, Bacillus, Pseudomonas, mycorrhizal fungi, and Trichoderma.

Globally, biofertilizers are classified into nitrogen-fixing, phosphate-solubilizing, and potassium-mobilizing types. They are applied across cereals, fruits, vegetables, oilseeds, legumes, and ornamentals. Liquid formulations are increasingly popular due to their stability and ease of application.

Innovation and Market Challenges

Innovation in biofertilizers involves adapting products to local conditions, ensuring economic feasibility, and improving their stability, efficiency, and acceptability. Advances include soil chemical analysis to guide application schedules, optical sensors for monitoring soil and plant needs, and biofertilizer liquids with longer shelf lives.

Nevertheless, challenges remain:

- Market limitations: Biofertilizers must be available at low cost and in sufficient quantity, which is not always the case.
- Storage stability: Some formulations deteriorate under certain environmental conditions.
- Farmer reluctance: Many producers distrust microbial products due to cultural associations with disease.
- Variability in quality: Not all production units maintain consistent standards.

In Mexico, biofertilizer production is carried out primarily by small companies, universities, and institutions such as INIFAP, often supported by public investment. However, large-scale commercialization and distribution remain limited (Grageda-Cabrera et al., 2012).

Meanwhile, chemical inputs remain dominant. In Michoacán alone, around two million agrochemical containers are generated annually, equivalent to 171,000 tons of toxic waste. Many containers are burned or dumped in ravines, water bodies, and landfills, releasing contaminants into air and water and posing serious health risks, including cancer (SAGARPA, 2015).

Partial Least Squares Structural Equation Modeling (PLS-SEM)

Taking into account the 129 questionnaires completed during several visits to producers in Los Reyes and Ziracuaretiro, Michoacán, a data matrix was created with 29 indicators that were incorporated into the three exogenous latent variables and the endogenous variable of innovation. Using the SmartPLS4 program, structural equation modeling of partial least squares was conducted to carry out the present research.

In this study, a Likert scale ranging from 5 to 1 was used as the measurement scale, where 5 indicates complete agreement with the particular statement in the questionnaire and 1 indicates complete disagreement.

A Likert-type coding was used in this study, as mentioned above, where numbers were assigned to responses in the questionnaire to facilitate the measurement process, offering symmetry concerning the central category of response options for each question. PLS-SEM makes no assumptions about the distribution of data.

In this research, respondents rated the questions on a 5-point Likert-type m scale, where higher scores described higher levels of agreement with a particular statement in the questionnaire provided to them.

In the data matrix of the model, columns represent specific survey questions, and rows contain the responses of each respondent. For example, the first row includes the reactions of respondent 1. Columns display responses to the survey questions. SmartPLS4 software was used to conduct the PLS-SEM analyses.

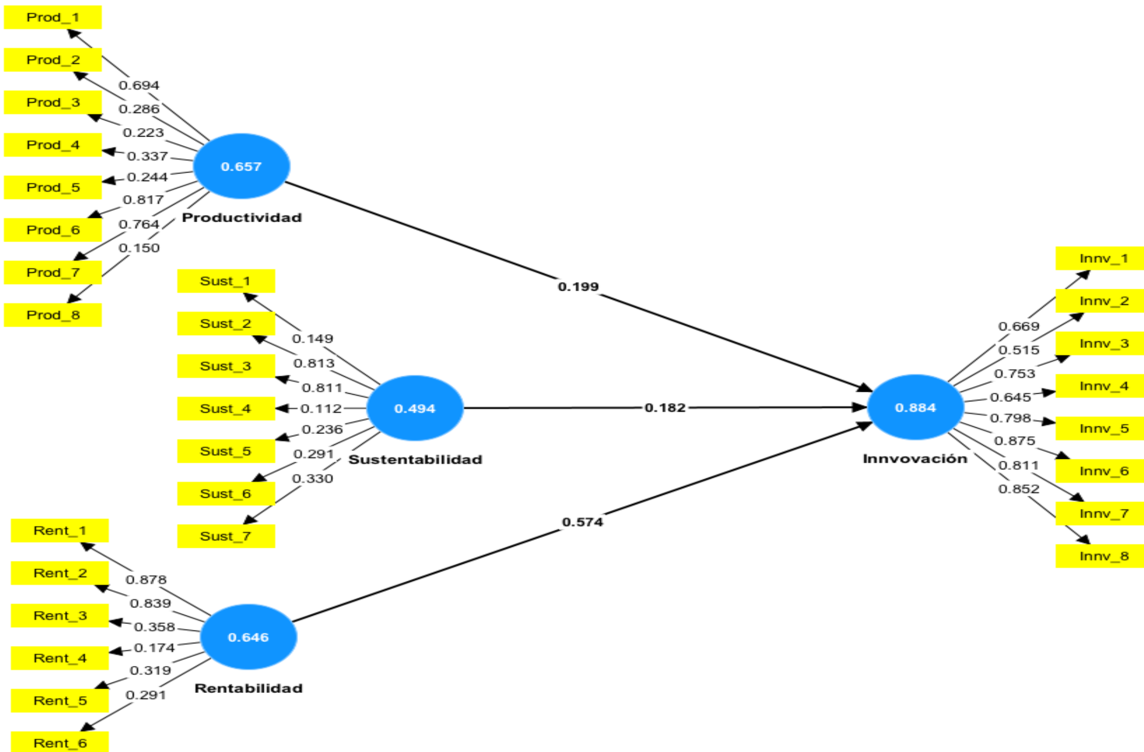
For Cohen (1992), only 54 observations are needed to detect R2values of around 0.25, assuming a significance level of 5% and a statistical power of 80%. A t-value of 1.96 corresponds to a p-value of 0.05. P-values in formative measurement models must be less than 0.05 to assert that the external weights are significant at a 5% significance level.

Results

Below are the results obtained using the statistical technique of Partial Least Squares Structural Equation Modeling (PLS-SEM). Taking into account the 129 questionnaires completed during several visits to producers in Los Reyes and Ziracuaretiro, Michoacán, a data matrix was created with 29 indicators that were incorporated into the three exogenous latent variables and the endogenous variable of innovation. Using the SmartPLS4 program, structural equation modeling of partial least squares was conducted to carry out the present research.

Graph 1

Structural Model with the Endogenous Variable Innovation as the Dependent Variable

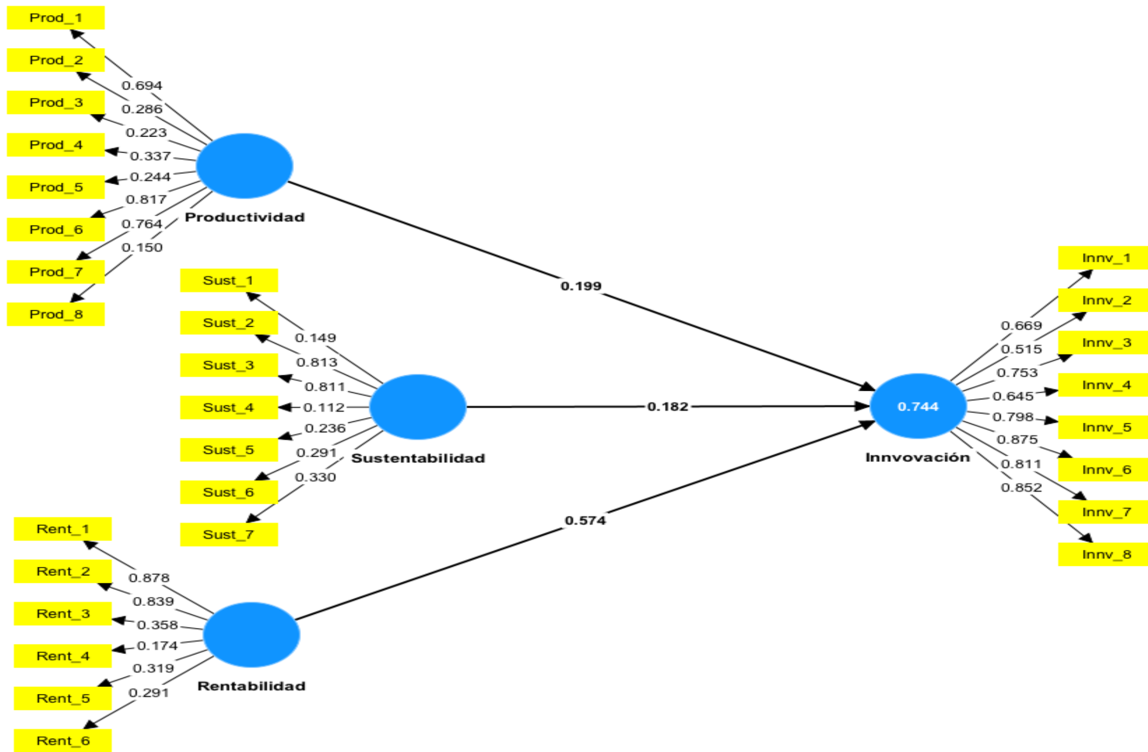


Source: Authors' design using SmartPLS4 software

In the above nomogram, the blue circles on the left represent the exogenous latent variables: productivity, sustainability, and profitability, and the blue circle on the right is the endogenous latent variable or dependent variable: innovation. The yellow rectangles connecting to each variable or construct are the indicators or items, the lines connecting them are the relationships or hypotheses established between indicators and variables, and variables between variables. The numbers between indicators and constructs represent their contribution to the constructs, and if their outer weight is greater than 0.10, the items are significant. The numbers between the circles in this nomogram represent the Cronbach's alpha, which represents the reliability of the constructs and the model. The nomogram is reflective since the path lines go from constructs to items. The model is interpreted as having a reliability degree of 88.4%, with the constructs and indicators considered. These indicators arose from the responses given to each of the questions in the survey directed to agricultural producers.

Graph 2

Initial Structural Model with Complete Survey Indicators

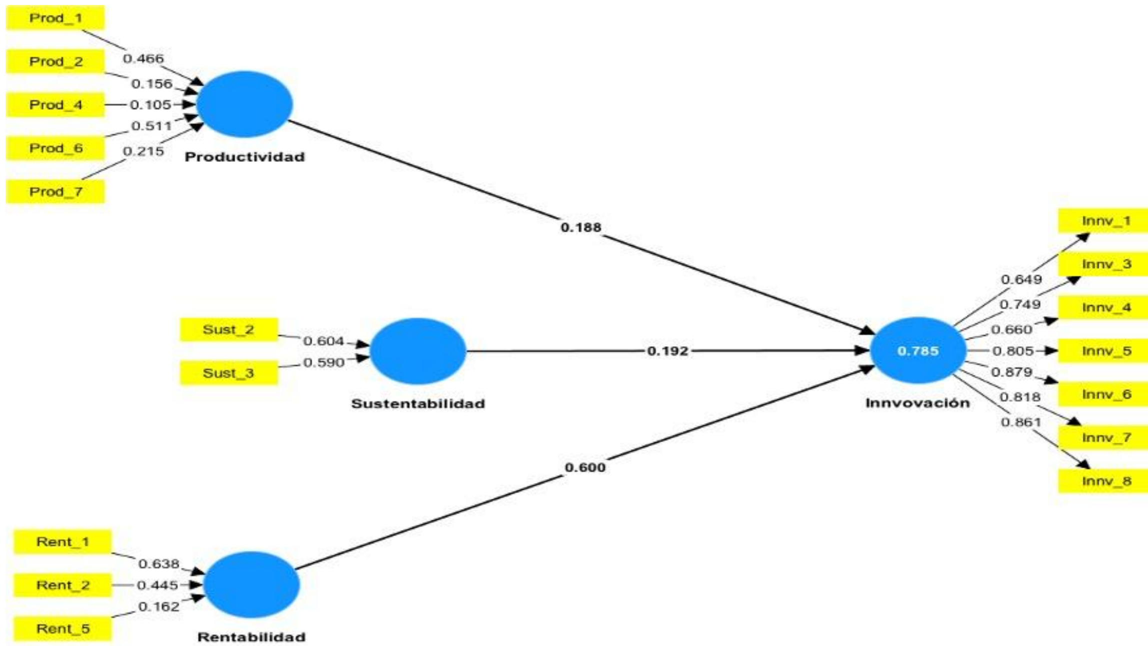


Source: Authors' design using SmartPLS4 software

The following image can be interpreted as follows: the exogenous latent variable Profitability has the most significant effect (0.574) on the endogenous variable Innovation, which consists of 6 items; followed by Productivity (0.199) with 8 items; and Sustainability (0.182) with 7 items. All three constructs explain 74.4% of the variance in Innovation (R2=0.744). This is before discarding items based on their weight and external loading of both independent and dependent variables. Those indicators with weights less than 0.10 and loadings below 0.40 were eliminated from the measurement model, as well as those indicators that showed high collinearity, which in the model are apparent with a negative sign; their relative and partial contribution to the model prediction was also taken into account.

Graph 3

Structural Model of Innovation-Biofertilizers



Source: Authors' design using SmartPLS4 software

The exogenous latent variable Profitability contributes the most to the endogenous latent variable Innovation, being responsible for 60% of the prediction of Innovation. The item with the most significance on Profitability Pursuit is item 1 (0.638), which is related to profit gain, as producers seek better profits by using biofertilizers. Item 2 (0.445) is related to fair pricing, supporting what was mentioned by producers in meetings, indicating that one motivation for using biofertilizers is to seek a differentiated price by offering organic products, mainly targeting the export market. Item 5 (0.162) relates to the reduction of production costs. The items discarded due to having a lower external weight than 1 and a low external loading were items 3, 4, and 6, representing sales, biofertilizer prices, and government support received through agricultural support programs, respectively.

Sustainability is a significant variable in the innovation of biofertilizer production and marketing, but not as much as Profitability Pursuit. The most significant indicators of sustainability, as indicated by producers and the SmartPLS4 program, are the positive impact of biofertilizer use on the environment and its impact on improving agricultural soil fertility, represented by items sust_2 and sust_3. The indicators that were discarded from the model due to their low significance in prediction were those related to the reduction of groundwater contamination, the generation of new jobs, the notion that biofertilizers are less harmful to health, their adaptability to crops, and those related to their packaging and storage.

The independent variable Productivity (0.188), having more items, has a significant impact on innovation although it is less than Profitability Pursuit and Sustainability. The most significant items in Productivity are prod_6 (0.511), referring to higher productivity pursuit by having more fertile soils; prod_1 (0.466), where producers believe that the use of biofertilizers leads to increased production; prod_7 (0.215), indicating that farmers are motivated to switch from synthetic fertilizers to inoculants; prod_2, which considers the importance of biofertilizers to generate less waste, making them more effective than conventional fertilizers, of which only about 20% is utilized. Additionally, prod_4 reflects farmers' views on the importance of government support programs for the development of the agricultural sector. However, they mention receiving little to no government support, and the state-level biofactory program has not provided training in the region. Furthermore, the few biofertilizers that have arrived are ineffective, as the essential microorganisms they contain are practically dead.

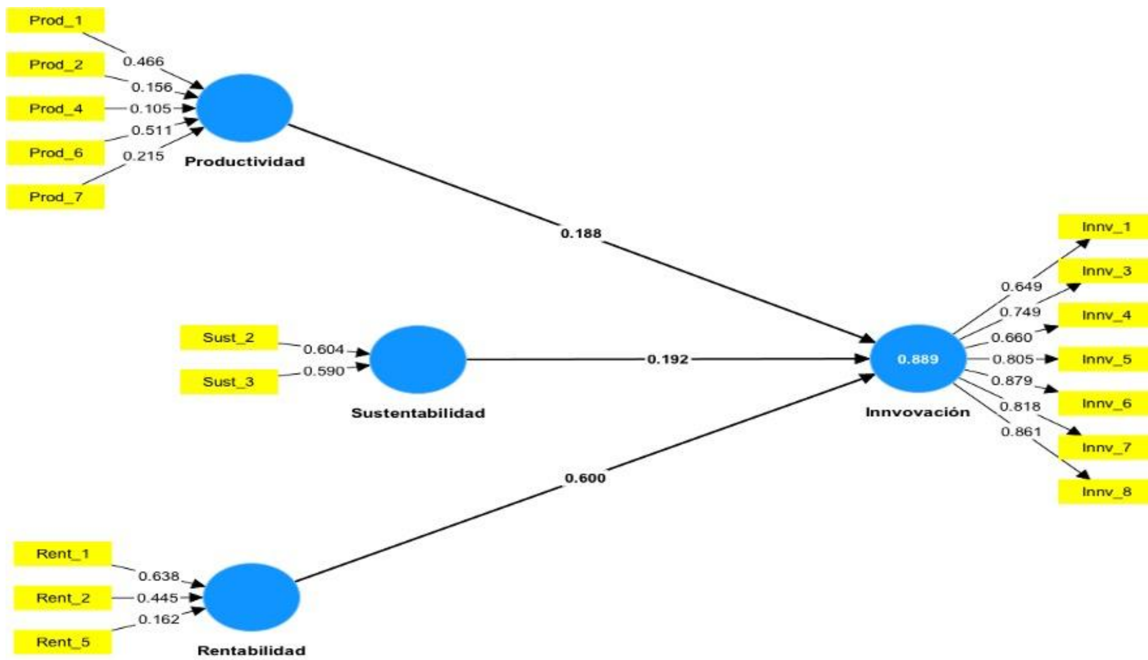
The items forming part of the Innovation variable are innv_1, referring to the use of any special technology in biofertilizer application; innv_3, indicating whether any physical-chemical soil analysis has been performed; innv_4, whether training has been received in the use of biofertilizers; innv_5, awareness of the benefits of biofertilizers; innv_6, considering the need to patent biofertilizers; innv_7 regarding availability; innv_8, whether any innovation support is received. Some insignificant determinants were related to the impact of advertising and the availability of sufficient brands in the market.

In a Formative-Reflective model, an R2 of at least 0.50 is required. The obtained model has an R2 of 0.785, demonstrating convergent validity. Variables Sustainability, Productivity, and Profitability contribute sufficiently to the Innovation variable. These three variables explain 78.5% of biofertilizer use innovation in Michoacán's agricultural sector, where the research was conducted. The remaining 21.5% is explained by other indicators not included in the model, such as those previously eliminated and others that were not considered. Profitability, Sustainability, and Productivity are the three exogenous latent variables with significant effects on Innovation in the agricultural sector. These three latent independent variables, with only these items incorporated, explain the model by 78.5%, indicating that there may be other variables or indicators not considered in this structural model that could explain the remaining 21.5%.

The nomogram shows how the Cronbach's alpha, taking into account the determinants of the variables with the most significance, increases the structural model's reliability from 0.884 to 0.889. These determinants have a weight greater than 0.10, making them significant, with an external loading closer to one. Significant weight refers to its relative significance, while external loading refers to its absolute significance. Although the Cronbach's alpha increases very slightly, the less significant determinants of each variable are eliminated to meet statistical parameters.

Graph 4

Cronbach's alpha in the Structural Modeling of Biofertilizer Innovation



Source: Authors' design using SmartPLS4 software.

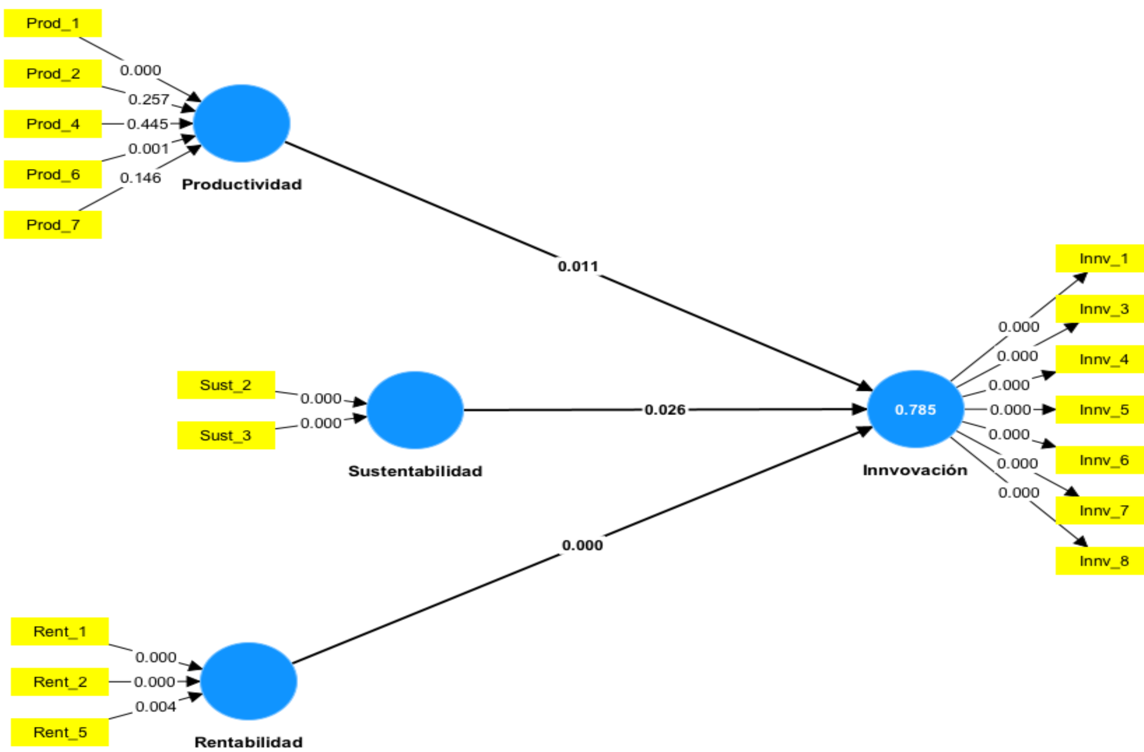
Collinearity does not reach critical levels in any of the formatively measured constructs and is not a problem in estimating the PLS nomogram of the extended Innovation model. The graph displays the external weights of each of the indicators that comprise the model's variables; they are significant as all are above 0.10. The lowest weight is 0.105, which is part of the Productivity variable, indicating that for producers, the impact of seeking higher productivity is directly proportional to the use of biofertilizers.

The weight of 0.638 is the highest and corresponds to the exogenous variable Profitability, explaining its high importance for producers through a pursuit of higher profitability by reducing production costs and offering a differentiated product. Farmers are encouraged to use biofertilizers to offer their product to the organic export market, which offers a higher price that farmers consider fair. Innv_6 (0.879) and innv_8 (0.861) are the indicators of the Innovation variable that have the most significance overall in the structural model.

For the exogenous variables, the mosts significant are prod_6 (0.842), rent_1, rent_2 (0.837), sust_2 (0.841), and sust_3 (0.833). Next, the external weights will be analyzed according to their significance and relevance using the bootstrapping process with the Bias Corrected and Accelerated (BCA) Bootstrap option, with a 0.05 significance level, 5,000 bootstrap samples, and a two-tailed test.

Graph 5

Booststrapping P-values



Authors' design using SamrtPLS4 software.

P-values in the formative measurement model shown with values below 0.05 assert that the external weights are significant at a 5% significance level. For agricultural producers in Michoacán, the search for new markets, higher profits, increased sales, reduced production costs, the pursuit of sustainable fertilization alternatives, as well as new brands of biofertilizers and knowledge transfer, significantly impact the use of biofertilizers. Additionally, variables Profitability, Sustainability, and Productivity, with external weights of 0.011, 0.026, and 0.00, respectively, are significant in determining Innovation related to biofertilizers in Michoacán's agricultural sector. This confirms that the measures of the constructs are reliable and valid.

The P-values are below 0.05, and the t-statistic for the three relationships between the exogenous and endogenous variables is above 1.96, indicating significance at a 5% level.

The constructs located in the upper right of the importance-performance map have both high importance and high performance, such as the exogenous variable Profitability, which implies a potential for performance improvement. It is within the indicators comprising these variables where actions should be taken to drive innovation in the use, marketing, and production of biofertilizers, specifically in Michoacán's agricultural sector.

The graph above shows how indicators Rent_1 and Rent_2 of the Profitability variable demonstrate greater importance and performance. This suggests that actions should be focused on these indicators to have an impact on innovation in the agricultural sector based on the variables and items proposed in this research.

The variable contributing the most to the dependent variable Innovation is Profitability and its indicators. The factors driving farmers to use bioinoculants are the search for an organic differentiated product for export, with a higher price leading to profitability, as well as the reduction in production costs due to biofertilizers being much cheaper than traditional chemical fertilizers and more efficiently utilized in plants. Sustainability is also a significant variable, although not as much as Profitability.

The indicators that contribute most to sustainability are those that pursue more fertile agricultural soil. Although farmers are aware that agrochemicals harm both human health and other species, this awareness does not motivate them to change their practices. This is evident as the use of biofertilizers has shown growth compared to synthetics, but it is only between 5 and 10%.

Productivity is also a significant variable since farmers have observed that biofertilizers increase productivity by restoring soil fertility and being more efficiently absorbed by agricultural crops. The pursuit of more profitable crops is their main motivation.

Cronbach's alpha assumes that all indicators are equally fallible, making it a rather conservative measure of internal consistency reliability. Composite reliability takes into account the different values of external loadings of indicator variables, ranging from 0 to 1. The higher the value, the greater the reliability achieved. Values between 0.60 and 0.70 are considered acceptable, and values between 0.70 and 0.90 can be considered satisfactory. Values beyond 0.90 are not desirable. As can be observed, all four variables are acceptable in terms of their reliability, especially the endogenous variable and the Productivity variable.

Conclusions

Based on the hypothesis of this research, sustainability, productivity, and profitability are the key factors influencing biofertilizer innovation produced and marketed by biofactories in the agricultural sector of Michoacán, Mexico. This hypothesis is quantitatively confirmed by the SmartPLS4 software. In the structural model with its constituent indicators, Profitability accounts for 60% of innovation in the agricultural sector in Michoacán, Sustainability accounts for 19.2%, and Productivity for 18.8%.

Biofertilizers are primarily used in organic crops destined for international markets, with the United States being the primary market, followed by Canada, another target market, Japan, and some European countries such as Germany.

The significance of sustainability (0.192) and productivity (0.188) in biofertilizer innovation was also confirmed. The positive environmental impact of using biofertilizers and their role in improving soil fertility in agricultural soils are significant factors. Despite being less significant, they are of great importance, such as their non-harmful effects on human health, consumers, field workers, people living near the areas where they are applied, and soil microflora and microfauna. Biofertilizers also generate less waste as they are more efficiently absorbed by plants compared to conventional chemical fertilizers.

Regarding the Productivity variable, the indicator with the most impact on it is improving soil fertility, as enriching the soil with nutrients increases agricultural production, and their absorption by plants is much more efficient. However, a factor that undermined credibility is that the biofertilizers received in 2022 from the state program were not effective as the microorganisms, which are an essential part of biofertilizers, arrived dead.

The main indicators are that the pursuit of higher profits constitutes an investment as opposed to conventional ones, as biofertilizers are much more affordable, more effectively absorbed by plants, and they reduce production costs. Larger quantities of conventional fertilizers are needed each cycle, whereas biofertilizers increasingly enrich the soil. According to the information provided, infertile soils will be able to recover in approximately 5 years. The organic export market is a major incentive in seeking fair prices.

Among the innovations found in agricultural systems are the following: Product innovation: Diversification of new crops for export (horticultural and grains), new and different crop varieties, improved and hybrid seeds, seedling generation, planting of organic and/or exclusive crops, reforestation, use of rootstock, payment of royalties for patents of new varieties, agro-industrial transformation. Innovations in production processes: Intensive biotechnologized production, fertigation, protected and precision agriculture, drones, improved agrochemical and fertilizer management, organic production, good agricultural practices (safety, health, and quality), agroclimate monitoring, cold rooms and conservation chambers, automated packaging and selectors, greenhouses for seed germination, fertilization with vermicompost, automation of subsoil water pumping, "smart" machinery with GPS to streamline planting and harvesting processes, design and construction of harvesting vehicles, computer systems for production process management, use of crop dusters, new plant driving systems (pergola system), refrigerated transportation, integrated disease management (cultural, genetic, biological, and chemical control), agroecological management.

Organizational innovation Includes Financial diversification, the installation of computer systems to manage administrative and organizational processes, new flexible hiring methods for agricultural workers (day laborers), such as hiring by day or by task, and the rental of agricultural machinery.

Marketing innovations: contract farming, direct marketing (without intermediaries), search for better market windows (summer and winter), promotion campaigns and/or fairs, improvements in presentation and packaging (bags and boxes), worldwide quality certificates, website and social network management (Facebook, Twitter, Blogs) with company information, search for government support.

One of the main economic incentives to use any innovation that impacts agricultural sustainability is the surcharge for agricultural products in the organic market, mainly foreign. In the case of Mexico, the United States of America is the main destination for agro-exports.

Biofertilizers are sustainable inputs, as they can assure harmless crops; in addition to not harming human health, flora, fauna, and agricultural soils themselves, do not pollute the environment, mainly aquifers, and the atmosphere. Currently, they are a source of employment generation through biofactories that are being promoted in the state of Michoacán under the administration of Governor Ramírez Bedolla, generating paid employment opportunities in their production, distribution, and dissemination through training programs. Their efficiency has been demonstrated in increasing the productivity of agricultural soils by around 40% by increasing their fertility. This leads to cost reduction, alongside a boost for both the organic export market and national markets, resulting in a more attractive differential price.

Thus, biofertilizers are an innovative bioproduct that significantly impacts each dimension of sustainability by enhancing traditional basic grains such as corn, beans, rice, coffee, and cocoa. These crops continue to generate significant innovations in the agricultural sector, together with other commercially interesting products such as sugarcane, bananas, limes, berries, and avocados.

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