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EFFICIENCY AND PRODUCTIVE STRUCTURE OF POULTRY ASSOCIATIONS IN THE CENTRAL ZONE OF ECUADOR

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ABSTRACT

The study evaluated the productive efficiency of poultry associations in the central area of Ecuador, with a particular focus on the province of Tungurahua. The relationship between organizational structure and productive results was analyzed, where it was considered that, despite the importance of the sector in the rural economy, there are outstanding distinctions in efficiency between farms. These discrepancies are associated with factors such as infrastructure, health control, information management, and operational practices. The research adopted a quantitative approach with a descriptive, explanatory, and correlational design, in which secondary information from the technical cadastre of 213 poultry farms was used. The employment of the MIC MAC tool and econometric models such as Logit and Probit facilitated the identification of the determinants of efficiency. The marginal effects enabled the interpretation of the results in terms of probability ratios. The validity of the models was evaluated using the Hosmer-Lemeshow test and the ROC curve, in order to estimate the predictive capacity in terms of sensitivity and specificity. The findings indicated that the organizational structure exerted a significant influence on the efficiency of the poultry sector. Consequently, the findings yielded actionable guidelines to bolster production management and strategic decision-making within the associations.

KEYWORDS: Production efficiency, organizational structure, poultry associations, poultry productivity, Logit, Probit, and ROC Curve models.

1. INTRODUCTION

Poultry farming is a strategic pillar for food security in Ecuador, particularly in provinces such as Tungurahua and Cotopaxi, which are distinguished by their high production of chicken meat and eggs, thereby ensuring a reliable national supply. This sector has been demonstrated to have a multifaceted impact on the rural economy, generating a substantial number of both direct and indirect employment opportunities (Ortiz et al., 2025). However, poultry associations encounter challenges stemming from the absence of definitive organizational frameworks and constraints in their production processes. According to the expert, the implementation of effective management systems and the adoption of technological innovations are essential to increase competitiveness. In this way, strategies are generated that facilitate adequate use of resources and allow associations to adjust quickly to market demands, which contributes to improving their ability to face both internal and external obstacles Barzallo et al. (2019).

In Tungurahua, the predominant economic activity is poultry farming, which is characterized by its preeminent role in the regional economy. The province accounts for approximately 50% of the national production of table eggs and houses approximately 27% of the registered poultry companies (Primicias, 2024). The presence of approximately 300 farms dispersed throughout cantons such as Patate, Baños de Agua Santa, and Cevallos has been demonstrated to generate employment opportunities and stimulate the local economy. However, industry faces significant challenges, including a shortage of corn, which directly impacts feed costs, accounting for approximately 70% of total expenses. This, in turn, affects profitability. However, the State has implemented support programs through inputs and training (El Heraldo, 2025). Nevertheless, limitations persist in the infrastructure, biosecurity, and technical documentation.

The absence of a consolidated organizational structure has been demonstrated to exert a deleterious effect on the efficiency and competitiveness of farms. Silva (2023) underscores the significance of an effective internal organization in optimizing resources and enhancing productive outcomes. In this context, the objective of this study is to evaluate the efficiency in terms of the productive structure of poultry associations in central Ecuador, with the purpose of generating proposals that contribute to the strengthening of the sector.

The present study is divided into three sections. The initial section delineates the theoretical concepts pertinent to efficiency across its various dimensions: technical, economic, and productive. Additionally, it expounds upon the productive structure of the poultry sector. The definitions, approaches, and determining factors that affect the optimal use of resources, the maximization of yield, and the organization of the production process will be analyzed. Furthermore, the primary challenges confronting the poultry sector in Tungurahua have been identified, with a particular focus on small-scale production units. The second section delineates the MAC MIC models for Logit and Probit econometric models, Marginal Effects, and Roc Curve. These models facilitate the analysis of relationships between organizational practices and productive results. The third section of this study presents the primary findings and examines their ramifications, with a particular focus on strategies designed to enhance the efficiency of poultry associations in Tungurahua.

LITERATURE REVIEW

Efficiency is defined as a key indicator of the optimal use of available resources to achieve production objectives with minimum waste. He asserts that efficiency is paramount for companies to optimize production and competitiveness through the judicious utilization of factors such as labor, capital, and materials. It is imperative to recognize that efficiency is not merely a matter of achieving a desired outcome; rather, it encompasses the optimization of resources, including time, financial capital, and effort, within each operational process. This approach entails the reduction of superfluous expenditures and the maximization of the potential gains derived from available inputs. This condition has been linked to effective management and execution of productive activities. Therefore, a competent firm can transform its inputs into high-performance results, which is essential to improve productivity and maintain comparative efficiency in the current environment (Rojas, 2018; Ochoa & González, 2024; Martínez & Valdivié, 2021).

Efficiency is a fundamental tool that analyzes the internal factors of an organization, directed in economic and technical aspects to optimize resources. The primary objective of the company is to minimize the costs associated with the transformation of inputs into products or services. Concurrently, the company endeavors to ensure the quality and performance of the goals established by the company. Operational effectiveness is defined as the ability of an organization to achieve its objectives through the effective use of available resources, without generating any type of waste. In order to achieve this objective, it is imperative to optimize the utilization of materials, time, and effort to obtain superior outcomes, enhance performance, and generate greater value. This can be accomplished by reducing costs (Wu et al., 2022; Gómez et al., 2021).

Technical efficiency is defined as the ability of a production unit to maximize output while operating within a fixed set of inputs, thereby ensuring optimal resource utilization. Farms that implement advanced technologies, such as automated feeding and environmental control systems, have been shown to achieve superior productivity with equivalent inputs. The appropriate formulation of balanced diets and the incorporation of natural additives have been demonstrated to enhance feed conversion and improve poultry health, thereby increasing technical efficiency in the poultry sector (Khan et al., 2022; Velázquez & Ramírez, 2024; Ramukhithi et al., 2023).

Economic efficiency is defined as the ability to achieve a level of production with minimum costs through proper selection and effective use of inputs, in order to maximize economic efficiency. The enhancement of resource management and the optimization of hosting and management systems has been demonstrated to result in a reduction in operating expenses and an augmentation of productivity. The implementation of these practices has been demonstrated to result in a reduction in waste and an enhancement of profitability. This, in turn, has been shown to contribute to the enhancement of the competitive position of farms in the context of increasingly demanding and sustainability-oriented markets (Shuai & Fan, 2020; Liu & Dong, 2021; Qaid et al., 2023).

Production efficiency signifies the optimal utilization of resources to augment production without compromising other processes, thereby preserving a sustainable balance. In the context of poultry farming, this efficiency is reflected in indicators such as feed conversion, growth, and mortality, which are contingent upon the direct management of environmental conditions. Research has demonstrated that the implementation of technological advancements in agricultural settings has been associated with enhanced outcomes, primarily attributable to the implementation of stringent controls. However, it is noteworthy that conventional farms, when managed effectively, can also attain substantial levels of productivity. He comments that the increase in production efficiency contributes significantly to raising the profitability of companies and strengthening their permanence in an increasingly demanding market. The continuous improvement of processes is instrumental in optimizing resources, reducing costs, and minimizing environmental impacts, which is imperative to maintain a competitive advantage (Biesek et al., 2022; Casas et al., 2022). Rozhkova and Stepanova (2021) further emphasize the significance of this approach.

Efficiency in the context of poultry organizations can be defined as the ability to manage available resources in a manner that aligns with established objectives. This entails the optimization of inputs such as feed, work time, and workforce, with the objective of stimulating growth in sales, fostering innovation, and upholding stringent standards of quality for both products and internal processes. An efficient poultry entity is one that achieves its objectives by optimizing its resources and minimizing costs. This contributes to the entity's strengthening of its position within the industry. Accordingly, efficiency emerges as a pivotal element in enhancing the market position and safeguarding the sustainability and continuous development of the poultry sector (Kiani, 2022). As stated in the research conducted by Oahu and Zaime in 2024,

Productive optimization is defined as the organization and composition of the productive sectors within an industry, encompassing the production, distribution, and planning of goods and services. According to this structure, it is imperative to ascertain the competitive performance and economic growth of a nation. Within the domain of the poultry industry, it delineates the organizational framework encompassing the production of balanced feed and the subsequent marketing of the final products. A fundamental element of this structure is vertical integration; a strategy employed by poultry companies to manage the entire operational cycle and enhance efficiency. A well-organized production structure has the potential to stimulate the growth of the poultry industry and contribute to enhanced food security (Cando et al., 2024; Pomboza et al., 2018).

Productive performance is defined as the maximization of output while minimizing unit cost through the effective utilization of resources, thereby ensuring that quality is not compromised. This level is attained when the company operates at its maximum capacity without the ability to increase production, input, or the impact on other products. Achieving this objective necessitates the continuous enhancement of processes through the integration of advanced technology, the implementation of rigorous quality controls, and the execution of efficient strategic management. This approach has been shown to yield increased profits, reduced material and time expenditures, and a competitive market position. Moreover, it contributes to environmental balance by minimizing waste and promoting responsible practices. This is essential for profitable and sustainable management (Ramírez & Ojeda, 2022; Zapata et al., 2024).

An effective housing and ventilation system is imperative for ensuring the health and productive performance of poultry. The development of these systems is driven by the necessity to maintain an optimal environment, with the objective of regulating variables such as temperature, humidity, and air quality. The implementation of proper ventilation measures is paramount in preventing the accumulation of toxic gases, such as ammonia, and ensuring the continuous supply of fresh air. This is of the utmost importance for the well-being of birds. These systems are equipped with adjustable fans, allowing for adaptation to specific climatic conditions, including warm regions or the handling of particular breeds, such as hens, which can withstand higher temperatures. By regulating air exchange and maintaining optimal temperatures, these mechanisms help to reduce stress and vulnerability to disease in birds, thus contributing to healthy growth and increased productivity. Consequently, the development of a precise housing infrastructure, designed with an efficient ventilation system, is imperative to ensure the success of a more profitable poultry farm. As demonstrated in the works of Cevallos, Peña, and Díaz (2023), Pereira et al. (2020), Chan, Franks, and Hayek (2022), and Marmelstein et al. (2024),

One of the pivotal factors influencing the productivity of the poultry sector in Tungurahua is the dearth of adequate infrastructure on smaller farms. Producers frequently experience health complications, including poultry health issues, which exert a direct influence on the efficiency and quality of the process outcome. The text asserts that the correlation between poultry production and economic development is significant; however, this correlation is contingent upon the capacity of producers to uphold stringent quality standards and adhere to sanitary regulations. As farms adopt improved biosecurity practices, there is a notable increase in producer productivity and income levels (Houedjifonon et al., 2020; Hennessey et al., 2021).

Operational performance in poultry associations is defined as the organization and coordination of physical, human, and technological resources to transform inputs into value-added goods and services. According to this organization, innovation and efficiency are pivotal to ensuring quality within the production system. The ability to adapt to constant technological changes and market dynamics is key to maintaining competitiveness in unstable economic environments. Conversely, he underscores the significance of comprehensive public policies that fortify the productive infrastructure and guarantee sustainable, equitable, and inclusive growth, while maintaining a harmonious balance between social and economic imperatives within the poultry sector. Chaiban et al. (2020) (Singh et al., 2024). As stated by Bumanis et al. (2022).

The success of poultry farming is contingent upon the effective management of several fundamental factors. Of paramount importance is the provision of a nutritious diet that fosters the healthy development of birds. Additionally, stringent measures must be implemented to prevent the emergence of diseases. The regulation of environmental conditions, such as temperature, ventilation, and lighting, is also crucial in ensuring the well-being and growth of the animals. A synergistic combination of these factors is imperative to ensure the sustainable and responsible production of quality poultry. Additionally, they assert that the integration of advanced monitoring technologies is conducive to enhancing animal welfare and operational efficiency. They emphasize that ongoing personnel training and technological updating are imperative to ensure sustained profitability, productivity, and sustainability of poultry farms, as stated by Abaddel et al. (2022) and Bosco et al. (2021).

Achieving optimal poultry production necessitates a commitment to environmental and social sustainability. The proponents of this technology assert that its implementation leads to a reduction in the consumption of resources such as water and energy, thereby minimizing the adverse environmental impacts of waste. It is also noted that the implementation of appropriate management models contributes to maintaining an economic and environmental balance, while ensuring that production remains constant over time. It has been determined that the implementation of rigorous traceability and control systems throughout the production chain is imperative to ensure compliance with international standards and to enhance consumer confidence and acceptance (Bosco et al., 2021; Álvarez et al., 2024; Bravo et al., 2021).

The poultry production system comprises multiple interconnected sectors, including primary production, input supply, processing, and marketing. The effective integration of this chain, as explained, contributes to the control of costs, the maintenance of product standardization, and the improvement of quality. The argument is made that an integrated vertical structure enables companies to respond expeditiously to fluctuations in demand and market demands. As demonstrated in extant research, investment in infrastructure and the incorporation of advanced technologies are pivotal factors in ensuring ecological stability within each component of the system (Goossens et al., 2022; Zimunya & Dube, 2021).

The fundamental factors influencing the development and growth of the poultry production infrastructure are the implementation of advanced technology, specialized training, and sufficient regulatory frameworks. Technological innovation plays a pivotal role in enhancing the productivity and sustainability of the poultry industry. Golyomytis et al. (2023) posit that Toscano et al. (2022) underscore the significance of effective public policies and continuous training programs in addressing the challenges posed by globalization. These programs are crucial for facilitating access to financing for international market entry, a factor that is imperative for the expansion and consolidation of the poultry production industry in economic centers (Bailey, 2020).

An adequate duration of light has been demonstrated to promote nutrition and reduce stress, while certain wavelengths have been shown to enhance muscle development. Furthermore, temperature and humidity must be meticulously regulated, as their fluctuations have the potential to compromise immune function and augment susceptibility to disease. Contemporary residential architecture has adopted control systems that perpetually monitor environmental conditions, enabling the implementation of timely adjustments to ensure a stable internal environment. Accordingly, the implementation of accurate lighting in conjunction with effective environmental management has been demonstrated to enhance growth rates and promote the health and well-being of avian subjects, thereby augmenting overall productivity (Delgado, 2023; Smetana et al., 2021; Ifeanyichukwu, 2022).

The poultry sector exerts a substantial influence on the economy, generating employment, promoting rural development, and contributing significantly to the national and agricultural GDP. He interprets that modernization and technification increase international competitiveness and improve social and economic income levels. A robust and effective structure fortifies the sector's capacity to confront global challenges, including climate change and market volatility, thereby ensuring food security and national well-being (Ruiz, 2020; Hurtado & Martínez, 2025).

In the contemporary business landscape, the adoption of integrated organizational models by poultry companies has become a prevalent strategy. These models encompass a multifaceted integration of production, processing, and marketing functions, with the objective of achieving a harmonious balance between operational efficiency and the quality of the final product. He notes that this vertical integration enables greater process control, facilitating the rapid adoption of technological innovations. It is emphasized that automation and digital systems facilitate comprehensive monitoring of traceability and health control. Technological advances are imperative to guarantee food safety and consumer confidence in regulated and competitive markets. This assertion is supported by the research of Birhanu et al. (2023), Nasser et al. (2020), and Ornelas et al. (2020).

METHODOLOGY

The study was developed under a quantitative approach, supported by secondary information from the poultry cadaster of Agrocalidad. The cadasters in question constitute the official and updated source on the farms registered in the province of Tungurahua. By providing reliable and standardized data on the structural, organizational, and productive aspects of poultry units, these cadasters fulfill a crucial role in the realm of agricultural research. The elements considered included farm infrastructure, access to technical services, biosecurity practices, management of feed and water consumption records, and sanitary control applied on farms. The use of this input facilitated the circumvention of primary survey processes, thereby enabling a more focused analysis that identified patterns and relationships between the most salient variables affecting production efficiency.

TABLE 1. Description and coding of variables for structural analysis

No.	Long label	Short Label	Description	Topic
	Original variable	**Suggested short name**		
1	**Is there accessibility to the information of the property by the owner?**	Acceso_info_predio	The owner knows and provides information about the property.	Poultry sector
2	**Do you have CZPM-F AGROCALIDAD registration/Certification?**	Certificado_AGROCALIDAD	It has an official sanitary registration of Agrocalidad.	Poultry sector
3	**The farm has veterinary assistance**	Asistencia_veterinaria	The farm receives visits or regular veterinary advice.	Poultry sector

4	**It has a record of feed consumption, water, production**	Registro_consumo_producción	Control of feed, water and poultry production.	Poultry sector
5	**Does the farm use correct biosecurity measures in its opinion**	Medidas_bioseguridad	Application of good sanitary practices on the farm.	Poultry sector
6	**Do you have a stamping plan?**	Plan_sacrificio_sanitario	Procedure in the event of outbreaks or animal health emergencies.	Poultry sector
7	**Condition of the facilities**	Estado_instalaciones	Physical and structural conditions of the place.	Poultry sector
8	**The food is stored in:**	Almacenamiento_alimento	Place where the balanced feed is kept.	Poultry sector

The research design was non-experimental and descriptive explanatory in nature, as the variables were not deliberately manipulated. To explore the interdependencies between the selected factors, the Cross-Impact Matrix – Multiplication Applied to a Classification (MIC MAC) method was applied. This method is predicated on the notion that a variable acquires relevance in a distinct manner through its interactions with other variables. This facilitates the mapping of relationships of influence and dependence within complex systems (Villegas et al., 2020).

The procedure comprised three fundamental stages:

First stage. The Direct Influence Matrix was developed to evaluate the interactions between each pair of selected variables. Each relationship was evaluated on an ordinal scale ranging from 0 to 3, where 0 denotes absence of influence, 1 signifies a weak influence, 2 indicates a moderate influence, and 3 designates a strong influence. This procedure enabled the identification of the critical relationships within the production system, thereby highlighting the variables that exert the greatest impact on others and are significantly influenced by surrounding factors. The MID offers a methodical and quantifiable depiction of the internal dynamics of the poultry sector. This depiction facilitates the subsequent identification of strategic variables that determine the efficiency and competitive development of farms.

TABLE 2 *Matrix of influences*

	1 : Acceso_inf	2 : Certi_AGRO	3 : Asis_veter	4 : Regis_cons	5 : Medida_bio	6 : Plan_sacri	7 : Estado_ins	8 : Alma_alime
1 : Acceso_inf	0	3	3	3	3	1	2	2
2 : Certi_AGRO	3	0	3	3	3	1	2	2
3 : Asis_veter	3	3	0	3	3	1	2	2
4 : Regis_cons	3	3	3	0	2	1	2	2
5 : Medida_bio	3	3	3	2	0	1	2	2
6 : Plan_sacri	2	2	2	2	2	0	1	1
7 : Estado_ins	3	3	2	2	2	0	0	1
8 : Alma_alime	3	3	2	2	2	1	1	0

SECOND STAGE. Following the construction of the MID, the variables with the greatest relevance for the analysis of production efficiency were identified. From an initial set of 14 dichotomous variables, the eight most strategic variables were selected based on their level of influence and dependence within the system. This filtration enabled the analysis to prioritize critical factors that determine the evolution of poultry associations in the province of Tungurahua, ensuring that the results accurately reflect the most decisive organizational and productive dynamics. This stage was instrumental in understanding how organizational structure and operational practices impact productivity. It is a crucial input for interpreting subsequent statistical models.

FINAL STAGE. The direct and indirect relationships between the selected variables were evaluated to determine those with the greatest influence within the system. This analysis enabled the development of a Cartesian plane, in which each variable was positioned according to its degree of influence and reliance. This approach facilitated the identification of strategic variables that primarily influence productive performance. This visual representation facilitates the interpretation of the results and offers a robust basis for decision-making and the formulation of management strategies in the poultry sector, according to the methodological approach recommended by Ratnasari et al. (2020) and Kochański (2022).

Once the critical variables were identified, econometric models of binary response (Logit and Probit) were estimated. The purpose of these models was to calculate the probability that a poultry association will achieve productive efficiency based on its organizational characteristics. The selection of these models is substantiated by the fact that the dependent variable was defined dichotomously (if = 1; no = 0), which renders the implementation of linear regression techniques unfeasible and necessitates specialized methodologies for categorical data. In this context, productive efficiency was established based on the performance records available in the cadaster. In this way, well-defined parameters were considered in advance to differentiate efficient associations from those that are not.

The analysis was based on a set of working hypotheses that guided the application of the models: The following factors contribute to achieving productive efficiency: (i) associations with better infrastructure, (ii) veterinary care, (iii) the application of biosecurity measures, and (iv) access to technical information, together with systematic records of consumption and production.

The models estimated the quality of fitness using the Akaike (AIC) and Bayesian (BIC) information criteria. This was done to identify which specification offered the best balance between fitness and parsimony. The statistical significance of the coefficients was contrasted using the Wald test, while the global goodness of fit was verified through the Hosmer-Lemeshow test, which is used in classification models. The predictive capacity was then evaluated using the ROC curves and the calculation of the area under the curve (AUC). These indicators allow for the assessment of the sensitivity, specificity, and discriminant precision of the model. As a result, the coefficients were interpreted through marginal effects and odds ratios, which made it possible to translate the results into practical implications for the management of poultry associations. This link between statistical evidence and concrete decisions on biosecurity, infrastructure, and technical assistance is a significant contribution to this study.

The methodology employed a dual-pronged approach, integrating structural analysis using MICMAC to identify the most influential variables and econometric modeling to quantify the impact of these variables on production efficiency. The combination of both methods ensured that the results were based on solid data and applicable to the reality of the poultry sector. As a result, the findings provided reliable inputs for the formulation of management strategies and organizational strengthening in the province of Tungurahua.

RESULTS

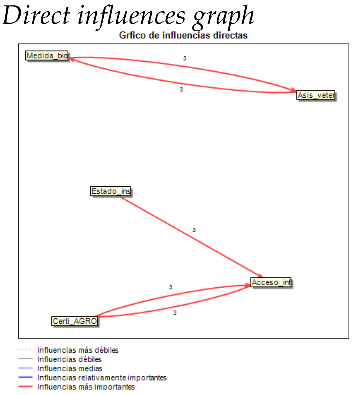
Current situation of the structure and productive efficiency of poultry associations in the central zone of Ecuador

The MIC MAC analysis provided a detailed graphical representation of the relationships between key organizational variables affecting production efficiency in Tungurahua poultry farms. Through the matrices of direct and indirect influences, as well as their visual representations, the most determining factors in the improvement of productivity could be identified.

As illustrated in the Direct Influences Graph (Figure 1), there is a strong relationship between the variable "Biosecurity measures" and "Veterinary care" (value of 3), indicating that biosecurity practices are an essential component for the success of health management, supported by veterinary care. This relationship indicates that farms that prioritize biosecurity and veterinary care are more likely to maintain stable and efficient production by reducing health risks.

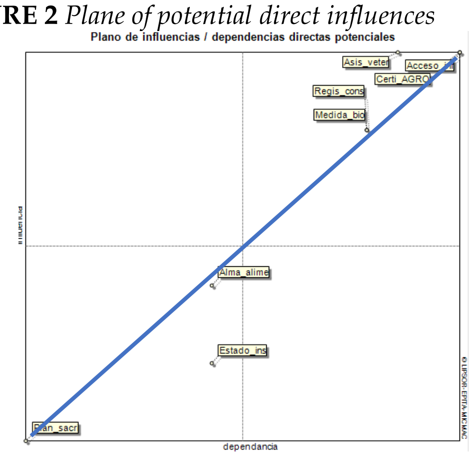
Conversely, the variable "Accessibility to property information" is closely linked to "Condition of the facilities." This underscores the significance of having precise and current information on the conditions of the facilities to enhance the organization and operation of the farms.

FIGURE 1*Direct influences graph*



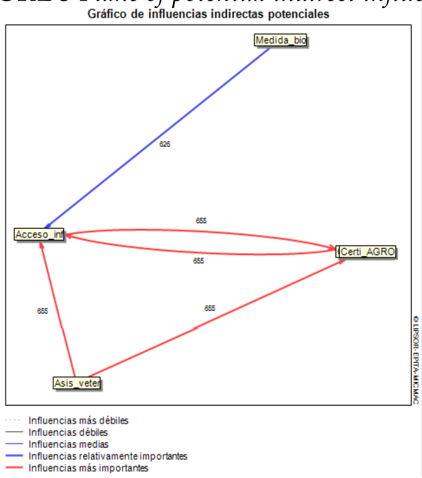
The Potential Direct Influences Chart (Figure 2) illustrates the dependencies between the variables according to their ability to influence production efficiency directly and indirectly. In this plane, variables such as "Veterinary assistance" and "Access to information" are in the area of "Most important influences," which reflects their direct and essential impact on poultry farms. These variables are essential for enhancing the productivity of the sector. They play a pivotal role in strategic decision-making and the effective management of resources, with the aim of achieving higher levels of efficiency in farms.

FIGURE 2 *Plane of potential direct influences*



The Graph of Potential Indirect Influences (Figure 3) builds on the previous analyses by showing the future projection of the relationships between variables. As illustrated in the graph, "Accessibility to information" and "Veterinary care" are identified as key elements due to their ability to have both a direct and indirect impact on farm performance. The value assigned to indirect influence relationships demonstrates that an adequate structure of information and timely access to veterinary advice generate long-term effects, with a positive impact on the sustainability and operational efficiency of the poultry sector.

FIGURE 3 *Plane of potential indirect influences*



The Logit and Probit econometric models, when complemented by marginal effects and the calculation of odds ratios using the antilogarithm, allow for the quantification of the impact of each organizational variable on production efficiency.

TABLE 3 *Results of the Logit and Probit models*

	Logit Reportes de morbili dad y mortalidad	Probit Control roedores	Probit Control insectos	Probit Agua potable	Probit Perros y/o gatos tien en acceso a galpones o áreas de crianza
(Intercept)	-20.671020 (4442.657915)	-5.959614 (251.312346)	-5.827820 (256.657255)	-0.983270 (0.656578)	0.359944 (0.575442)
¿Existe accesibilida d a la información d el predio por parte del dueño?	0.454185 (5394.029164)	4.399288 (251.312924)	4.306242 (256.657810)	0.808844 (0.754466)	-0.669503 (0.692361)
La explotación cuen ta con asistencia vet erinaria	18.927623 (3059.140759)	1.785652** (0.635844)	1.666213** (0.624645)	1.450131** (0.537712)	0.289858 (0.468125)
Tiene registro de co nsumo de alimento, agua, producción	3.615003*** (0.947603)	0.352831 (0.387939)	0.598085 (0.374143)	0.084491 (0.529381)	-0.533762 (0.341328)
Correctas medidas de bioseguridad	2.616671** (0.947603)	0.906488** (0.351044)	0.757738* (0.350002)	0.706143 (0.453108)	-0.535738 (0.313766
Dispone de un plan de sacrificio sanitari o	1.010226 (1.350153)	0.473514 (0.372768	0.251783 (0.331446)	0.079175 (0.470669)	0.095871 (0.241556)
N	213	213	213	213	213

In the econometric analysis, the Logit and Probit models showed consistent results. In the morbidity and mortality report (Tables 6 and 7), veterinary care was the most influential predictor, with odds ratios with remarkably high results. The record of food and water consumption, biosecurity measures, and the sanitary culling plan also showed positive associations, while access to information had a stable, although more moderate, effect.

TABLE 6 *Estimation of ratios using the antilogarithm for the Logit of the variable morbidity and mortality reports*

> exp(coef(logit_Rep.morbi.y.mort))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 1.053634e-09 1.574890e+00 1.660207e+08 3.715145e+01 1.369008e+01 2.746221e+00

TABLE 4 *Estimation of ratios using the antilogarithm for the Probit of the variable morbidity and mortality reports*

> exp(coef(probit_Rep.morbi.y.mort))
(Intercept) A.a. The.info Asis.vete Reg.of.consume M.of.biosegurity Plan.sacri.sanitary 1.231023e-03 1.160488e+00 3.408206e+02 6.811715e+00 3.665219e+00 2.005717e+00

In rodent control, the results reflected a determining weight of access to information and veterinary care (Tables 8 and 9). In the Logit model, access to information reached an odds ratio of 5,488,375, while in the Probit it reached 81.39. Veterinary care also showed a significant effect on both models, confirming its relevance in health management.

TABLE 5 *Estimation of ratios using the antilogarithm for the Logit of the Control.roe variable*

> exp(coef(logit_Control.roe))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 1.402149e-08 5.488375e+06 1.804532e+01 1.952935e+00 5.190778e+00 2.392361e+00

TABLE 6 *Estimation of ratios using the antilogarithm for the Probit of the Control.roe variable*

> exp(coef(probit_Control.roe))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 0.002580909 81.392929288 5.963466250 1.423091247 2.475613044 1.605626001

In the case of insect control, access to information was positioned as the most influential predictor (odds ratios greater than one million in Logit and 74.16 in Probit), followed by veterinary care, which increased the probability of success fifteen times. The consumption registry, the biosecurity measures, and the health plan presented additional positive contributions (Tables 10 and 11).

TABLE 7 *Estimation of Ratios Using the Antilogarithm for Logit Control.insec*

> exp(coef(logit_ Control.insec
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 4.261500e-08 1.913545e+06 1.502994e+01 2.915206e+00 4.001504e+00 1.577626e+00

TABLE 8 *Estimation of ratios using the antilogarithm for Probit Control.insec*

> exp (coef (probit_ Control.insec))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 0.002944488 74.161297047 5.292087417 1.818632717 2.133444448 1.286316977

In relation to access to drinking water, veterinary care showed a relevant effect, increasing the probability of success almost twelve times in the Logit model and more than four times in the Probit model. Access to information and biosecurity measures also had a positive influence, while consumption records and health plans showed a more moderate effect (Tables 12 and 13).

TABLE 9 *Estimation of ratios using the antilogarithm for the Logit Drinking Water*

> exp (coef (logit_ Agua.potable))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 0.171743 4.299957 11.811591 1.342536 4.108837 1.310936

TABLE 10 *Estimation of ratios using the antilogarithm for the Probit Drinking Water*

> exp (coef (probit_ Water.p otable))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 0.3740858 2.2453113 4.2636716 1.0881625 2.0261612 1.0823940

In the Logit model, veterinary care has a value of 1.58, which means that its increase increases the probability of access to and breeding of animals by 58%. In the Probit model, this value is 1.33, which confirms an important positive effect. In contrast, the consumption record and biosafety have values less than 1 in the Logit of 0.41 and in the Probit of 0.58, which indicates that, as these variables increase, the probability decreases. Veterinary care clearly highlights its impact on the outcome, showing that this variable is the one that contributes most to success in animal health control (Tables 14 and 15).

TABLE 11 *Estimation of ratios using the antilogarithm for the Logit Animal.acce.gal.y.ár.crian*

> exp (coef (logit_ Animal.acce.gal.y.ár. crian))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 1.8060626 0.3392443 1.5832740 0.4081995 0.4100625 1.1783648

BOARD 12. *Estimation of ratios using the antilogarithm for the Probit Animal.acce.gal.y.ár.crian*

> exp (coef (probit_ Animal.acce.gal.y.ár.crian))
(Intercept) A.a. la.info Asis.vete Reg.de.consumo M.de.bioseguridad Plan.sacri.sanitario 1.4332488 0.5119631 1.3362371 0.5863948 0.5852375 1.1006166

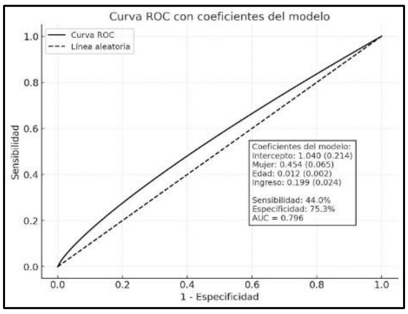
The goodness of fit of the models was evaluated using the Hosmer-Lemeshow test (Table 16), which presented a Chi-square statistic of 11.392 with 9 degrees of freedom and a p-value of 0.251, which validates the robustness of the fit to the observed data.

TABLE 13 *Goodness of Fit - Hosmer and Lemeshow Test*

Indicator	Result
Chi-square statistic	11.392
Degrees of freedom (df)	9
P-Value	0.251

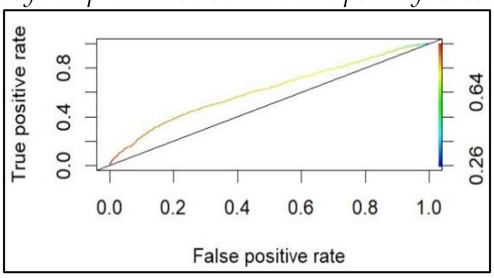
The discriminative capacity of the models was evaluated using the ROC Curves. In the Probit model (Figure 3), the area under the curve (AUC) was 0.796, indicating a strong performance in differentiating between efficient and non-efficient associations. The sensitivity reached 44% and the specificity 75.3%, thus confirming its usefulness in the detection of inefficient associations.

FIGURE 3 *ROC curve of the Probit model for the prediction of efficiency and production structure in poultry associations*



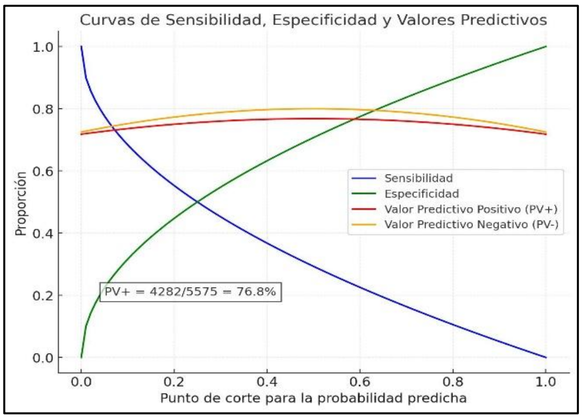
In the estimated binary model (Figure 4), the decision thresholds ranged from 0.26 to 0.64. Low values maximized the identification of efficient associations, but increased false positives, while high values reduced this error at the cost of increasing false negatives.

FIGURE 4 *ROC curve of the estimated binary model for efficiency and production structure in poultry associations*



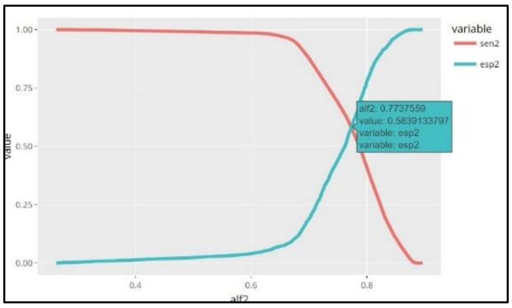
The ROC curve of the Probit model applied to the Tungurahua associations (Figure 5) showed a trajectory close to the upper left corner, thus reflecting a high discriminative capacity. A cut-off point close to 0.6 optimized the balance between sensitivity and specificity, with a positive predictive value of 76.8%.

FIGURE 5 *ROC curve of the Probit model in poultry associations*



As a result, sensitivity and specificity analysis allowed us to identify an approximate sweet spot of 0.77 (Figure 6), with a sensitivity of 58.4% and a specificity of 77.4%. These values show an adequate balance in the classification of efficient and non-efficient associations.

FIGURE 6 *Sensitivity, Specificity and Optimal Point of the Probit Model for Poultry Efficiency and Production Structure*



DISCUSSION

The results obtained confirm the main hypothesis: a solid organizational structure significantly increases the probability of achieving productive efficiency in poultry associations in central Ecuador. Among the variables analyzed, veterinary care was identified as the most influential factor, given its direct impact on reducing morbidity and mortality, pest control, and access to basic resources. This finding aligns with the observations made by Bosco et al. (2021), who underscored the significance of professional technical support as a cornerstone of effective health management.

The MIC MAC analysis demonstrated that biosecurity measures enhance productivity, with their effectiveness contingent on their integration with veterinary care. This outcome aligns with previous research, which underscores the limitations of isolated biosecurity measures. However, when integrated with technical guidance, it has been shown to enhance disease outbreak prevention (Hennessey et al., 2021).

Conversely, input recording emerged as a pivotal practice, facilitating traceability, optimizing feed and water usage, and reducing losses. This aligns with the findings reported by Casas et al. (2022). Likewise, access to accurate and timely information strengthened the capacity for planning and strategic decision-making, confirming that document management is an axis for competitiveness in agro-productive systems (Ochoa & Gonzáles, 2024).

In contrast, the restriction of access to breeding areas for domestic animals did not demonstrate a substantial impact on overall efficiency. This finding indicates that certain biosecurity practices necessitate the development of more customized strategies tailored to each production context.

From a methodological perspective, the statistical validation using the Hosmer-Lemeshow test and the performance of the Probit model, with an AUC of 0.796, confirmed the predictive capacity of the applied model. The optimal balance between sensitivity and specificity is essential for identifying inefficient associations, a vital aspect for guiding public policies and sectoral strengthening plans.

CONCLUSIONS

This article confirms that an efficient organizational structure is key to achieving high production efficiency in the Tungurahua poultry farms. Key factors such as veterinary care, input registration, and biosecurity measures are crucial for enhancing animal health, optimizing resource use, and mitigating health risks. This, in turn, leads to increased productivity.

The MIC MAC analysis indicates that veterinary care and access to accurate information are pivotal factors for production efficiency, underscoring the importance of structured information management and the availability of technical resources. The Logit and Probit models corroborate these findings, demonstrating that effective input management and veterinary support directly impact sanitary control and enhance operational efficiency.

While biosecurity measures are essential, their direct impact on efficiency is more limited compared to other factors. Furthermore, the control of domestic animals in the breeding areas did not show a significant relationship with efficiency, suggesting the need for more specific control strategies.

The positive odds ratios associated with key variables, such as access to information, veterinary assistance, and the implementation of biosecurity protocols, indicate that these productive and organizational practices increase the probability of achieving efficiency in poultry associations. Therefore, it is essential to strengthen these aspects to improve productive performance.

The Probit model's evaluation revealed that the productive structure of poultry associations significantly impacts their efficiency. The results demonstrated a strong performance, as evidenced by an AUC of 0.796, indicating a high degree of accuracy in differentiating between efficient and non-efficient associations. The ROC curve demonstrated an optimal point near 0.6, which achieves an acceptable balance between sensitivity and specificity. This results in a high positive predictive value, enabling the accurate identification of relevant cases for decision-making purposes.

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