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Ecuacientífica
REVISTA MULTIDISCIPLINARIA

ISSN: 3091 -1796

REVISTA MULTIDISCIPLINARIA ECUACIENTÍFICA

Volumen 3
Número 6

DOI: https://doi.org/10.56519/jhbaq449

ISTOG

Edición especial
20 - 08 - 2025

Ecuacientífica
ISSN: 3091-1796
Vol. 3, No. 6, PP.1-11
DOI: https://doi.org/10.56519/9nz9vq45
Agosto 2025

CULTURA TRIBUTARIA Y SU INFLUENCIA EN LA TOMA DE DECISIONES ESTRATÉGICAS DE LAS EMPRESAS EN EL MERCADO GLOBAL

TAX CULTURE AND ITS INFLUENCE ON STRATEGIC DECISION-MAKING BY COMPANIES IN THE GLOBAL MARKET

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Fecha de recepción: 01/07/2025 / Fecha de aceptación: 19/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN

La cultura tributaria comprendida como el entramado de valores, percepciones y conductas que una sociedad adopta respecto al cumplimiento de sus deberes impositivos modula de forma decisiva y variada el proceso de toma de decisiones estratégicas de las empresas que operan en mercados globales. Este trabajo, llevado a cabo con la rigurosidad propia de los análisis ingenieriles, postula que la actitud tributaria de una firma, lejos de reducirse a una formalidad reglamentaria, se constituye en un tenaz determinante que caracteriza su competitividad, su reputación ante los agentes interesados y su capacidad de perdurabilidad en el tiempo. Se articula a partir de una revisión sistemática de la producción académica, empleando el enfoque PRISMA con el fin de depurar y consolidar la evidencia más solvente proveniente de revistas científicas indexadas, de modo que se adense el entendimiento de esta interrelación en un horizonte global y se desvele, con singular atención, las consecuencias que presenta para las empresas emplazadas en la ciudad de Riobamba, Ecuador. Los resultados analizados indican que una cultura tributaria bien arraigada está asociada con una disminución del riesgo fiscal, una elevación de la reputación corporativa y la consolidación de una ventaja competitiva duradera. En contraste, una cultura de evasión, si bien puede traducirse en ganancias inmediatas, acarrea un riesgo elevado de sanciones, deterioro de la credibilidad y obstáculos en el proceso de expansión. Por consiguiente, la cultura tributaria no debe concebirse como un mero gasto operativo, sino como un fundamento estratégico que las organizaciones precisan administrar de forma anticipada para consolidar su éxito en un entorno global cada vez más complejo y cambiante. El presente trabajo ofrece un examen exhaustivo, que incluye tablas y figuras, las cuales sustentan estas afirmaciones y proporcionan un referencial operativo para la gobernanza empresarial

Palabras clave: Cultura tributaria, cumplimiento fiscal, responsabilidad social corporativa, sostenibilidad corporativa

ABSTRACT

Tax culture, understood as the framework of values, perceptions, and behaviors that a society adopts regarding the fulfillment of its tax obligations, decisively and variably shapes the strategic decision-making process of companies operating in global markets. This study, carried out with the rigor typical of engineering analyses, postulates that a firm's tax attitude, far from being a mere regulatory formality, becomes a significant determinant that characterizes its competitiveness, reputation with stakeholders, and long-term sustainability. It is based on a systematic review of academic literature, employing the PRISMA approach to filter and consolidate the most reliable evidence from indexed scientific journals, aiming to deepen the understanding of this interrelationship in a global context and revealing, with particular attention, the implications for companies based in Riobamba, Ecuador. The analyzed results indicate that a well-rooted tax culture is associated with a reduction in fiscal risk, an enhancement of corporate reputation, and the consolidation of a lasting competitive advantage. In contrast, a culture of evasion, while potentially leading to immediate gains, carries a high risk of penalties, credibility deterioration, and obstacles in the expansion process. Therefore, tax culture should not be seen as a mere operational cost, but as a strategic foundation that organizations must proactively manage to secure their success in an increasingly complex and dynamic global environment. This study offers a thorough examination, including tables and figures, which support these claims and provide an operational reference for business governance.

Keywords: Tax culture, tax compliance, corporate social responsibility, corporate sustainability

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INTRODUCTION

In the contemporary global economic context, organizations face an environment characterized by dynamism and competition, which requires that strategic decisions transcend the traditional focus on profitability. A critical dimension that has become consolidated in this analysis is tax culture, whose incidence is manifested in corporate behaviors and guidelines. Defined as the set of perceptions, values, and attitudes that subjects hold regarding the fulfillment of tax obligations, tax culture exerts its influence both at the micro level, where financial management is articulated, and at the macro level, where it is linked to corporate reputation and long-term sustainability.

At the global scale, tax avoidance and evasion constitute a persistent challenge that erodes the foundations of the economy, distorts competition, and restricts the capacity of States to finance essential public services (1), (2). In this context, international research has confirmed that the perception of equity of the tax system and the degree of trust in public institutions constitute decisive determinants of the level of tax compliance by companies (3), (4).

The fiscal landscape in Latin America, at the regional scale, faces particularities that result in recurring problems, such as a large informal economy and a weak culture of tax compliance (5), (6). These characteristics not only diminish the State's collection capacity but also hinder the establishment of a competitive and equitable market for economic agents. In Ecuador, the design of the tax system has been the object of multiple reforms aimed at increasing collection and stimulating automatic compliance with tax duties (7).

However, the obstacles surrounding tax culture and the valuation of the tax burden remain of notable magnitude (8). Under such circumstances, the behavior of

ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11

DOI:
https://doi.org/10.56519/9nz9vq45
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companies located in cities such as Riobamba, a relevant commercial and services hub in the Andean corridor, warrants a particularized examination. Given the predominance of small and medium-sized enterprises (SMEs) in the productive structure of the city, the interaction between fiscal culture and the strategic management of organizations acquires decisive prominence (9), (10).

Tax culture plays a decisive role in fiscal cohesion and the promotion of economic development; however, the gap in empirical evidence regarding its impact on the strategic decisions of companies remains unaddressed, especially in emerging markets and in specific local environments such as Riobamba. Existing literature privileges macro studies on the architecture of fiscal policy or micro analyses of individual compliance with tax obligations, and the intermediate link that connects both dimensions remains insufficiently examined.

The inquiry must focus on determining whether an organizational culture oriented toward tax compliance translates into lower financing costs, elevated reputation, and, consequently, competitive advantage; or whether, conversely, companies that normalize evasion achieve immediate rents that, however, are unable to be sustained over time. The absence of a rigorous and systematized analysis of this interaction hinders both the design of coherent public policies and the construction of business strategies that seek alignment between profitability and tax responsibility.

This work is justified by its significance on three planes: theoretical, methodological, and practical. From the theoretical plane, it enriches the discussion on fiscal culture and strategic management through the development of an analytical framework aimed at revealing the way in which social values and attitudes toward taxation are translated into corporate actions. In the methodological sphere, the systematic review of the literature synthesizes the accumulated evidence in a rigorous and objective manner, which in turn lays a robust foundation for further inquiry.

From a practical perspective, the results become valuable tools for managers, who can formulate more grounded fiscal decisions. Tax administrations, in turn, will have information that allows them to design programs and policies that cultivate a compliance culture, which in the long term will result in more efficient collection and a more equitable market environment. Likewise, the study is conducted in the context of Riobamba, which makes it an empirical reference that can be replicated in other cities and regions, thereby expanding its utility and relevance.

The main objective of this research is to analyze the influence of tax culture on the strategic decision-making of companies in the global market, through a systematic review of the scientific literature, with special attention to the context of the city of Riobamba.

MATERIALS AND METHODS

The present research is based on a systematic bibliographic review procedure designed to locate, evaluate, and critically consolidate the relevant studies on a given phenomenon. Such a method offers an exhaustive and bias-free overview of the existing scientific production, attenuating the probable influence of selection biases.

ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11

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https://doi.org/10.56519/9nz9vq45
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For the execution of this analysis, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) normative consideration was adopted, a consolidated reference in the scientific community (11).

Type of research and approach

The study is classified as documentary and bibliographic, with a qualitative-descriptive analytical design. By virtue of the nature of the work, no empirical measurements were carried out on individuals or samples, focusing the inquiry on the critical review of the available written production.

Population, sample, and setting

The comprehensive population is constituted by recognized and indexed scientific articles that discuss the interface between tax culture and the administration or formulation of strategic decisions. The sample selection resulted from the sequential application of inclusion and exclusion criteria, obtaining a representative subset. The study setting encompasses the sphere of international and multidisciplinary academic research.

Measurement and statistical analysis

Given the qualitative nature, the application of statistical analyses was omitted. Instead, thematic analysis was used, a technique by means of which the essential results of the selected texts are identified and grouped. The instrumentation consisted of a data extraction matrix that recorded: author(s), year, title, journal, objective, design, main results, and conclusions.

Table 1. Methodological framework

Aspect	Detail
Type of research	Bibliographic (Systematic review)
Population/Sample	Scientific articles, reports, and case studies
Setting	Global context and specific to Riobamba, Ecuador
Measurements	Qualitative and quantitative analysis of fiscal policies and their impact
Statistical analysis	PRISMA method for the bibliographic review. Inclusion: Articles from indexed journals (Q1, Q2), published in the last 10 years, in English and Spanish, that address the relationship between tax culture and business decisions. Exclusion: Non-systematic review articles, undergraduate theses, books, and non-peer-reviewed publications

Source: Authors' own elaboration

RESULTS

The methodical examination of the literature highlights decisive findings that illustrate how tax culture conditions the strategic decisions of business organizations. Three central territories of influence have been distinguished: the management of fiscal risk together with public perception, the generation of competitive advantages, and the integration of corporate social responsibility.

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DOI:
https://doi.org/10.56519/9nz9vq45
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Impact on fiscal risk and reputation

Tax culture, understood as the internal perception and practice regarding tax obligations, is decisive in the calibration of tax risk and in the valuation that the market assigns to the company. The reviewed works confirm that an organizational environment that privileges compliance with fiscal regulations minimizes the probability of audits, sanctions, and litigation with the tax administration; this phenomenon translates into a reduction of costs associated with litigation and audit processes (12), (13). In contrast, an orientation toward regulatory avoidance, while it may offer advantages in terms of immediate liquidity, imposes on the entity a considerable exposure to severe fines and possible disruptions in the continuity of its operations. Reputation, as an intangible asset of difficult valuation, suffers the impact of these decisions through an erosion of the trust of consumers, investors, and regulators.

In the contemporary context characterized by almost instantaneous access to financial data, the treatment that corporations give to their tax obligations has acquired a notable degree of visibility, such that social opinion on the moral correctness of their tax optimization strategies begins to have quantifiable correlations with customer loyalty and shareholder disposition, which, in turn, can directly impact the perception of brand strength and the dynamics of its quotation in organized markets (14), (15).

Table 2. Relationship between tax culture and risk/reputation

Area of impact	Key findings from the bibliographic review	Strategic implications and analysis
Fiscal risk and reputation	The analysis evidenced a negative correlation between the strength of corporate tax culture and exposure to fiscal risk. A solid internal discipline oriented toward regulatory compliance reduces the frequency of audits, the imposition of sanctions, and the probability of jurisdictional disputes. This phenomenon translates, in monetary terms, into a significant reduction of costs and the preservation of operational continuity (12), (13). Complementarily, the adoption of fiscal transparency practices correlates with the consolidation of a favorable corporate reputation, which, in turn, strengthens the trust of consumers and investors, constituting an intangible capital of considerable strategic importance (14), (15).	Investing in a culture of compliance must be conceived as a risk and reputation management strategy, and not as a mere accounting cost. Organizations that adopt a practice of fiscal transparency, in essence, consolidate a reputational capital that, in competitive markets such as that of Riobamba, provides a comparative advantage that is difficult to replicate. This practice not only restricts exposure to sanctions and unfavorable audits, but also cushions the impact of possible financial or credibility crises, by revealing a sustainable commitment to integrity and respect for the rules.

Source: Authors' own elaboration

Tax culture and competitive advantage

A robust tax culture can be transformed into a lasting competitive advantage. It is not reduced to a mere expense; conscious fiscal management grants organizations the capacity to focus on their core activities, clearing the path of financial surprises linked to evasive practices (16). Regulatory adherence translates into a clear message of solidity and rigor, which in turn facilitates the obtaining of financing, the incorporation of excellent human capital, and the building of strategic alliances. In an environment in which stakeholders increasingly value corporate integrity, ethical tax behavior is

ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11

DOI:
https://doi.org/10.56519/9nz9vq45
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identified as a distinctive element that not only ensures the trust of investors, but also attracts customers and talent who seek organizations with a genuine commitment to responsibility.

Figure 1. Conceptual model of the relationship between tax culture and competitive advantage.

(This representative model demonstrates how a favorable normative and fiscal environment promotes strategic choices oriented toward sustainability, whose cumulative consequences include a strengthened reputation, a reduction of exposures to regulatory risk, and an expansion of financing opportunities. These interrelated variables give rise to a competitive capital that is reinforced through the reinvestment of the surpluses obtained in good governance and compliance practices. The consolidation of the cycle occurs as a result of external recognition, which, by validating the model, stimulates an additional cycle of improvement and regulatory compliance.)

Table 3. Tax culture and competitive advantage

Area of impact	Key findings from the bibliographic review	Strategic implications and analysis
Competitive advantage	Academic research indicates that organizations that integrate regulatory compliance into their corporate culture can achieve a lasting competitive advantage. Such an advantage originates in the fact that prudent fiscal management preserves resources that, in the absence of such a culture, would be employed in the defense against tax contingencies. In addition, the commitment to compliance regulates the external perception of the firm, projecting an image of stability and rigor, which translates into more favorable access to financing and the creation of strategic associations.	The present finding forcefully contradicts the habitual conception that considers tax evasion as a mere cost-optimization tactic. Indeed, a tax culture founded on ethical principles enables organizations not only to mitigate exposure to legal contingencies, but also to divert resources and attention toward innovation and sustained expansion. Moreover, such behavior establishes itself as a distinctive value in the market, capable of attracting strategic partners and customers who weigh profitability and integrity equally.

Source: Authors' own elaboration

Corporate Social Responsibility (CSR) and taxation

ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11
DOI:
https://doi.org/10.56519/9nz9vq45
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The findings of this review indicate a significant relationship between tax culture and corporate social responsibility (CSR) (17), (18). Organizations that exhibit a high level of commitment to the fiscal obligation tend, frequently, to channel resources toward social responsibility initiatives. Taxation is increasingly considered an essential dimension of CSR, given that it constitutes the mechanism through which societies contribute directly to collective well-being and community development (19). In this framework, the fulfillment of tax obligations is configured as one of the most direct and visible interventions that a corporation can make for the benefit of society.

DISCUSSION

The results of this systematic review reinforce and expand the findings of previous research on the interaction between tax culture and strategic orientation. The examined literature reveals that a culture of tax compliance must be conceived not as a mere operational cost, but as an investment that, properly managed, produces sustainable value. This assertion aligns with the argumentation of (20), who maintains that the evaluation of compliance goes beyond the risk of financial sanctions, equally incorporating the depreciation of corporate reputation and the deterioration of trust among stakeholders. Likewise, our inquiry corresponds with the work of (21), which documents that entities characterized by consistent tax behavior are the object of higher valuations in the capital market.

In the city of Riobamba, despite the scarcity of empirical studies on the topic, the findings of this review retain high relevance. The small and medium-sized enterprises that predominate in the region operate under a context characterized by high levels of informality and the absence of a consolidated tax culture (22). However, the internalization of a culture of regulatory compliance could constitute a differentiating factor, allowing these economic units to gain the trust of the local consumer and project an image of formality that, in turn, would facilitate access to new markets and to sources of financing that are currently closed to them. This scenario matches the results of the research by (23), which underscores the role of tax education in the sustainability of small enterprises.

In contrast to approaches focused exclusively on tax evasion as a negative, the present review approaches taxation as a cultural and managerial phenomenon, placing emphasis on the strategic construction of organizational tax culture. This approach challenges the conventional conception of evasion as mere optimization of tax burdens (24). When comparing our discoveries with the evidence of (25), which demonstrates that firms that adopt aggressive tax practices exhibit lower profitability over prolonged horizons, it is reiterated that durability and business success remain linked to fiscal behavior characterized by ethics and transparency.

CONCLUSIONS

Tax culture stands as a strategic axis that conditions, in a determining manner, the persistence and long-term competitiveness of organizations. Adherence to fiscal regulations becomes, beyond mere formality, a management instrument capable of reducing exposure to contingencies and consolidating a corporate image of reliability.

ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11

DOI:
https://doi.org/10.56519/9nz9vq45
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The adoption of practices of total transparency operates as a buffer against audits, fines, and judicial actions, producing a decrease in unexpected outlays and greater resilience in daily operations. Simultaneously, such conduct nourishes the credibility that consumers, shareholders, and commercial allies place in the entity, thereby elevating the reputational capital that the brand administers in the competitive sphere.

Likewise, developing and maintaining a culture of tax compliance has been evidenced as a factor that generates durable competitive advantage. Far from the conviction that tax evasion can be interpreted as a valid cost-reduction tactic, proactive and transparent fiscal management restores legitimate resources, which can be redirected toward research, innovation, and business expansion. This responsible conduct, in turn, improves the perceived mitigation of fiscal risk, facilitating access to financial capital and fostering the establishment of strategic alliances. In this way, the organization will consolidate a more robust competitive position. Ethical conduct in tax matters is established, consequently, as a decisive differentiator that attracts customers and partners who value integrity and social responsibility among their criteria.

Responsible taxation has acquired recognition as a crucial pillar of Corporate Social Responsibility (CSR). Corporations that satisfy their fiscal duties in a coherent and anticipatory manner do not limit their action to mere normative compliance; they add demonstrative social value by contributing to the support of cohesive structures such as education and health. By designing tax planning policies that prioritize redistributive justice over financial optimism, these entities link their economic activity to collective well-being and ground, before the citizenry and their own stakeholders, a status of legitimacy that transcends simple business reputation.

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3091-1796
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DOI:
https://doi.org/10.56519/9nz9vq45
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ISSN:
3091-1796
Vol. 3, No. 6, PP.1-11

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Ecuacientífica
ISSN: 3091-1796
Vol. 3, No. 6, PP.12-26
DOI: https://doi.org/10.56519/7byke923
Agosto 2025

DISEÑO 3D COMO RECURSO PUBLICITARIO: CASO DE ESTUDIO; GLOSS PUBLINEON

3D DESIGN AS AN ADVERTISING RESOURCE: CASE STUDY; GLOSS PUBLINEON

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Fecha de recepción: 16/07/2025 / Fecha de aceptación: 23/07/2025 / Fecha de publicación: 20/08/2025

RESUMEN: El presente trabajo pretende realizar un análisis sobre el uso del diseño 3D como recurso publicitario en el caso de Gloss Publineon en la ciudad de Ambato, la investigación es significativa debido al creciente interés en el empleo de tecnologías avanzadas para mejorar la efectividad de las campañas publicitarias y atraer audiencia de toda la cuidad de Ambato, el objetivo principal es diseñar una estrategia publicitaria de posicionamiento utilizando técnicas de modelado 3D en la empresa Gloss Publineon, en la presente investigación se adoptó un enfoque mixto, combinando metodologías cualitativas y cuantitativas pues se llevaron a cabo entrevistas cualitativas a 12 docentes de la carrera de Diseño Gráfico de la Universidad Nacional de Chimborazo expertos en diseño gráfico, publicidad y diseño 3D para discutir aspectos clave del tema de investigación y se utilizaron encuestas cuantitativas a 50 residentes de la zona urbana de Ambato con preguntas cerradas mediante encuestas digitales para de esta manera analizar los datos estadísticamente, las encuestas se diseñaron para ser representativas de la población objetivo a estudio aplicando un muestreo adecuado y proporcionando instrucciones claras a los participantes, la metodología proyectual empleada fue el Design Thinking, que incluyó cinco fases: empatizar, definir, idear, prototipar y evaluar los datos recopilados permitieron identificar necesidades y preferencias del público objetivo y conceptualizar soluciones creativas a través de storyboards, los prototipos desarrollados incluyeron videos animados que integraron productos de la empresa en lugares estratégicos de la cuidad de Ambato, evaluados mediante pruebas de usuario, el principal resultado fue la creación de varios videos animado-finales que lograron captar de manera efectiva la atención del público ambateño, demostrando que el diseño 3D puede ser un recurso poderoso en la publicidad local, mejorando la percepción y atractivo de las campañas publicitarias de Gloss Publíneon impulsando de esta manera el aprendizaje del modelado 3D.

Palabras clave: Diseño 3D, publicidad, Design thinking, Ambato, campañas publicitarias

ABSTRACT: This study aims to analyze the use of 3D design as an advertising resource in the case of Gloss Publíneon, located in the city of Ambato. The research is relevant due to the growing interest in employing advanced technologies to enhance the effectiveness of advertising campaigns and attract audiences throughout Ambato. The main objective is to design a positioning advertising strategy using 3D modeling techniques within the company Gloss Publíneon, a mixed-method approach was adopted, combining both qualitative and quantitative methodologies. Qualitative interviews were conducted with 12 professors from the Graphic Design program at the

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 12-26.

ISSN:
3091-1796
Vol. 3, No. 6, PP.12-26

DOI:
https://doi.org/10.56519/7byke923
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Universidad Nacional de Chimborazo, all experts in graphic design, advertising, and 3D design, to explore key aspects of the research topic. Additionally, quantitative surveys were administered to 50 residents of the urban area of Ambato using closed-ended questions in digital format, enabling statistical analysis of the data. The surveys were designed to be representative of the target population, applying appropriate sampling techniques and providing clear instructions to participants, the project-based methodology used was Design Thinking, which included five stages: empathize, define, ideate, prototype, and evaluate. The collected data allowed for the identification of the target audience's needs and preferences, and supported the conceptualization of creative solutions through storyboards. The developed prototypes included animated videos integrating the company's products in strategic locations throughout the city of Ambato, which were then evaluated through user testing, the main outcome was the creation of several finalized animated videos that effectively captured the attention of the Ambato public, demonstrating that 3D design can be a powerful resource in local advertising. This approach enhanced the perception and appeal of Gloss Publíneon's campaigns, while simultaneously promoting the learning and application of 3D modeling techniques.

Keywords: 3D design, advertising, Design Thinking, Ambato, advertising campaigns

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INTRODUCTION

Technological evolution in advertising has transformed the way brands communicate with consumers. 3D design, in particular, has revolutionized the advertising industry by providing a new dimension of creativity and precision in the presentation of products and services (1). This tool has enabled brands to create more immersive and attractive experiences, standing out in an increasingly competitive market. In a context where capturing consumer attention is a constant challenge, 3D design has emerged as a powerful solution to generate memorable, interactive, and effective advertising campaigns (2). In this environment, Gloss Publineon, a prominent company in the advertising products sector in the city of Ambato, has identified an opportunity to use 3D design as a key resource to connect with its current clients and attract new consumers (3).

Competition in the current market is fierce, and companies must constantly seek innovative ways to differentiate themselves from others, as traditional advertising no longer has the same impact as before, since consumers are exposed to countless advertising messages through multiple digital channels. In this scenario, brands are forced to use advanced technologies to stand out and capture the attention of their audience. 3D design allows companies to present their products in a more realistic and

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https://doi.org/10.56519/7byke923
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attractive manner, providing consumers with a more immersive visual experience. This technique not only improves the aesthetics of advertising campaigns but also facilitates a more precise and detailed representation of the products offered, which can positively influence purchasing decisions (4).

Gloss Publineon has decided to incorporate 3D design into its advertising strategies in order to improve the effectiveness of its campaigns and generate a higher level of engagement among its clients. The company seeks to innovate in the way it presents its advertising products such as vinyls, banners, tapes, and acrylics through three-dimensional representations that allow consumers to explore the products in a more realistic manner. This not only has the potential to increase consumer interest and satisfaction but can also improve the perception of quality and value of the products, which in turn could lead to an increase in sales (5).

The main objective of this study is to analyze how 3D design can be used effectively in Gloss Publineon's advertising campaigns and evaluate its impact in terms of consumer perception and campaign performance. In this way, the aim is to design a positioning advertising strategy using 3D modeling techniques in the company Gloss Publineon, which will allow the brand to stand out in the local market, improving its visibility and strengthening the relationship with its clients.

Although an increase has been observed in the use of technologies such as 3D design in various industries, there is still a lack of empirical studies that clearly demonstrate its effectiveness compared to traditional methods. This work focuses on filling that gap by providing empirical evidence on how 3D design can improve advertising campaigns and strengthen the connection between the company and its consumers (6).

The use of 3D design in advertising is not a new trend, but its application in the context of advertising production is relatively recent. In recent years, studies have shown that 3D design has a positive impact on the effectiveness of advertising campaigns, as it is mentioned that “3D design allows a more realistic and detailed representation of products, which can increase consumer confidence” (p. 45). This is especially relevant for companies like Gloss Publineon that offer products that require detailed visualization so that consumers can appreciate their characteristics such as texture, finish, and material quality. The implementation of this technology in its advertising campaigns could facilitate a better emotional connection with consumers and generate a more significant visual impact (7).

In previous studies, it is argued that “3D design transforms the way consumers interact with advertisements, creating more immersive and memorable experiences” (p. 30) (8). This capacity of 3D design to help create more immersive visual experiences is crucial in the advertising world of the city of Ambato, where brands must capture the attention of consumers in an environment saturated with information (9). Companies that use 3D design not only benefit from a more attractive visual representation, but also manage to generate greater interaction with users, which can translate into greater audience retention and, therefore, greater success in their campaigns (10).

The present study is based on information processing theory, which suggests that consumers process visual information more effectively when it is presented in a detailed and realistic manner. The theory is supported by the Elaboration Likelihood

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Model (ELM), proposed by Petty and Cacioppo in 1986, which explains that complex visual stimuli such as those created through 3D design can lead to a deeper and more lasting processing of advertising information. This theory supports the idea that three-dimensional visual representations not only improve the aesthetics of advertisements but also facilitate a more effective processing of information, which in turn can influence consumers' purchasing decisions (11).

Unlike previous studies that have focused on abstract theories, this research focuses on a real and specific case within the advertising industry. By analyzing how Gloss Publineon has integrated 3D design into its advertising campaigns, the aim is to provide practical evidence on the effectiveness of this technology in the context of a real company. This approach allows obtaining valuable insights that can be used by other marketing and advertising professionals to improve their strategies and evaluate the adoption of new technologies in their own campaigns (12).

The present study focuses on evaluating the impact of 3D design on the effectiveness of Gloss Publineon's advertising campaigns, analyzing both the benefits and the challenges that this technology presents (13). Through this analysis, it is expected to provide a practical framework so that companies can understand how 3D design can be used effectively in their own advertising strategies, improving the perception of their products and generating a significant competitive advantage in the market (14).

This work is relevant not only for its focus on 3D design but also for its contribution to the understanding of how companies can use technology to improve their advertising campaigns (15). The research provides a solid foundation for future investigations on the use of 3D design in advertising and offers marketing and advertising professionals a practical framework to evaluate the effectiveness of their campaigns and make informed decisions about the adoption of new technologies (1).

RESULTS

For the results, surveys and interviews were applied that determined the following findings:

Table 1. Survey.

Question	Options	% Total	Key analysis and comments
1. Familiarity with 3D Animated Video Design	Very familiar	9.23%	There is a significant opportunity to educate respondents about animated 3D.
	Somewhat familiar	40%	This group can be converted into advocates of animated 3D through educational content.
	Little familiar	35.38%	Key segment for introductory educational strategies on the benefits of animated 3D.
	Not at all familiar	15.38%	Increasing the perception and knowledge of animated 3D in

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			advertising is crucial.
2. Effectiveness of 3D Animated Video Design compared to Traditional Advertising Resources	Very effective	47.69%	High acceptance, indicating that animated 3D is perceived as a powerful advertising tool.
	Somewhat effective	43.08%	The majority sees 3D as effective; successful campaigns can strengthen this perception.
	Little effective	4.62%	Low percentage, but they can benefit from more examples and effectiveness tests.
	Not effective	0%	Very few reject animated 3D as an advertising option.
3. Types of Products/Services Benefited	Technological and consumer products	–	3D is perceived as useful in technological and consumer sectors, which guides future strategies.
4. Main Advantages of 3D Animated Video Design in Advertising	Visual impact	–	Highlighted as the main advantage, key to capturing the viewer's attention.
5. Main Challenges or Limitations of Using Animated 3D	High costs	—	A significant challenge; companies should allocate an appropriate budget.
	Production time	—	Another key challenge to consider when planning 3D advertising campaigns.
	Technical complexity	—	Requires skilled personnel, which may represent a barrier for some organizations.
6. Customer Response to Animated 3D Video Campaigns	Very positive	44.62%	The predominant perception is positive; animated 3D generates favorable responses among most respondents.
	Positive	40%	High potential for audience acceptance.
	Neutral	12.31%	Represents an opportunity to educate audiences and generate greater enthusiasm.
7. Important Considerations When Using Animated 3D	Product relevance	—	A crucial factor: the product should align with the use of 3D to maximize effectiveness.

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 12-26.

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Video Design in Advertising			
	Campaign objectives	—	Clearly defining campaign objectives is essential to fully leverage the potential of animated 3D.
	Target audience sector	—	Aligning the campaign with the target audience is vital to ensure a positive response.
8. Tools Required to Implement Animated 3D Design in Advertising	Advanced 3D software	—	Specialized software and a competent graphic design team are required.
	Specialized technical team	—	Essential for ensuring the technical and aesthetic quality of the design.
9. Future Evolution of 3D Design in Advertising	Growing trend	69.23%	Most respondents perceive animated 3D as a growing trend, reinforcing its long-term potential.
	Stable trend	20%	Some respondents consider it an established resource within the advertising industry.
	Declining trend	6.15%	Very few believe that animated 3D is declining, suggesting that it will remain relevant.

Table 2. Interview

Question	Response	Interpretation and key comments
1. Experience or knowledge about the use of 3D design in advertising.	"I have seen 3D on social networks, but we have not used it in our company due to lack of personnel and knowledge".	Limited familiarity with 3D design. Growth potential if investment is made in specialized training and hiring.
2. Advantages of 3D design compared to traditional resources.	"3D can help better visualize products such as signs and LED lights, especially when clients do not understand how they will look".	Facilitates realistic visualization, which improves decision-making and the adoption of complex products.
3. Main challenges or limitations when using 3D design.	"Learning to handle the software and adapting it to our signage and printing area".	Learning curve and lack of experience in 3D design. Need for specific training and technical support.
4. Impact of 3D design on consumer	"3D design will attract more people and have a greater	3D design increases the visibility and attractiveness of

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perception	impact if done well".	products, improving public perception and attracting more clients.
5. Considerations when designing 3D elements for an advertising campaign.	"The design must be fundamental, and must align with the client's objectives. Sometimes less is more".	The design must be clear, effective, and aligned with communication objectives. Less visual saturation is often more.
6. Technical aspects or tools necessary to create 3D content.	"Design is the main factor. Tools are important, but design is key".	Design continues to be the most important. Adequate software and technical skills are required, but the focus must be on design quality.
7. Future evolution of 3D design in advertising.	"Technology, such as 3D printing, will eliminate limitations and allow personalization. 3D design will be fundamental in advertising".	Optimism about the future of 3D. It is expected to evolve with technological advances, such as personalization and creativity.
8. Recommendations to improve the integration of 3D design in advertising strategies.	"Incorporate an additional 3D service to complement our traditional approach. Use social networks to show 3D videos".	Integrating 3D as an additional service can be a good first step. Social networks are key to showing 3D content and increasing visibility.
9. Influence of 3D design on consumer behavior.	"It depends on the client and the type of product. Not everything in 3D has the same impact".	3D design can influence, but its effectiveness depends on the context and the target audience. Personalization is key.

Source: Interview conducted

The analysis of the collected data reflects a positive and growing perception of 3D animated video design as an innovative and effective advertising resource. Although only 9.23% of respondents consider themselves very familiar with 3D design, 40% are somewhat familiar and 35.38% indicate being little familiar. Regarding the effectiveness of 3D compared to traditional resources, a notable 47.69% consider it very effective and 43.08% somewhat effective, showing strong acceptance. The main challenges identified are high cost, production time, and technical complexity, which indicates the need to have specialized teams and planned budgets. Despite these challenges, client perception is highly positive: 44.62% consider it very positive and 40% positive, which indicates strong support from the target market. Regarding the future projection of 3D in advertising, 69.23% believe it is a growing trend, which confirms its long-term relevance.

Initial prototypes of animated videos were created using 3D design to integrate the company's products in tourist contexts of Ambato. These prototypes were

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fundamental to explore how the animated elements would interact with real environments, simulating scenarios where the products are presented in the city as a way to attract the local public and potential tourist clients (16).

Audiovisual content capture methods

For the capture of audiovisual content, recordings were made in key locations of Ambato. The objective was to maximize user interaction with the material, achieving an immersive experience (17). Both aerial and terrestrial recording techniques were used to generate a dynamic and diverse approach to the urban environments.

High-definition cameras: An iPhone 15 was used for terrestrial shots due to its high recording quality and advanced image stabilization. This allowed precise and high visual fidelity capture, suitable for the urban environments of Ambato.

Drone for aerial shots: A DJI Air 3 Fly drone was used to capture panoramic views and elevated angles of the city. The aerial shots provided an additional perspective, enriching the spatial perception of the video and contributing to a more immersive context.


Figure 1. Camera


Figure 2. Drone

Recording procedures

Multiple strategic locations in the city of Ambato were selected, considered of high visual value and attractiveness. The recording was coordinated with a specific approach to achieve a coherent visual narrative in both terrestrial and aerial shots in order to ensure continuity and fluency in the production.

Video editing and tracking

In the post-production phase, software was used to improve the quality of the content:

Davinci Resolve: Used for color correction, providing a professional finish through a node structure. This software allowed adjusting the color and contrast of the recordings to make them more visually attractive.

Adobe After Effects: For tracking and animation of 3D objects, motion tracking was used to follow the movement of objects within the video, allowing the integration of 3D models coherently with the original shots.

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Figure 3. Editing and Tracking

3D modeling and texturing of products

The Blender software was used to model and texture the products that would be animated in the video. Detailed 3D models of products such as solvent inks, decorative bolts, acrylics, and advertising banners were created, which were incorporated into the recorded content, providing a fluid visual integration with the recorded environment.

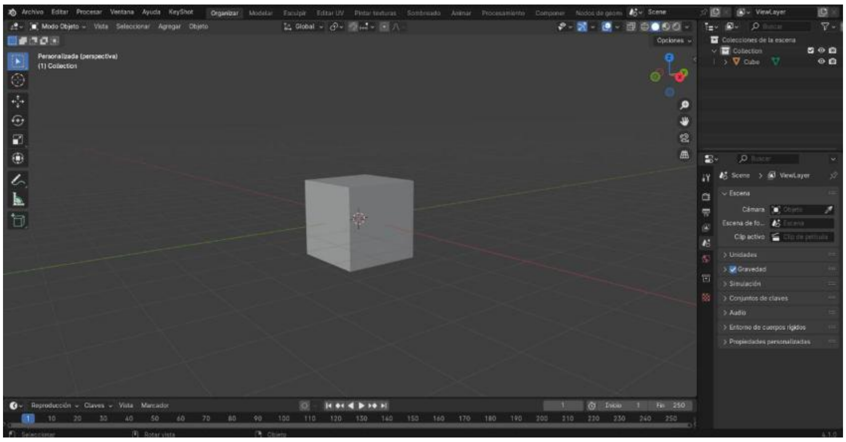

Figure 4. Modeling

Integration of videos and 3D models

The use of .json scripts was employed to facilitate data transfer between After Effects and Blender. The process involved motion tracking in After Effects, the creation of solids with camera, and the export of data for subsequent import into Blender, where the 3D objects were adjusted to the video shots, ensuring that camera movements and models were precisely aligned.

Animation of 3D Objects in Blender

Once the 3D objects were integrated, they were animated using keyframes, adjusting their movement to simulate natural interactions with the environment. The animations were refined to improve fluidity and coherence with the video.

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Rendering and final export

Rendering was performed using Blender's Cycles engine, which offers high-quality graphic processing allowing a realistic finish in the animations. The output was configured in 1080x1920 resolution at 30 fps, in .mov format to guarantee high visual quality in a size optimized for dissemination on social networks.

Prototype evaluation

The prototypes were evaluated by experts in graphic design, advertising, and 3D animation. The evaluation was carried out through a detailed rating that broke down different performance criteria such as scene quality, animations, product modeling, visual cohesion, and the use of shadows and lighting.

Evaluation results

The overall results were positive with a total score of 26 out of 28 in a global evaluation. The most outstanding aspects were visual cohesion and the integration of 3D products, while areas for improvement were identified in the animations, the quality of shadows and lighting, and the transition between scenes.

Animations: Although the animations were good, it was suggested to improve fluidity and eliminate visible errors to increase naturalness in the movements.

Shadows and Lighting: Some experts suggested adjustments in the implementation of shadows and lighting to improve the realism of the scenes.

Transitions between scenes: Opportunities were identified to improve fluidity and continuity between the different scenes of the video, optimizing the visual narrative.

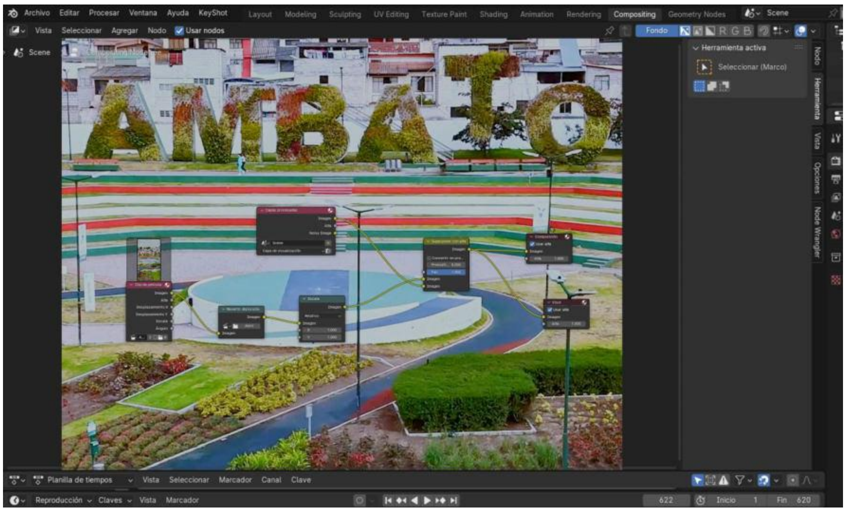

Figure 5. Test video

DISCUSSION

The evaluation of the 3D animated video developed for Gloss Publineon, a company located in the city of Ambato, evidences a deep analysis of key technical and creative aspects, such as content quality, animation effectiveness, coherence with brand identity, as well as the use of shadows, lighting, and modeling. The results obtained in

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the expert evaluations were, in general, positive, although they also revealed areas susceptible to improvement to reach a higher standard of visual quality.

One of the most relevant aspects observed was the quality of the animations. Although the majority of experts agreed that these were fluid and realistic (18), some pointed out unnatural movements. This observation is consistent with what is stated by (19), who highlights that the credibility of the animated environment depends largely on the naturalness of the movement, a key aspect to achieve spectator immersion. The lack of fluidity in the animation can negatively affect the perception of the product (9), especially in advertising contexts where immediate visual connection is crucial.

Product modeling obtained ratings that ranged between 3 and 4 points. Some experts highlighted deficiencies in the detailed representation of certain objects, which underscores the need for greater precision in textures (3), proportions, and finishes. This observation aligns with the findings of (20), who argue that hyperrealism in 3D modeling significantly increases the degree of acceptance of animated content in non-technical audiences.

Regarding the use of shadows and lighting, the results were varied. Although their contribution to the realism of the scenes was recognized, inconsistencies in their application were also identified. Specialized literature, as indicated by (21) and (22), emphasizes that correct lighting in three-dimensional environments is a determining factor to achieve depth and spatial coherence, directly affecting the perception of the environment and the product.

Visual cohesion was valued positively, especially for its capacity to integrate with the company's visual identity. This is consistent with studies such as those of (23), who highlights that a coherent visual identity reinforces brand recall and improves the emotional connection with the consumer. Some reviewers pointed out the need to incorporate more innovative proposals in visual composition, which suggests that although coherence was achieved, there is still room to increase creativity and differentiation.

Attention to detail was appreciated, but small oversights were identified that affected the overall perception of the video. This reinforces what is stated by (24), (25), who affirm that professional quality in visual content is achieved not only through major technical successes but also through meticulous care of each visual component, from modeling to post-production.

CONCLUSIONS

The conclusions obtained in this research are directly aligned with the main objective of the study, which was to analyze how 3D design can be used effectively in Gloss Publineon's advertising campaigns and evaluate its impact on consumer perception and brand performance. The evaluation carried out by experts revealed that the use of 3D modeling and animation represents an advertising tool with high potential, capable of generating an immersive visual experience, coherent with the brand identity and attractive to the target audience.

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The findings make it possible to evidence that 3D design not only improves the visual presentation of products but also contributes to strengthening the relationship between the brand and the consumer, by facilitating a more dynamic and emotional communication. This result supports the proposal to design a positioning advertising strategy based on 3D modeling techniques that will allow Gloss Publineon to differentiate itself within the local market of Ambato, increase its visibility, and project an innovative image.

The study demonstrates that, if aspects such as the naturalness of animations, the realism of modeling, and visual cohesion are adequately addressed, 3D design can become a key strategic resource to enhance the impact and effectiveness of the company's advertising campaigns, thus fulfilling the objectives set out in the research.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.27-50

DOI:
https://doi.org/10.56519/bp3eny18
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FOMENTO DEL CUMPLIMIENTO TRIBUTARIO VOLUNTARIO: UN MODELO INTEGRAL BASADO EN TRANSPARENCIA, INCENTIVOS CONDUCTUALES Y SIMPLIFICACIÓN ADMINISTRATIVA

ENCOURAGING VOLUNTARY TAX COMPLIANCE: A COMPREHENSIVE MODEL BASED ON TRANSPARENCY, BEHAVIORAL INCENTIVES AND ADMINISTRATIVE SIMPLIFICATION

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Fecha de recepción: 16/07/2025 / Fecha de aceptación: 28/07/2025 / Fecha de publicación: 20/08/2025

RESUMEN: El objetivo del presente estudio es el de analizar la manera en cómo la transparencia institucional, los incentivos conductuales y la simplificación administración inciden en el cumplimiento tributario voluntario en Ecuador, tomando en cuenta la importancia de los factores mencionados en el fortalecimiento del sistema fiscal. La metodología empleada incluyó un enfoque metodológico mixto, con un diseño no experimental y de alcance correlacional, los datos empleados fueron de tipo cuantitativos y cualitativos que permitió un mejor análisis del problema de investigación. La recolección de la información se realizó mediante la aplicación de encuestas estructuradas que fueron realizadas a los contribuyentes, también fueron dirigidas entrevistas semiestructuradas a expertos fiscales de la provincia de El Oro. Los resultados obtenidos demuestran que, en variables como percepción de la justicia fiscal, la facilidad en los procesos tributarios y la efectividad de las campañas informativas llegan a ejercer influencia de forma positiva, aunque moderada, en la disposición que tienen los contribuyentes a cumplir de forma voluntaria con sus obligaciones tributarias. Se llega a determinar que los contribuyentes valoran de forma positiva la claridad que tiene la normativa, la reducción de trámites que podrían ser innecesarios y la existencia de información accesible y oportuna. Sin embargo. La investigación realizada evidencia un hecho muy importante, que es la percepción de que gran parte de los contribuyentes no cumplen con sus obligaciones tributarias y no existen consecuencias por eso, lo cual conduce a desmotivar y perder la confianza en el sistema tributario. En este contexto, se propone analizar y evaluar con una mayor precisión el impacto que tienen el tipo de intervenciones conductuales, así como también extender similares estudios al presentado a otras provincias y a diferentes segmentos de contribuyentes, con el propósito de diseñar políticas públicas que resulten de mayor efectividad y contextualizadas a la realidad.

Palabras clave: Transparencia fiscal, moral tributaria, incentivos no coercitivos, cultura de cumplimiento, gestión pública, simplificación de trámites

ABSTRACT: The objective of this study is to analyze how institutional transparency, behavioral incentives, and administrative simplification impact voluntary tax compliance in Ecuador, taking into account the importance of the aforementioned factors in strengthening the tax system. The methodology used included a mixed methodological approach, with a non-experimental design and correlational scope. The data used were both quantitative and qualitative, allowing for a more thorough

ISSN:
3091-1796
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https://doi.org/10.56519/bp3eny18
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analysis of the research problem. Data were collected through structured surveys conducted with taxpayers, and semi-structured interviews were also conducted with tax experts in the province of El Oro. The results obtained demonstrate that variables such as perceptions of tax justice, ease of tax processes, and the effectiveness of information campaigns exert a positive, albeit moderate, influence on taxpayers' willingness to voluntarily comply with their tax obligations. It was determined that taxpayers positively value the clarity of the regulations, the reduction of potentially unnecessary procedures, and the availability of accessible and timely information. However, the research conducted reveals a very important fact: the perception that a large proportion of taxpayers do not comply with their tax obligations and face no consequences, which leads to demotivation and a loss of confidence in the tax system. In this context, it is proposed to more precisely analyze and evaluate the impact of behavioral interventions, as well as to extend similar studies to the one presented to other provinces and different taxpayer segments, with the aim of designing public policies that are more effective and contextualized to reality.

Keywords: Fiscal transparency, tax morality, non-coercive incentives, compliance culture, public management, simplification of procedures

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INTRODUCTION

Currently, all countries face great pressure to finance the services available to their citizens, including health, education, infrastructure, and social security. This need has driven interest in having tax systems that are more efficient, equitable, and sustainable. Although actions have already been taken in many countries, tax evasion, economic informality, and high levels of distrust in public sector institutions continue, which become obstacles to achieving the efficiency and effectiveness of the tax system.

To achieve a better tax system, there are many strategies, but it is important that these are not only coercive or punitive. Therefore, it becomes essential to have strategies that motivate taxpayers to fulfill their tax obligations, and that this is done voluntarily. The Organisation for Economic Co-operation and Development (1) mentions that in scenarios where the demand for public resources stands out, actions prioritized in fiscalization may not be adequate. Therefore, achieving high voluntary tax compliance is an important challenge for tax administrations, mainly where the presence of evasion, highly complex regulations, and the absence of institutional trust is evident.

Tax evasion, intentional omissions, and economic informality have become major obstacles that minimize the capacity that a State can have to achieve the collection of its revenues in a more equitable and sustainable manner (2), (3). It is important to emphasize that this type of practices, in addition to decreasing the availability of public resources, negatively affect what citizens perceive about the legality of the system and the use of public spending.

ISSN:
3091-1796
Vol. 3, No. 6, PP.27-50

DOI:
https://doi.org/10.56519/bp3eny18
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To face this situation, from this study an integral model is proposed that contributes to improving voluntary tax compliance, for which the use of three axes is proposed: institutional transparency, behavioral incentives, and administrative simplification. Various authors have mentioned that transparency in public administration is important for the incentive of voluntary compliance. Thus, the theory is supported that citizens estimate that those resources that are used with equity, efficiency, and responsibility increase their disposition to voluntarily comply with their obligations (4), (5).

It is also mentioned that from a public administration that exercises its functions in a transparent and responsible manner, it contributes to motivating the compliance of their obligations voluntarily by taxpayers and decreases the possibilities of tax evasion (6). Thus, it can be affirmed that the legality of the tax system is closely related to transparency in the management of public resources.

Some authors assure that a transparent tax administration helps to legitimize the legality of the tax system and lead citizens to have a greater predisposition to compliance (7). This affirmation is considered correct because it is considered that the efficient and fair use of taxes allows strengthening trust in the institutions and fosters a tax culture that has its support in cooperation (8).

It is also considered necessary to analyze the perception of justice in the application of the norms, which also become necessary factors for the incentive of tax compliance. These elements come to have a direct impact on the decisions that citizens make (9); while having a responsible, transparent, and equitable public administration strengthens the commitment of taxpayers (10). On the other hand, the perception of a corrupt system, diversions in benefits, and unequal treatment decreases tax commitment and promotes evasion (11).

Regarding behavioral approaches, these have developed and evolved as necessary tools to motivate compliance with tax obligations. Considering behavioral theory, these approaches seek to establish scenarios that positively influence fiscal behavior, not only in specific aspects, but also by strengthening the relationship between the State and the citizen taxpayers (12). By focusing on aspects such as institutional trust, equity, and the sense of belonging, implementing these strategies contributes to considering more important causes such as evasion.

Considering that there are various factors that can influence the behavior of taxpayers in a determining way, some investigations have estimated the need for the use of nudges or also known as behavioral interventions, through which it is sought to promote tax compliance without the need for the use of sanctions. As strategies to fulfill this aspect, the simplification of tax forms, the sending of reminders with the due date of obligations, the effective communication of the benefits of paying taxes are mentioned, which have evidenced being highly effective (13), (14). Nudges are defined as tools of efficiency in strengthening the relationship between the tax administration and taxpayers, which also promotes a culture of compliance that has as its support co-responsibility.

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DOI:
https://doi.org/10.56519/bp3eny18
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At the same time, administrative simplification is presented as an indispensable factor in the reduction of the barriers that prevent tax compliance. In this sense, the elimination of procedures that can represent great complexity for the taxpayer, in addition to the improvement in institutional management, not only improve the operational aspect, but also strengthen the perception of legality and accessibility on the part of taxpayers.

In Ecuador, the strengthening of the tax system and voluntary tax compliance are critical areas to address. Regarding tax compliance, it faces several limitations due to the high percentage of economic informality, the scarce tax culture, corruption, and the distrust of institutionalism that taxpayers have. Despite the work carried out by the Internal Revenue Service (SRI) to improve management and facilitate compliance, tax evasion still remains, which is common to identify in sectors such as informal commerce, the free exercise of the profession, and micro and small enterprises (15).

According to data published by the Central Bank of Ecuador (16) and the Internal Revenue Service (17), the evasion of taxes such as VAT and Income Tax has a significant percentage within the GDP; in this way, the Ecuadorian State sees its financing capacity reduced, neglecting key aspects such as the offer of public services. Another situation that aggravates what has already been presented is the perception of corruption on the part of the citizenry, regarding a misuse of public resources, which demotivates tax compliance. Therefore, given the above, it is fundamental to analyze compliance strategies, and that these stop being focused solely on sanctions toward the taxpayer.

MATERIALS AND METHODS

The present research takes a mixed methodological approach, that is, it refers to those techniques of quantitative and qualitative type, whose purpose is to achieve better visibility of the research problem, in this case, tax compliance in Ecuador. From the quantitative aspect, the possible relationship between the variables institutional transparency, behavioral incentives, and administrative simplification is studied statistically. While from the qualitative aspect, it seeks to address from a more practical aspect the perceptions, limitations, and motivations that influence the tax behavior of citizens.

A correlational and propositional methodology is also applied; that is, it seeks to determine the degree of association between the factors already mentioned and tax compliance; while the propositional aspect proposes an integral model that has been used as a basis for those future strategies in the field of Ecuadorian fiscal policy.

The design adopted is non-experimental, cross-sectional, and of explanatory type, since variables are not manipulated, but are observed as they occur in their natural environment, at a determined moment in time (18). The unit of study is composed of taxpayers registered in the Internal Revenue Service (SRI), including natural and legal persons belonging to the RIMPE regime and the general regime, in the province of El Oro.

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Regarding the population, object of study, this is composed of the taxpayers who were active between the years 2022 and 2024; for more precision, a convenience sampling was carried out, according to (19), this type of sampling is based on the accessibility to the participants. In this way, the researcher can arbitrarily determine the number of participants and the characteristics of the people who make up the sample. This methodological technique was chosen due to the nature of the study and the need to obtain the information directly from the main stakeholders.

As inclusion criteria for the participants, those taxpayers who carried out their declarations in at least one of the last fiscal years were chosen. On the other hand, taxpayers with definitive closure processes or with legal causes related to tax evasion were excluded.

Once the population and the sample of the study were determined, the collection of information was carried out; in this way, as a first activity, surveys were applied to the selected taxpayers; the questionnaire was structured under a Likert scale, in areas such as: Institutional transparency, tax incentives, ease of the tax system, and voluntary compliance. Complementarily, a documentary analysis was carried out, where information from the SRI, OECD, and scientific articles on tax compliance was studied.

The instruments that were used include a questionnaire and a documentary analysis sheet. In all cases, prior informed consent was applied, ensuring the confidentiality of the data, voluntary participation, and the academic use of the information, in accordance with the ethical principles of research in social sciences (20). This documentary analysis allowed defining the study variables; thus, as dependent variable there is voluntary tax compliance, which is defined as the disposition that the taxpayer has to spontaneously comply with the tax system. Regarding the independent variables, it was determined that they are: institutional transparency, behavioral incentives, and administrative simplification.

Table 1. Study variables.

Variable	Type	Operational definition
Voluntary tax compliance	Dependent	Degree to which the taxpayer complies with their obligations without coercive intervention.
Institutional transparency	Independent	Perception about the clarity and efficiency of the use of fiscal resources by the State.
Behavioral incentives	Independent	Use of non-coercive strategies (messages, reminders, recognitions) to promote compliance.
Administrative simplification	Independent	Ease, clarity, and accessibility of the tax processes for the taxpayer.

Note: The dependent variable measures the level of spontaneous compliance of the taxpayer; the independent ones represent institutional, behavioral, and administrative factors that can influence said conduct.

The analysis of the quantitative data was carried out using the SPSS software. Descriptive statistics were applied to characterize the sample, normality test, correlation test, and multiple linear regression to establish the effect of the independent variables on voluntary tax compliance. The qualitative data obtained from the interviews were analyzed through thematic coding and content categorization (21).

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RESULTS

During the period 2023-2024, in Ecuador an evident increase was perceived regarding collection; for the year 2024 it reached a total of USD 20,131 million, which means an increase of 15.6% compared to the collection of the previous year, representing a compliance of 104.8% with the established goal (17). It is estimated that the mentioned collection was motivated by reforms such as the increase in the rate of the Value Added Tax (VAT) and the Currency Exit Tax (ISD).

The information presented in Table 2 demonstrates the relative variation of collection by tax in the period 2023-2024. The results evidence the variation that each analyzed tax has presented, with Income Tax and VAT being those that present significant variations.

Table 2. Variation in collection by tax.

Tax	Collection 2023 (million USD)	Collection 2024 (million USD)	Absolute variation (million USD)	Relative variation (%)
Income Tax	5,818	6,639	821	14.11
VAT	8,444	9,767	1,323	15.67
ICE	827	755	-72	-8.71
ISD	1,088	1,272	184	16.91
Other incomes	1,243	904	-339	-27.27

Note: Adapted from the Internal Revenue Service (2024).

As shown in Table 2, VAT presents the greatest increase in absolute value with USD 1,323 million, which represents a relative variation of 15.67%. This fact is directly attributable to the increase of this tax that went from 12% to 15% starting in April 2024, and whose impact is observed more prominently from the second quarter.

In second place, with greater increase, is the collection of Income Tax, with USD 821 million more than in the year 2023, whose variation is at 14.11%. It is estimated that this increase in the collection of this tax has as its origin the mandatory self-withholding for the largest taxpayers; another aspect that influenced was the application of the tax remission in the first six months of the year 2024.

The Currency Exit Tax (ISD) also evidences an increase, where it presents a relative variation of 16.91% and a collection that amounts to USD 184 million. It is estimated that this increase has as its origin the increase of the rate up to 5% that was carried out in the first quarter of 2024. On the other hand, among the taxes that evidenced a reduction is the Special Consumption Tax (ICE) with USD 72 million, which represents a variation of 8.71%. It is analyzed that this decrease is due to the decrease in imports, also to the increase in the national production of substitute products for imports.

Finally, in the group of other incomes, it was the one that experienced the greatest decrease in absolute and relative values, thus decreasing by USD 339 million, its variation being 27.27%. It is estimated that this decrease responds to a lower generation of incomes, fewer special taxpayers, and fewer fiscal regularizations, which means a transformation toward a financing model with greater sustainability.

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Table 3. Statistical analysis by main provinces.

Province	Collection 2023 (Million USD)	Collection 2024 (Million USD)	Absolute variation (Million USD)	Relative variation (%)
Pichincha	8,740	10,192	1,452	16.61
Guayas	5,265	6,229	964	18.31
Azuay	867	939	72	8.30
Manabí	343	399	56	16.31
El Oro	284	292	8	2.82

Note: Adapted from the Internal Revenue Service (2024).

Regarding the analysis carried out by provinces, in Table 3 a positive behavior can be observed between the years 2023 and 2024. The provinces that lead the collection are Pichincha and Guayas, with relative growths of 16.6% and 18.3%. This situation can be a consequence of these provinces having a high number of taxpayers.

In the provinces of Azuay and Manabí an important percentage of participation was also evidenced, presenting a relative variation of 8.3% and 16.1% respectively. These results are key to establishing that in these provinces the levels of tax compliance increased. In the last place of the table, the province of El Oro can be observed, in which a growth of around 3.1% was established, so the collection increased, going from USD 284 million in the year 2023 to USD 292 million in 2024. At first glance these results could be interpreted as positive; the comparisons observed in Table 3 place it in the last place with respect to the other provinces.

On the other hand, the results that were obtained from the surveys carried out in the province of El Oro, whose population currently amounts to 714,592 inhabitants, the information was obtained from 385 people, a sample that was obtained from the formula for finite populations and selected from a convenience sampling. This type of sampling refers to the fact that the participants were selected according to the disposition presented to collaborate in the research, contributing to the data being more accessible, although it is important to mention the limitations regarding its statistical representativeness.

As mentioned by Hernández (2021), convenience sampling contributes to the ease of access to the participants of the investigations, which leads the researcher to be able to determine, arbitrarily, the number of people and the characteristics that they must evidence. For the present study, the target population was composed of those taxpayers duly registered in the Internal Revenue Service (SRI), where both natural and legal persons belonging to the RIMPE regime (Tax Regime for Microenterprises) and the general regime, domiciled in the province of El Oro, were included.

The selection of the participants was carried out in commercial zones, offices, and in tax attention centers. Basic inclusion criteria were also applied such as having a valid Unique Taxpayer Registry (RUC) and having been active in the 2024 fiscal year. The results obtained in the survey are presented in Table 4.

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Table 4. Variables with greater statistical representation.

Variable	Mean	Standard deviation	Median
1. Compliance: Perception of non-compliance	3.14	1.477	3.0
2. Incentives: Awareness campaigns	3.09	1.433	3.0
3. Simplification: Ease of the process	3.05	1.410	3.0
4. Compliance: Voluntariness without sanction	3.05	1.402	3.0
5. Transparency: Clarity of the use of taxes	3.02	1.428	3.0

Note: The data reflect the average values and dispersion for the main perceptions collected in the survey applied to taxpayers.

As can be observed in Table 4, the five variables with greater representativeness of the questionnaire carried out to the participants are presented, which were evaluated through statistical tests such as mean, standard deviation, and median. These variables reflect perceptions that are very important for determining tax compliance.

The variable "Perception of non-compliance" is the one that presents the highest mean with 3.14, which can be interpreted as the fact that the citizen perception that several taxpayers are not complying with their fiscal obligations can cause individual demotivation. On the other hand, the variable "Awareness campaigns" with a mean of 3.09 evidences a moderate acceptance of its influence.

While the variables "Ease of the process" and "Voluntariness without sanction" obtain a mean of 3.05 each. Finally, the variable "Clarity in the use of taxes" reached a mean of 3.02, demonstrating the existence of ambiguous perceptions regarding state transparency in the use of public resources. Among the results of the study, normality tests, correlation, and a multiple linear regression model were also carried out, with the objective of evaluating the relationship and the effect that the independent variables have with respect to compliance with their fiscal obligations without coercion.

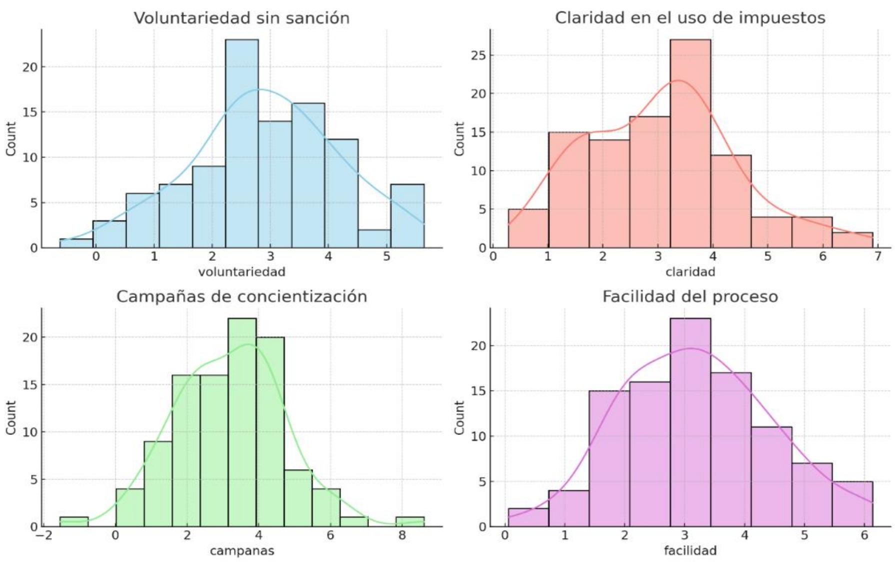

Figure 1. Distributions presented by the independent and dependent variables. Model of voluntary tax compliance.

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 27-50.

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Note: The figures presented show the distribution of the responses that were obtained in the analysis of each of the variables that form part of the model.

In Figure 1 the histograms with density curve for each of the variables that form part of the regression model are observed. As is evidenced in each of the variables, the distribution is very close to symmetry, indicator of normality, which is necessary to be able to carry out the symmetric tests. Many of the responses obtained are concentrated around the mean value of the scale, that is between 2.5 and 4, although the presence of dispersion is also evident.

It is necessary to emphasize that extreme asymmetries or marked outliers are not observed; therefore, it could be established that there is an adequate quality of the data collected to continue with the statistical analysis. In addition to the histograms with density curves, the Omnibus and Jarque-Bera normality tests were applied, whose results confirmed that the analyzed variables present an approximately normal distribution ($p > 0.05$ in all cases), which supports the validity of the use of parametric tests such as Pearson and multiple linear regression.

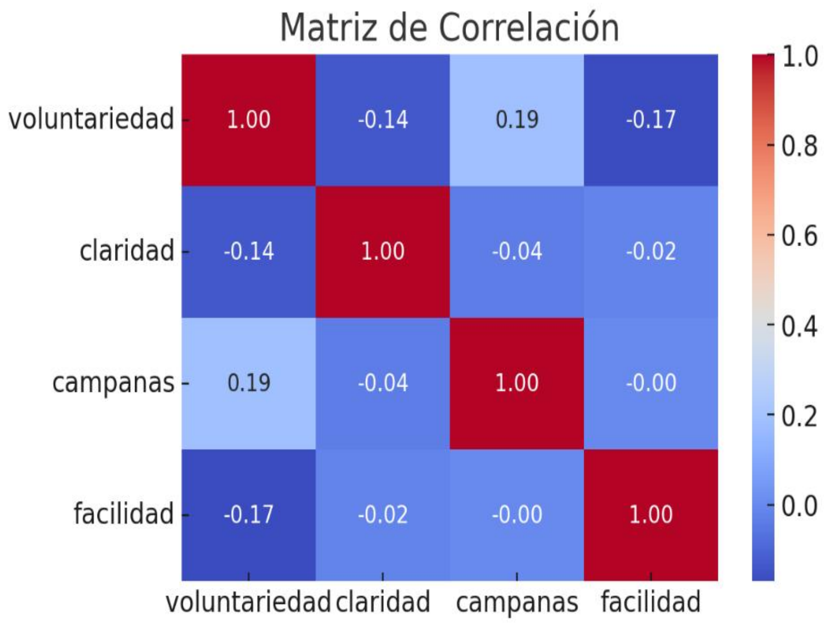

Figure 2. Correlation matrix between the variables of the voluntary tax compliance model.

Note: The matrix demonstrates the linear relationships that have low significance. The correlation with greater influence is found between awareness campaigns and voluntary compliance with r = 0.19.

To carry out the analysis of the relationships that are presented between the variables of the model, a correlation matrix was carried out, making use of the Pearson coefficient. This model was chosen because the quantitative variables evidenced an approximately normal distribution, as was visualized in the histograms with density curves exposed in Figure 1.

While Figure 2 contributes to visualizing the intensity and direction of the relationships between the variables present in the model. In this sense, the values that are visualized in the matrix put into evidence the degree of association between the pairs of variables; the instrument employed was a chromatic scale that allowed a better

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interpretation of the results. The values that are signaled with the color red demonstrate the existence of higher and positive correlations; on the other hand, the blue color tones indicate negative and weak relationships.

Table 5. Regression results.

Note: The dependent variable is voluntary tax compliance. The model is significant at the global level ($p < 0.05$), although no individual variable reaches statistical significance at 5%.

The multiple linear regression analysis sought to establish voluntary tax compliance through transparency in the use of what is collected by taxes, awareness campaigns, and the ease that can be presented in the process, for which the applied model was a multiple linear regression by ordinary least squares:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$

Where:

Y: Voluntary tax compliance

X_1: Clarity in the use of taxes (institutional transparency)

X_2: Awareness campaigns (behavioral incentives)

X_3: Ease of the process (administrative simplification)

β_0: Intercept

β_1, β_2, β_3: Regression coefficients

ε: Error term

Where the model was statistically significant ($p = 0.039$) and explained 8.3% of the variability of the dependent variable ($R^2 = 0.083$).

Awareness campaigns demonstrated a positive influence close to significance ($p = 0.060$); on the other hand, the ease of the process evidences a marginally significant negative effect ($p = 0.081$). Clarity in the use of taxes did not result significant. The fulfillment of the assumptions is considered a support regarding its validity, although the effects that were observed establish the need to carry out additional studies that allow confirming the influence that each factor may come to have.

Although the results obtained offer valuable information to understand as a whole the institutional, behavioral, and administrative factors that explain tax compliance; the analyzed variables do not evidence statistical significance individually within $p < 0.05$, their contribution as a set of variables is significant and offering the opportunity to deepen in future lines of research.

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```
                            OLS Regression Results
==============================================================================
Dep. Variable:          voluntariedad   R-squared:                       0.083
Model:                            OLS   Adj. R-squared:                  0.054
Method:                 Least Squares   F-statistic:                     2.894
Date:                Mon, 16 Jun 2025   Prob (F-statistic):             0.0392
Time:                        01:56:05   Log-Likelihood:                -161.22
No. Observations:                 100   AIC:                             330.4
Df Residuals:                      96   BIC:                             340.9
Df Model:                           3
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          3.3619      0.519      6.483      0.000       2.332       4.391
claridad      -0.1240      0.091     -1.356      0.178      -0.306       0.058
campanas       0.1524      0.080      1.901      0.060      -0.007       0.311
facilidad     -0.1762      0.100     -1.765      0.081      -0.374       0.022
==============================================================================
Omnibus:                        0.202   Durbin-Watson:                   2.030
Prob(Omnibus):                  0.904   Jarque-Bera (JB):                0.272
Skew:                           0.103   Prob(JB):                        0.873
Kurtosis:                       2.850   Cond. No.                         24.2
==============================================================================
```

Figure 3. Residuals plot of the multiple linear regression model.

Note: The figure shows a homogeneous distribution of the residuals around zero, without evidence of systematic patterns.

In Figure 3 the relationship between the adjusted values of the regression model and the residuals that were obtained is evidenced. The red line allows observing the possible deviations from the expected pattern. The validity of the model is demonstrated due to the stability in the variance of the errors and not recognizing structures that insinuate adjustment problems. In this context, the validity of the estimated model is strengthened.

The results evidence that the considered variables come to fulfill the normality assumption, so it is possible to employ parametric techniques, among which are Pearson correlation and multiple linear regression. It is precise to indicate that the correlation matrix evidenced that linear associations that were not so strong remained, while a moderate positive relationship was also observed between the variables "awareness campaign" and "voluntary compliance" with $r = 0.19$. The regression model presented itself statistically significant ($p = 0.039$) and it was possible to explain 8.3% of the variability of the tax behavior, which in the joint analysis of the model is moderate, but of relevance. Regarding the variables, the one that presented with potential to exercise greater influence was "awareness campaigns," with a marginal significance of $p = 0.060$.

TRIS Model for the improvement of voluntary tax compliance in Ecuador: A strategy based on transparency, incentives, and simplification

Tax compliance should not be considered as a response of citizens before the threat of receiving sanctions, but should be considered as a situation that depends on various factors, whether these of institutional, behavioral, or operational type. Under this perspective the TRIS model is composed of three basic axes:

1) Institutional transparency; 2) Behavioral incentives and 3) Administrative simplification. From this model, it is expected to demonstrate the relationship

ISSN:
3091-1796
Vol. 3, No. 6, PP.27-50

DOI:
https://doi.org/10.56519/bp3eny18
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between them and the capacity that they may have to achieve a tax system that is fair, equitable, and sustainable.

1. Institutional transparency

Institutional transparency is a basic component to reinforce the fiscal parameters, defined as the reciprocal agreement between the State and the citizens, in relation to the collection of taxes and the supply of public goods. Distrust in the institutions and the perceived levels of corruption seem to lead people to see taxes as an illegitimate burden, which in turn weakens tax morale and the general will to comply with their taxes. On the contrary, if the public administration assumes in a transparent manner the responsibility for the public resources and communicates well the use of these resources, it improves the integrity of the fiscal system and fosters that people pay their taxes (22).

The open government model as a new political design with principles to act, which bets on transparency and collaboration between the institutions, allows the population to approach the way in which fiscal management is carried out. The presence of available and detailed updated information on public incomes and expenses, and the social audit of projects and mechanisms of citizen participation in budgetary control increase the perception of fiscal justice. Taxpayers are more prone to comply with their taxes if they perceive that the public resources are managed in an effective, fair manner and without favoritism (23).

In Ecuador, the creation of portals that allow knowing the management of the institutions mainly of the Internal Revenue Service (SRI) and of the Ministry of Economy and Finance stands out as an important decision, although the problems regarding accessibility to the portals, communication, and digital and fiscal literacy continues being an aspect at the institutional level.

The data obtained from the SRI indicate that the cantons of the province of El Oro, with more relevant public investment are Machala and Santa Rosa, while the other cantons are found below the average of the province (17). This information, in a certain way, communicates that citizens react positively when they feel that their taxes are returned in the form of public services, which improves their lifestyle by having public infrastructure, basic services, the implementation of social projects, among others.

In the same way, the participatory budget and the public hearings fostered by the lower levels of the autonomous governments can be a complementary system to increase transparency in the use of public resources. That will not only equalize the collection of incomes of the fiscal management and the level of the citizen as an active actor in the circle of public management, but also distinguishes the principle of fiscal co-responsibility (24).

2. Behavioral incentives

In line with the theory of behavioral economics, the use of non-coercive tools, such as personal reminders, messages that appeal to the social norm or symbolic recognitions, could foster the voluntary compliance of taxes (25). In contrast with the conventional

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https://doi.org/10.56519/bp3eny18
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approaches centered on sanctions or direct economic incentives, the behavioral interventions operate through psychological and social pathways that affect the decisions of people.

The success of the strategies already mentioned has been demonstrated in various scenarios at the institutional level. Countries such as the United Kingdom, Peru, and Argentina have demonstrated positive results regarding tax compliance, where a growth of the tax collection between 4% and 10% is observed (26). The results obtained by these countries evidence that taxpayers are not only motivated before the sanctions for non-compliance, but also positive results are observed with a better communication of the norms and the tax benefits and the reciprocity that they receive from the tax system.

In scenarios where trust in the State is not high and where the tax culture presents itself with limitations, the behavioral incentives take great importance. Some authors affirm that the behavioral incentives can be contextualized to the socio-cultural environment, reinforced with messages that incentivize voluntary compliance (27). Moreover, it is estimated that when the tax authority remits the information in a clear manner toward where their taxes are directed, their disposition to exercise their obligations on time is seen increased.

In Ecuador, this type of initiatives are carried out by the Internal Revenue Service in the period 2022 and 2023, they took into consideration the diffusion of motivational messages, making use of a positive language, making the messages very visual on their digital platforms for the compliance of the fiscal obligations.

3. Administrative simplification

A tax administration that is accessible, transparent, and intelligible enjoys a substantial reduction of the compliance costs, particularly for the taxpayers who experience technical limitations, have minimal digital knowledge, or are economically restricted. In this sense, the simplification of the administration not only improves voluntariness, but is also an instrument of fiscal inclusion, since it reduces the structural obstacles that prevent small taxpayers, informal workers, and new entrepreneurs from participating in the formal tax structure (28).

The simplification of the tax procedures from the point of view of the user means, for example, that the procedures are computerized, the forms are simplified, and irrelevant documentation is dispensed with. An initiative of cost saving like this has an impact on the perception of equity and professionalism within the headquarters.

Recent studies have demonstrated that a positive experience in the interactions with the tax administration can influence directly the disposition of the taxpayers to declare and pay taxes, especially in simplified systems (29). In the country, the Internal Revenue Service has taken actions to simplify the tax processes and make them much more understandable for the citizens. In addition, financial and technological literacy campaigns have been implemented (30). It is expected that with these strategies the errors and omissions are reduced, in addition to motivating the citizens to comply with their obligations on time and in a voluntary manner.

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Applicability of the TRIS model

It is important that the adoption of the TRIS Model is carried out in a progressive and collective manner, being carried out in three stages: diagnosis, pilot intervention, and then expanded at the national level. Upon being implemented in this order the local appropriation, the gradual implementation, its evaluation, the validity of the results obtained, and its sustainability in the long term are assured. From the diagnosis it is intended to identify the barriers for tax compliance, which requires a methodology focused on the statistical and qualitative, for better precision, it must be carried out by sector and region, seeking to characterize the fiscal risk profiles and how to generate greater trust in the tax system (31).

The pilot process must prioritize the implementation of the model in territories that demonstrate typical conditions and operative capacity in different types of institutions. The action must be implemented jointly by the Internal Revenue Service (SRI), the decentralized autonomous governments (GADs), business organizations, and civil society. This multilevel governance could lead to a more socially acceptable and legitimized implementation.

For the three dimensions of the TRIS Model there are respective indicators to evaluate them. Regarding transparency, one can consider measuring the level of transparency of the citizens in the use of the taxes, that is, how much the citizens know about how their taxes are used and how fair they perceive that the public investment is, since it has been found that this is a strong determinant of tax compliance (22).

Regarding the behavioral incentives, the indicators are the response rates to messages that are not coercive, the number of times that interactive content is experienced, and the impact of the comparison of the respective response in terms of compliance in treatment and control. For the simplification: average declaration times, reduction of formal errors, user satisfaction with the fiscal exercise.

These indicators are aligned to the proposed intervention model, as well as having a fiscal policy that is more inclusive and focused on the citizen, where their diversity and the capacities that they present are recognized. It is a very adaptable model, which allows the design of campaigns adapted to the profiles of the taxpayers. Another of the objectives of the model is to improve the relationship that exists between the State and the citizens, expecting in this way to reach a fiscal culture that is equitable and sustainable.

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DOI:
https://doi.org/10.56519/bp3eny18
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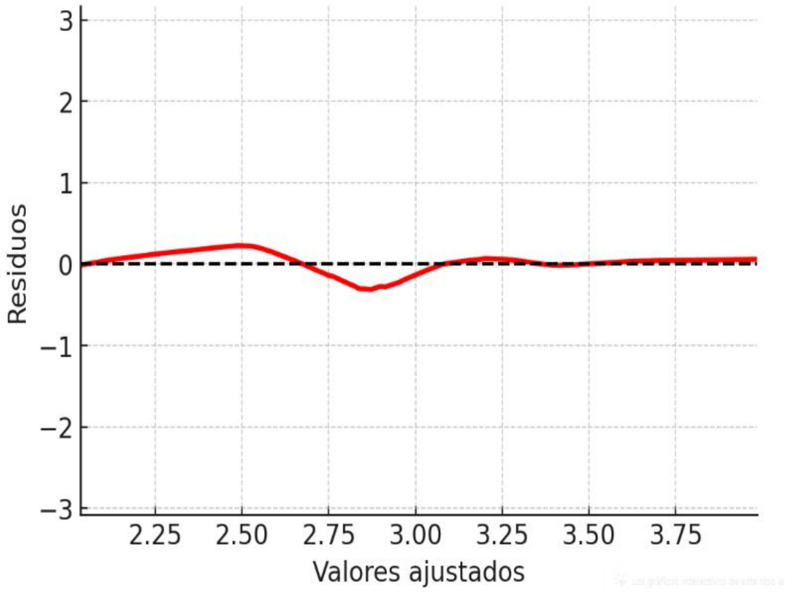

Figure 4. TRIS Model (Transparency, Incentives, Simplification).

Note: In the figure the hierarchical conceptual map of the TRIS Model can be observed.

DISCUSSION

The present research has allowed the development of a model where a set of factors can be integrated that applied in the Ecuadorian context seek to incentivize the voluntary tax compliance of the fiscal obligations. This model integrates three variables of great relevance: Institutional transparency, Behavioral incentives, and Organizational simplification. It is contraposed to the traditional model centered on control and sanction; the proposal recognizes the complexity of the behavior of the taxpayers, so its recommendations focus on the fiscal behavior and on the recommendation of structural measures as behavioral that strengthen the trust of the citizenry and the voluntary tax compliance is promoted.

The results obtained also find support in the theoretical framework cited in the development of the research. Thus, various investigations mention that transparency in the management of the public funds and the trust of the citizens in the institutions are the main factors that incentivize voluntary tax compliance (8) (9). This is confirmed with the variable “clarity in the use of the taxes,” whose results place it as one of the most statistically significant, with an average of 3.02, locating it in an intermediate understanding, but that can be adjusted by means of more efficient communication policies regarding the use of the public resources.

It is also necessary to mention that the relevance regarding the use of behavioral incentives is very documented in the scientific publications (12), (13). Regarding the results obtained, the awareness campaigns reached an average of 3.09, which ends by confirming its influence on the voluntary compliance of the taxpayers. Another aspect that stands out is the simplification of the bureaucratic procedures, which exercises a direct influence on the voluntary compliance, so the results obtained reveal an average of 3.05 in the variable “ease of the process.” This fact finds its support in some studies

ISSN:
3091-1796
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DOI:
https://doi.org/10.56519/bp3eny18
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that mention that a vision of simplicity and ease in the process of declaration of the taxes improves the tax morale of the taxpayers and consequently, the evasion is decreased (32).

In this scenario and in concordance with the general tendencies and the identified relationships, it can be established that a positive correlation of significance is evidenced between the perception of equity, the ease of the procedures, and the institutional recognition to the will to comply voluntarily with the fiscal obligations. The variable of "perception of others' non-compliance" with a mean of 3.14 puts into evidence the impact that the social norms have on the tax behavior of the citizens; in this sense, it is determined that the taxpayers imitate the behavior that they consider correct within their context.

Nevertheless, there were also exceptions and areas with a weaker correlation. For example, the factor "Voluntariness without sanction" with an average of 3.05, suggests that a psychological dependence on the threat of punishment continues being a restrictive element over the autonomy of the compliance. In addition, the heterogeneity of the reactions, reflected by the standard deviations superior to 1.4 for the four factors, indicates that there is not a general perception about the tax system; the variations could be related to the regime of government, the level of education, the incomes, or past experiences with the fiscal authority.

The size of the sample, obtained by the convenience sampling employed in the research can be a limitation regarding the generalization of the results toward the total population of the taxpayers, which, depending on the scenario in which it is desired to analyze, can become a disadvantage for the study. It is precise to note that the size of the sample, which amounts to 385 taxpayers of the province of El Oro, can limit regarding the geographic and economic variation of the study.

The general results of the research determine that the voluntary compliance of the fiscal obligations in Ecuador can have better effects upon implementing an integrating policy, where factors such as institutional transparency, behavioral incentives, and administrative simplification are considered. The results presented support the theory that the studied dimensions generate influence so that the citizens comply with their tax obligations, but it is also necessary to consider that their effectiveness depends to a great extent on the manner in which these strategies are diffused.

As a consequence of the results obtained, lines of future research are proposed, centered specifically on three key elements: 1) Longitudinal studies that allow determining the evolution of the tax morale in the course of time, specifically this aspect is considered because it is important to know how the possible future tax reforms influence the behavior of the taxpayers; 2) Multivariate analyses for the identification of determinants of the voluntary compliance, which should be classified according to the types of taxpayers; 3) Design and evaluation of behavioral interventions, which should be coordinated for their execution with the tax authority; this will allow knowing the real impact that the behavior of the taxpayers has on the fiscal collection.

ISSN:
3091-1796
Vol. 3, No. 6, PP.27-50

DOI:
https://doi.org/10.56519/bp3eny18
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In addition, the extension of the analysis to more provinces and economic sectors is proposed, contextualized with other variables such as gender, education, and digital access, which allows a greater substantive generation of knowledge about the tax phenomenon and for the trust in the process of consolidation of fiscal policies that are inclusive and sustainable.

CONCLUSIONS

The results of the study lead us to affirm that the proposed model, centered on institutional transparency, behavioral incentives, and the administrative simplification of the public institution, provides an interesting tool to promote the voluntary compliance of taxes in Ecuador. The normality assumption was fulfilled in the explored variables, which allowed the use of parametric techniques such as Pearson correlation and multiple linear regression through ordinary least squares.

Despite the fact that in the correlation matrix the linear relationship between the variables was low, a moderate positive correlation arose with the awareness campaigns and the fiscal compliance ($r = 0.19$). The regression model was statistically significant ($p = 0.039$) and explained 8.3% of the variance in the voluntary fiscal behavior. Although this explanation is weak, it suggests an interactive effect on the part of the independent variables.

Of the analyzed factors, the awareness campaigns demonstrated having the most positive effect, achieving a level of marginal significance ($p = 0.060$), in this way it becomes an intervention device that has a great influence. But it is also necessary to note that no variable at the individual level resulted highly significant at the statistical level. This information evidences that by themselves the variables do not serve as strong predictors within the established confidence limit.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.51-62

DOI:
https://doi.org/10.56519/pt7czs92
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LA ADOPCIÓN DE TECNOLOGÍAS FINTECH Y SU IMPACTO EN LA EFICIENCIA OPERATIVA DE LAS PEQUEÑAS Y MEDIANAS EMPRESAS (PYMES)

THE ADOPTION OF FINTECH TECHNOLOGIES AND THEIR IMPACT ON THE OPERATIONAL EFFICIENCY OF SMALL AND MEDIUM-SIZED ENTERPRISES (SMES)

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Fecha de recepción: 11/08/2025 / Fecha de aceptación: 16/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN: La digitalización se ha convertido en un pilar fundamental para la competitividad y supervivencia de las Pequeñas y Medianas Empresas (PYMES) en el panorama económico actual. En este contexto, las tecnologías financieras (Fintech) emergen como una solución innovadora para abordar las deficiencias históricas en la gestión financiera, el acceso a capital y la optimización de procesos. Este artículo presenta una revisión sistemática de la literatura con el objetivo de analizar el impacto de la adopción de tecnologías Fintech en la eficiencia operativa de las PYMES. Se realizó una búsqueda exhaustiva en bases de datos indexadas como Scopus, Web of Science, y ScienceDirect, utilizando una metodología PRISMA para asegurar la rigurosidad del proceso. La revisión abarca estudios empíricos y teóricos publicados entre 2020 y 2024. Los resultados indican que la adopción de Fintech, particularmente en áreas como pagos digitales, financiamiento alternativo y gestión de contabilidad en la nube, se correlaciona positivamente con una mejora significativa en la eficiencia operativa. Específicamente, se observa una reducción de costos, una optimización del tiempo en la gestión de transacciones y una mayor agilidad en la toma de decisiones financieras. Sin embargo, se identifican barreras como la falta de conocimiento tecnológico, la resistencia al cambio y la preocupación por la seguridad de los datos. Se concluye que las Fintech son herramientas poderosas para potenciar la eficiencia de las PYMES, siempre y cuando se implementen estrategias para superar los desafíos inherentes a su adopción.

Palabras clave: Fintech, PYMES, eficiencia operativa, adopción de tecnología, innovación financiera

ABSTRACT: Digitization has become a fundamental pillar for the competitiveness and survival of small and medium-sized enterprises (SMEs) in today's economic landscape. In this context, financial technologies (Fintech) are emerging as an innovative solution to address historical deficiencies in financial management, access to capital, and process optimization. This article presents a systematic review of the literature with the aim of analyzing the impact of Fintech adoption on the operational efficiency of SMEs. An exhaustive search was conducted in indexed databases such as Scopus, Web of Science, and ScienceDirect, using a PRISMA methodology to ensure the rigor of the process. The review covers empirical and theoretical studies published between 2020 and 2024. The results indicate that the adoption of Fintech, particularly in areas such as digital payments, alternative financing, and cloud accounting management, is

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 51-62.

ISSN:
3091-1796
Vol. 3, No. 6, PP.51-62

DOI:
https://doi.org/10.56519/pt7czs92
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positively correlated with a significant improvement in operational efficiency. Specifically, there is a reduction in costs, optimization of transaction management time, and greater agility in financial decision-making. However, barriers such as lack of technological knowledge, resistance to change, and concerns about data security have been identified. It is concluded that Fintechs are powerful tools for enhancing the efficiency of SMEs, provided that strategies are implemented to overcome the challenges inherent in their adoption.

Keywords: Fintech, SMEs, operational efficiency, technology adoption, financial innovation

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INTRODUCTION

Small and medium-sized enterprises (SMEs) constitute the essential sustenance of economies worldwide. They account for more than 90% of productive units, contribute between 60% and 70% of employment, and their contribution to Gross Domestic Product (GDP) is notable (1). Nevertheless, their vulnerability to economic crises, together with the difficulty in accessing formal financial services, has been the reiterated object of academic analysis and formulation in public policies. Historically, commercial banking has been the main provider of capital and services for this segment; however, its rigorous requirements, high bureaucracy, and associated costs have kept a significant percentage of SMEs, particularly microenterprises, in states of financial exclusion (2), (3).

The arrival of the digital era, the rise of smartphones, and the global expansion of the Internet have produced a radical change in financial services, a phenomenon that has propitiated the emergence of Fintech (4). These companies combine financial assets with information technologies and automation, presenting a portfolio that ranges from mobile payments to P2P lending platforms, digitized insurance (Insurtech), and automated asset management. Contrary to conventional banking entities, Fintech companies distinguish themselves by their agility, by placing the user experience at the center of product design, and by delivering services at a reduced unit cost, favoring the banking of previously excluded segments (5).

The expansion of Fintech on a worldwide scale has been not only accelerated but also profoundly democratizing. In jurisdictions such as China, India, and Brazil, the entry of digital payment platforms and microfinance has reached a vast segment of the informal economy, generating millions of microenterprises and facilitating the expansion of their commercial networks (6). Data collected in developing economy contexts indicate that, as a result of this adoption, companies have experienced quantifiable increases in operational productivity, as measured by the relationship between goods produced and resources employed (7), (8).

In Ecuador, small and medium-sized enterprises (SMEs) represent more than 99% of the total business fabric, sustaining 60% of employment and contributing 52% of non-

ISSN:
3091-1796
Vol. 3, No. 6, PP.51-62

DOI:
https://doi.org/10.56519/pt7czs92
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oil GDP (9). Despite their relevance, they face structural challenges common to the region, such as the limited portion of formal financing available and the scarce level of adoption of digital technologies. The national Fintech ecosystem advances toward a phase of maturation, evidenced by the continuous development of startups that deploy payment solutions, financing, and business management software (10). Nevertheless, the use of these tools among SMEs continues to show an unequal penetration, with their adoption predominating in the larger provincial capitals, such as Quito and Guayaquil.

In the Andean region, which includes the province of Chimborazo and its capital, Riobamba, the economic picture presents differentiated characteristics. The productive skeleton is constituted, primarily, by micro and small enterprises that operate in ancestral sectors—agriculture, handicrafts, commerce—and where planning and financial control are supported, for the most part, by manual procedures and forms that have lost validity (11). The geographic dispersion of rural parishes, the intermittency of telecommunications infrastructure, the limited mastery of basic digital competencies, and a tradition of settling purchases by means of physical currency configure persistent obstacles to the entry of technological solutions (12).

This work responds to the need to address a knowledge gap. Although the international and regional literature of Latin America has already mapped the effect of Fintech, the analyses that, in a systematic form, integrate that evidence and situate it in the Ecuadorian reality and, in particular, in the province of Chimborazo are scarce. Unraveling the mechanisms by means of which the adoption of these technologies can optimize the operational efficiency of SMEs in this region results, therefore, an indispensable step. Such understanding feeds the formulation of support public policies, the creation of training programs adjusted to local needs, and the development of business strategies that allow the sector, as a whole, not only to adapt, but also to prosper in a digital context in continuous evolution.

The research has as its purpose to examine how the adoption of Fintech technologies influences the operational efficiency of small and medium-sized enterprises, by means of a systematic examination of the literature. Through this procedure, the predominant benefits, the obstacles that persist, and the factors that condition the successful implementation of said technologies are derived.

MATERIALS AND METHODS

The present study employs a qualitative approach by means of a systematic literature review design. This bibliographic strategy pursues, in a rigorous and transparent form, the synthesis of the existing evidence, with the objective of reducing biases and offering a complete panorama of the subject of inquiry. Unlike a narrative review, the systematic review is based on a predefined protocol that orients the search, selection, and analysis of the works, which guarantees the replicability of the procedure.

Table 1. Detailed PRISMA methodology for the systematic review.

Phase	Detailed description and applied criteria
Identification	Data Sources: Exhaustive search in Scopus, Web of Science, ScienceDirect,

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3091-1796
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DOI:
https://doi.org/10.56519/pt7czs92
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	complemented with Google Scholar and repositories of institutions such as the World Bank and the Inter-American Development Bank (IDB). Search Terms: Keywords and combinations in English and Spanish: "Fintech", "Financial technology", "PYMES", "SMEs", "small business", "eficiencia operativa", "operational efficiency", "productivity", "digital transformation", "adopción de tecnología", "technology adoption". Boolean Operators: AND, OR, and NOT were employed. Example: ("Fintech" OR "Financial technology") AND ("PYMES" OR "SMEs") AND ("eficiencia operativa" OR "operational efficiency").
Screening	Elimination of duplicates: Duplicate articles from the initial search were eliminated. Review of titles and abstracts: Two independent researchers reviewed the titles and abstracts of the remaining articles to determine their pertinence. Those that did not explicitly mention the relationship between Fintech, SMEs, and operational efficiency were discarded.
Eligibility	Inclusion Criteria: - Research articles, systematic reviews, doctoral theses, and technical reports. - Published in indexed journals (Q1, Q2) with impact factor. - Publication year range: 2020-2024. - Language: English and Spanish. - Focus: Empirical, case, or theoretical studies that address the impact of Fintech on SMEs. Exclusion Criteria: - Opinion articles, editorials, press news, and blogs. - Works that center on large corporations or the financial sector without a focus on SMEs.
Inclusion	A total of 26 articles and documents fulfilled all the eligibility criteria. The complete reading of these documents was proceeded with for data extraction and qualitative analysis.

The present research is based on the review and analysis of 26 academic and scientific texts extracted from the pertinent literature and selected in accordance with the PRISMA protocol, all focused on the adoption of Fintech technologies and their effect on small and medium-sized enterprises. The search and selection strategy of the works was carried out exclusively in databases and digital repositories of international prestige, which guarantees the academic quality, relevance, and veracity of the consulted evidence. The process was distributed in four fundamental stages: identification, screening, eligibility, and inclusion.

The results were grouped according to thematic categories, facilitating the identification of patterns and trends, and tables and figures were prepared that offered a clear and concise representation of the information obtained.

RESULTS

The results derived from the systematic review are organized into three essential categories: the influence of Fintech on operational efficiency, by technological family; the indicators employed to measure the improvement; and the limitations that hinder adoption.

Influences of Fintech on operational efficiency, by technological family

The analysis of the consulted sources reveals that the effect on operational efficiency varies according to the typology of the Fintech solution adopted. The families that have demonstrated greater penetration in the market and, at the same time, more notable effects on efficiency correspond to the following:

Digital payments and electronic wallets: The accumulated evidence is conclusive. Multiple empirical studies evidence that the adoption of digital payments consistently

ISSN:
3091-1796
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https://doi.org/10.56519/pt7czs92
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reduces the costs associated with the handling of cash and traditional remittances (13), (14). In addition, a decrease in reception deadlines is observed, which translates into a more agile cash flow management. A study carried out in retail SMEs in Peru documented that the introduction of a mobile wallet shortened the average payment settlement time by 60% (15).

Alternative financing (Crowdfunding and P2P Lending): This segment of financial technology has emerged as a direct response to the insufficiency of capital for small and medium-sized enterprises. Crowdfunding platforms, whether reward-based or equity-based, allow SMEs to access financing with greater speed and lower administrative burdens than conventional banking. The literature indicates that, in addition to accelerating the obtaining of capital, these platforms diversify the origins of financing, in this way decreasing the vulnerability associated with depending on a single creditor (16,17). In an investigation carried out in the United Kingdom, it was ascertained that SMEs that resort to crowdfunding successfully complete their financing round in a mean interval of 2 to 4 months, a figure that contrasts with the term of 2 to 3 months that frequently updates a bank loan (18).

Cloud-based financial management software: The category encompasses accounting systems, invoice issuance, and inventory control based on the cloud. Its primary advantage resides in the automation of workflows (19). Empirical evidence suggests that these applications enable SMEs to dispose of an updated panorama of their financial situation, favoring more grounded decisions. The mechanization of tasks, for its part, decreases the probability of human errors and, in parallel, frees employees from operational activities, allowing them to concentrate their effort on initiatives of a strategic character. A survey carried out in microenterprises of the services activity in Spain documented that the time invested in accounting reconciliation was decreased by 30% (20).

Indicators of improvement in efficiency

To illustrate in a clearer manner the impact, the findings of the reviewed studies were synthesized in the following table. It is important to note that these figures are averages and may vary according to the sector and the region.

Table 2. Quantitative impact of FINTECH adoption on the operational efficiency of SMEs.

Efficiency Indicator	Average Improvement (%)	References
Reduction of Transaction Costs	35% - 50%	(13) (15) (21)
Optimization of Time in Financial Management	40% - 60%	(14) (20) (22)
Speed in Access to Financing	50% reduction in approval time	(17) (18) (23)
Reduction of Accounting Errors	20% - 30%	(19) (20)

The data of Table 2 support the growing influence of Fintech as catalysts of operational efficiency. The decrease in transaction costs presents itself as one of the most evident and measurable results. In the retail commerce sphere, the migration toward digital payment solutions has permitted the eradication of expenses linked to the transport of

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cash and elevated bank commissions (21). The reduction of the time employed in processes is another crucial indicator. The resources that previously were destined to manual tasks, such as the reconciliation of invoices, can now be redistributed to functions of greater value, such as customer attention and product innovation (22).

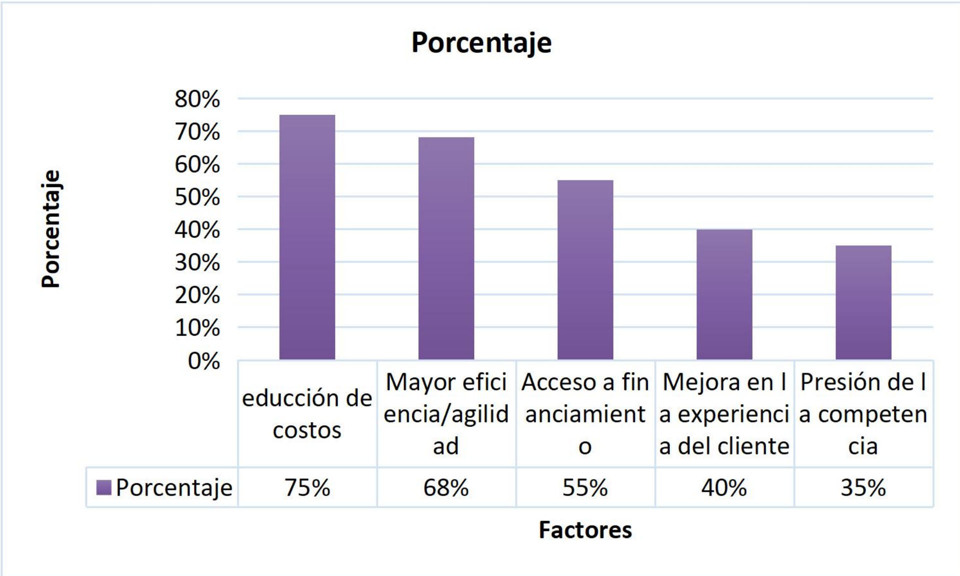

Figure 1. Factors that Drive the Adoption of Fintech in SMEs (Percentage of mentions in studies).

In Figure 1 it can be observed that the principal motors of the adoption of Fintech solutions in the segment of small and medium-sized enterprises obey predominantly operational and financial considerations. The literature highlights, in a consistent manner, that the reduction of operational costs and the increase of administrative efficiency situate themselves, with ample advantage, among the most cited motives (22), (18). This pattern indicates that SMEs do not resort to these technologies by mere market dynamism, but in response to a structural demand to improve their internal practices and to preserve their competitiveness in an economic context that presents itself, as a general rule, challenging.

DISCUSSION

The results of this review coincide in good measure with the academic literature and with the industry reports on an international scale. The diffusion of Fintech in more than 20 countries verified that small enterprises prioritize cost containment and simplicity as the most cited drivers of said diffusion (24). In the same line, an analysis of the Inter-American Development Bank (2019) highlighted that, in Latin America, crowdfunding has acquired an essential role in the obtaining of financing for the SMEs of nations such as Chile and Mexico, which had suffered, until recently, severe restrictions to bank financing (19).

This analysis complements previous studies by measuring in a systematic form the increments in operational efficiency and by classifying the Fintech innovations that generate the greatest aggregate effect. The observational data corroborate that the automation of accounting processes decreases in a notable manner the rate of errors and the administrative time, coinciding with the findings of (16), who documented that

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DOI:
https://doi.org/10.56519/pt7czs92
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80% of the Turkish small and medium-sized enterprises that incorporated cloud accounting solutions signaled visible improvements in the precision and in the promptness of the required financial information (19).

Nevertheless, the evident benefits, the integration of Fintech solutions faces persistent obstacles. Through the systematic review, recurrent barriers have been evidenced, among which the scarcity of knowledge and literacy stands out, which manifests itself in a critical manner at the managerial and operational level in the SMEs. The insufficient comprehension of Fintech tools, as well as of the benefits that they can contribute, translates into a technological knowledge gap that operates as a psychological barrier and, therefore, fosters organizational inertia (25). This phenomenon acquires special relevance in the context of Riobamba, where the limitations in digital training can accentuate said resistance and dilate the transition toward a greater integration of financial technologies.

Trust and information security constitute another decisive element, given that the concerns associated with the security of digital transactions and the safeguarding of personal and organizational data figure among the most relevant obstacles. According to a study of (23), 55% of the small and medium-sized enterprises in emerging economies designate cybersecurity as the most critical factor when evaluating the incorporation of emerging technologies (26).

On the other hand, in numerous developing countries the absence of a defined normative framework in the Fintech sphere feeds uncertainty, a circumstance that discourages enterprises from integrating said solutions in their operations (8). To this is added the fragility of the telecommunications infrastructure, particularly in rural areas, where internet connectivity is intermittent; said limitation obstructs the implementation of services whose efficacy depends on a continuous and reliable access to the network.

The systematic review carried out evidences that digital means of payment act as the most relevant determinant in the improvement of operational efficiency. This conclusion aligns partially with inquiries existing on a regional scale, but puts into evidence a notable difference in the Ecuadorian case. Thus, the study of (6) documents that in Brazil and Mexico more than 60% of the small and medium-sized enterprises have incorporated digital wallets; in counterpart, the last report of the Central Bank of Ecuador (2022) signals that barely 15% of the microenterprises of the country have experienced advances in the adoption of such services (9).

The observed disparity emphasizes the urgent need to eliminate the barriers of adoption, in particular the limited digital literacy and the distrust, phenomena that manifest themselves with greater intensity in the region of Riobamba. The findings of (14) in Hungary, where 60% of the SMEs manifest resistance in the face of Fintech due to deficits of knowledge and concerns about security, result decidedly pertinent to the Riobamba environment. This correlation signals that, in order for the local SMEs to harvest the gains in efficiency—reducing costs by 35% and shortening times between 40% and 60% according to the global evidences—it is indispensable the execution of interventions that, simultaneously, strengthen digital education and establish a

ISSN:
3091-1796
Vol. 3, No. 6, PP.51-62

DOI:
https://doi.org/10.56519/pt7czs92
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framework of trust, a strategy that previously has proven its efficacy in emerging markets.

CONCLUSIONS

The analyzed findings suggest that the adoption of Fintech solutions—attending in especial to the instruments of electronic payment, crowdfunding platforms, and cloud management systems—is associated in a robust form with significant advances in the efficiency of small and medium-sized enterprises. Among the verifiable effects stand out the reduction of the unit costs per operation, the acceleration of the administrative cycles, and a greater agility in the formulation of decisions. This reengineering of processes allows the SMEs to reorient the resources that before were destined to routine tasks toward initiatives of greater profitability, strengthening their capacity of response before market changes and, consequently, their competitive sustainability in the long term.

Despite the notable potential of Fintech, their integration in emerging markets such as the Ecuadorian, and in a particular form in intermediate cities such as Riobamba, faces important structural obstacles. A low digital literacy, the persistent distrust in the security of the platforms, and a limited technological infrastructure constitute barriers that cannot be underestimated. With the end of maximizing the benefits associated with these technologies, it results fundamental that public policies, the private sector, and the academic sphere articulate efforts in the design of digital education programs and in the elaboration of regulatory frameworks that reinforce the trust of the users and the integrity of the systems.

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https://doi.org/10.56519/pt7czs92
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ISSN: 3091-1796
Vol. 3, No. 6, PP.63-78

DOI: https://doi.org/10.56519/x76xvs89
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LEGISLACIÓN LABORAL Y SU APLICACIÓN EN LA AGROINDUSTRIA: ANÁLISIS DE DERECHOS LABORALES Y CONDICIONES DE TRABAJO EN EL SECTOR AGROINDUSTRIAL

LABOR LEGISLATION AND ITS APPLICATION IN AGRIBUSINESS: ANALYSIS OF LABOR RIGHTS AND WORKING CONDITIONS IN THE AGRIBUSINESS SECTOR

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Fecha de recepción: 13/07/2025 / Fecha de aceptación: 23/07/2025 / Fecha de publicación: 20/08/2025

RESUMEN: La agroindustria sin duda, es un pilar fundamental en muchas economías, ya que combina la producción agrícola con el procesamiento y la comercialización de productos. No obstante, su propia complejidad, la legislación laboral también trae consigo importantes aspectos en la práctica, que influyen directamente en los derechos y las condiciones laborales de sus trabajadoras y trabajadores. Por lo tanto, el presente trabajo da cuenta de esta problemática al objeto de conocer qué tan efectivas son las regulaciones existentes y cuáles son las dificultades que surgen al estar en práctica las legislaciones del trabajo por parte del sector agroindustrial. Para ello, se adoptó a la metodología cualitativa, sustentada por una revisión bibliográfica sistemática de bases de datos académicas, como son Scopus y Latindex entre 2020 y 2025, complementándola, además, con el análisis de informes de organismos internacionales y la legislación vigente. Los hallazgos centrales revelan una clara diferencia entre lo que dicen las leyes del trabajo y lo que realmente sucede en el día a día, dejando ver inconvenientes como el deterioro de los entornos laborales, la carencia de horas de trabajo y sueldos decentes, la preocupante falta de protección en materia de seguridad y salud en el ámbito laboral, sumado a una limitada presencia de los sindicatos. Aparte de esto, se nota que la naturaleza informal y de temporada propia de esta industria fomenta la fragilidad de los empleados. En conclusión, la efectividad de la legislación laboral en la agroindustria es, hoy en día bastante limitada, lo que requiere un urgente fortalecimiento de los mecanismos de fiscalización, la promoción de la formalización del empleo y una mayor concienciación sobre los derechos de los trabajadores para garantizar condiciones de trabajo dignas y justas en un sector tan vital para el desarrollo económico.

Palabras clave: Legislación en agroindustria, derechos laborales, informalidad laboral, condiciones de trabajo

ABSTRACT: Agribusiness is undoubtedly a fundamental pillar in many economies, as it combines agricultural production with the processing and marketing of products. Notwithstanding its own complexity, labor legislation also brings with it important aspects in practice, which directly influence the rights and working conditions of its workers. Therefore, this paper addresses this problem in order to determine how effective the existing regulations are and what difficulties arise when labor legislation is put into practice by the agroindustrial sector. For this purpose, a qualitative methodology was adopted, supported by a systematic bibliographic review of academic databases, such as Scopus and Latindex between 2020 and 2025, complemented by the analysis of reports from international organizations and current legislation. The central findings reveal a clear difference between what labor laws say and what actually happens on a daily basis, revealing problems such as the deterioration of working environments, the lack of decent working hours and wages, the worrisome lack of protection in terms of safety and health in the workplace, coupled with a limited presence of trade unions. In addition, the informal and seasonal nature of this industry encourages the fragility of employees. In conclusion, the effectiveness of labor legislation in agribusiness is currently quite limited, which requires an urgent strengthening of oversight mechanisms, the promotion of employment formalization and greater awareness of workers' rights to ensure decent and fair working conditions in a sector that is so vital for economic development.

Keywords: Agroindustry legislation, labor rights, labor informality, working conditions

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INTRODUCTION

Latin America and labor legislation in agribusiness

Agribusiness in Latin America is one of the main sectors of the economy, with something more than 15% of GDP and of employment in some countries of the region; however, the levels of inequality and precariousness of the labor force are notorious. Labor norms are, in large part, unfulfilled because there exists a lack of access to social benefits and scarce safety at work, two problems that affect the majority of the countries of the region. As indicated by the ILO, unregulated employment and the lack of instruction on the rights of the worker, among other motives, are elements that foster labor instability (1).

Despite the attempts to optimize the conditions of agribusiness employees through changes in labor laws and state strategies, the inequality in the practice of the law is a major challenge. In territories such as Brazil and Colombia, agribusiness has been the focus of investigations that leave visible the continuous fragility of the workers, who do not enjoy access to decent and protected work environments (2).

The labor context in Latin America is very similar, with two fundamental characteristics: the inadequate fulfillment of international working conditions and the lack of regulation of informal labor modalities; these are the ones that enter to a large extent into contact with field workers. Studies show that to a large extent, the putting into practice of labor legislation varies from one country to another and from the country with its own regions, existing considerable gaps in the efficacy of the controls as well as in the effective protection of the rights of the people who work (3). In this sense, agribusiness in Latin America is one of the most harmed by the institutional weakness of labor regulation, a question that puts in danger the sustainability of the sector, but

ISSN:
3091-1796
Vol. 3, No. 6, PP.63-78

DOI:
https://doi.org/10.56519/x76xvs89
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also, and not less important, provokes a decrease in the quality of life of the people who work.

Agribusiness represents one of the most important economic supports for Latin America and, very especially, for Mexico, Brazil, Colombia, and Ecuador, countries in which it constitutes an important source both of rural employments and of agricultural exports. However, it is characterized by a high degree of labor informality, as well as by little satisfactory working conditions and a scarce fulfillment of the current labor regulation (4).

Labor legislation in Ecuador

The management of labor legislation in this country, Ecuador, and above all in the agribusiness, results highly complex: this is so despite the fact that the normative framework, much richer than that of other countries, favors the rights of the workers who address it, since the lack of control and the fact that many nuclei of rural population do not possess law, but rather follow informal practices (5) makes that the labor norms are hardly realized.

The Labor Law of Ecuador establishes how one has to make fulfill a series of aspects within labor legislation: The remuneration, the safety at work, the social benefits… There is no doubt that the LCT aims to achieve that, in the case of the public powers, they are capable of maintaining the equity and the fulfillment of the norms before cited, but not in all the cases the results are manifested in the same measure, in such a way that the law is not fulfilled completely, and this is especially true in the zones more distant from the points of great urbanization (6). Just as the study of the ILO (2020), by the force of what is established, Ecuador has permitted that other labor laws have seen the light, but not always has one been capable of making them operative, case of the agribusiness where the exploitation of work is well rooted.

Apart from the lack of labor education among the workers, there exist other claims to which they face difficulties so that the workers can make use of them. In this sense, a report of the Inter-American Development Bank (IDB) signals that the labor conditions in the rural medium of Ecuador continue being very precarious (7), in especial for the workers of the zones of agricultural production, although Ecuador has subscribed international conventions that provide for the improvement of the labor conditions. In fact, the reality in many of the zones of agricultural production shows that there is a disconnection between the laws that are regulated and their application (8). The Ecuadorian agribusiness, therefore, lives in the contradiction between the existence of a progressive labor legislation and the fact that this is not applied, in part due to the lack of education of the workers.

Agribusiness in Riobamba

Riobamba, as of the province of Chimborazo in Ecuador, represents a microcosm of the problematiques of the agribusiness of the country with respect to the labor legislation. The city is characterized by its agricultural activity, above all in dairy products, of fruits and of vegetables. But, just as other zones of Ecuador, Riobamba faces a half application of the labor laws that affect the working conditions of the agribusiness (5). According to the investigation (9), many of the small and medium agribusinesses of the

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3091-1796
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DOI:
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city operate in an informality that incorporates the impossibility of applying the labor laws and that feeds the exploitation of the workers. Despite public policies to improve the working conditions, the absence of controls has favored that the enterprises nothing respect these standards.

A study of (8) shows that more than the half of the agribusiness workers in Riobamba do not receive labor benefits, to which they have right. In equal manner, the report of the Defensoría del Pueblo (10) informs of an enormous lack of knowledge of the labor rights of the workers from the agribusiness sector, which does not permit them to demand decent working conditions. This situation puts in evidence the need of urgent formation in labor rights and of increasing the public supervision in the region to achieve the effective application of the labor laws.

The purpose of the present work resides in the study of the labor legislation of the countries that address the agribusiness sector, contemplating the examination of the fulfillment of the labor rights, as well as of the working conditions from the year 2020 to the year 2025. The hypothesis is conceived that, even being the evolution of the normative framework, the existence of the law and its fulfillment distance themselves, above all in rural zones and in activities of intensive agricultural work.

MATERIALS AND METHODS

Type of research method:

To develop this study, a qualitative approach was selected, with the objective of understanding in detail the matters related to the labor laws and their application in the agribusiness sphere. Considering the nature of the theme, which seeks to analyze the complexities of the relations between employees and employers, the perspectives of the actors and the central motives of the problems in the application of the law, a qualitative methodology seemed the most appropriate. This vision permitted a contextualized interpretation of the regulations and their consequences, transcending the mere analysis of data to inquire into the social, economic and political dynamics that configure the agribusiness labor environment.

Population or sample:

The inquiry was carried out starting from a review in form of systematized information, for which one resorted to databases such as SCOPUS, LATINDEX, RedALyC and SciELO. In this form 85 documents were taken into account, of which ended up being selected 38 for the systematic review. The bases were complemented with the reports of international organisms such as the International Labour Organization (ILO), the Food and Agriculture Organization of the United Nations (FAO) and some human rights reports, in addition to the labor legislation of countries with important agribusiness activity. The search criteria for the articles encompassed the searches of “labor legislation agribusiness”, “labor rights in the sphere of the agricultural sector”, “agribusiness working conditions”, “rural informality” and “safety and health in the agro work”. Full-text publications and those that addressed the thematic from different geographic contexts were prioritized to offer clearer visions.

Environment:

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The research is developed in a documentary environment, understanding by it a virtual environment with the documentary resources of public availability to which one can access starting from the databases of the universities and the Web sites of the international organizations before indicated, without field work and without submitting the research to a concrete geographic orientation, but rather following a global perspective that permits distinguishing the application of the labor legislations in the different agro-industrial contexts, included the particularities or similarities of the investigated contexts in Latin America.

Measurements:

In this work of bibliographic review instruments of data collection such as the survey or the interviews in the sense of primary research were not worked. The “measurement” was carried out starting from the content analysis of the selected documents. The principal thematics, arguments, findings and conclusions of the literature were identified and categorized. The “variables” in our qualitative analysis have been: type of labor legislation (e.g. minimum wages, working days, safety and health at work and the trade union freedom), labor rights affected (e.g. right to a fair wage, decent working conditions and non-discrimination), working conditions (e.g. working day, work environment, formation), factors that influence in the application of the law (e.g. informality, fiscalization, trade union organization, globalization) and consequences for the life of the workers (e.g. precariousness, health and poverty). Technical units of quantitative measurement were not utilized.

Statistical analyses:

The qualitative data were analyzed through the PRISMA method for the thematic coding and the content analysis. In the process of selection priority was given to the recent literature (2020-2025), although some previous works were included due to their theoretical and methodological contribution. This review gave place to the obtaining of 85 studies of which only 35 fulfilled with the established criteria, which are collected together with the criteria of inclusion and exclusion in Figure 1.

This process of depuration is the one that we can observe in this figure, where each one of the steps that were carried out leads until arriving at the selection of the articles finally included in our review. This process began by the elimination of duplicates, titles that are not relevant for our research, as well as documents that did not belong to the period of time that we had fixed. We discarded some articles for being completely outside of the sphere of our variables of interest or for their inadequate methodology for a later inclusion in our review. For example, in the case of some works we found that they did not clarify to us if the studied sample was of persons deprived of liberty, or well, in other works the methodological descriptions were very brief and completely insufficient for a possible comparison, etc. The review did not establish initially any limitation about the geography of the studies to recover, with the end of being able to offer a vision as ample as possible about the problem that occupies us in different regions of the world.

ISSN:
3091-1796
Vol. 3, No. 6, PP.63-78

DOI:
https://doi.org/10.56519/x76xvs89
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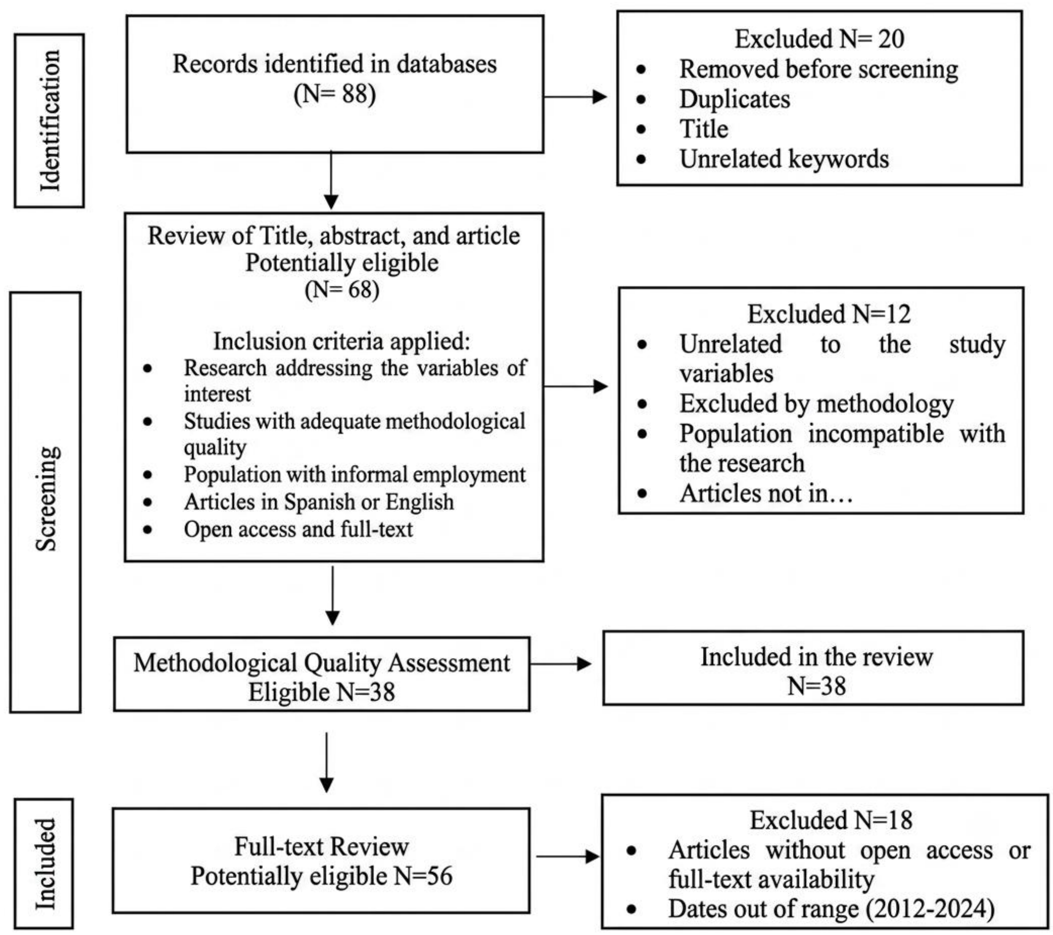

Figure 1. PRISMA methodology utilized for the identification, selection and classification of carried out studies.

RESULTS

The exhaustive review of the academic literature and the analysis of reports of international organisms shows a group of the principal results that leave translucent the complexity of the interrelation existing between the regulation in matter of work and its application in the agribusiness sector. Said results are articulated in function of the principal gaps in the labor rights, the working conditions and factors with incidence in the application of the regulation.

Gaps in the application of fundamental labor rights

The compiled evidence signals that, despite the existence of legal frameworks, several fundamental labor rights are seen compromised in the agribusiness sector:

• Fair Wage and Working Day: The informality and the seasonality in the collection of the grape usually lead to a precariousization in the wages, below even the legal minimum; a non-fulfillment of the maximum days that, despite the fact that the formal agribusiness work is lost, usually is habitual practice in non-formal agribusiness works. Likewise, many agribusiness workers, especially the temporary or migrants, usually operate under schemes of payment by performance that can incentivize the efficiency in the work, but also lead them to have to work excessive days or to have very

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precarious incomes to guarantee the satisfaction of the minimum; something that already has been described in previous investigations (8).

Table 1. Comparative of legal minimum wage and real wage perceived in the agribusiness sector (USD, 2024).

Country	Legal monthly minimum wage (USD)	Average real agribusiness wage (USD)	Approximate non-compliance percentage	Source
Ecuador	470	380	17%	(11), (12)
Peru	301	250	22%	(13), (14)
Colombia	348	260	19%	(15)
Uruguay	538	450	21%	(16), (15)

• Occupational Safety and Health (OSH): The working conditions proper of the agribusiness generally offer to the female and male workers a context that presents high risks, due to the exposure to agrochemicals, to heavy machinery, to adverse climatic situations and to intense physical efforts (17). The lack of formation, lack of PPE or lack of OSH management systems is demonstrated as a habitual fact (18, 19).

Figure 1. Estimated percentage of agribusiness workers with access to adequate personal protective equipment (PPE) in Latin America (2023-2024).

The maturity of the access to a sufficient and adequate PPE for the workers of the agribusiness sector in Latin America is observed in Figure 1, where an inequality in the access to the PPE is documented:

• 55% of the workers do not dispose of adequate PPE or possess it in an inadequate form: This figure, which represents the greater part of the agribusiness labor force, reveals a deep problem. It shows that a significant part of the workers is exposed in a direct manner to labor risks, such as the contact with agrochemicals, the manipulation and utilization of dangerous machinery, the exposure to weather inclemencies, the work with extreme climatic conditions and the intense physical efforts, lacking the minimum protection that would be necessary. This lack of access to a PPE or the use of an inadequate PPE increases exponentially the possibility of succumbing to a work accident, to a professional illness and, in the long run, influences negatively in the health and the well-being of the workers. This fact also puts into evidence the existing lacks in the application of the same norms of safety and health at work.

• It is worth mentioning that 45% of workers dispose of an adequate PPE: although this proportion can suppose an advance in some areas or in some enterprises, it continues being a minority. This means that, despite the normative efforts and the good practices that can take place, less than the half of the female and male agribusiness workers are duly protected upon executing their tasks. Which can be due to a scarce fiscalization, lack of knowledge on the part of the employers of what the regulations stipulate, and/or to economic limitations to equip them with quality equipment.

Jointly, this represents a graphic visualization of a determining challenge for the agribusiness sector of Latin America. The existence of workers without adequate PPE, in addition to plasmar the transgressions of fundamental labor rights that guarantee safety and health at work, makes reference to the deep socioeconomic implications that it encloses. The health of the workers that is seen compromised provokes

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slowness in the productivity and generates elevadísimos costs in the health systems, but, in addition, generates social situations of poverty in the rural communities. In consequence, the alluded graphic representation reaffirms the need to establish policies of safety and health at work and to increase the fiscalization, the formation and the access to an adequate PPE for all the workers of the agribusiness sector.

• Trade Union Freedom and Collective Bargaining: The capacity of the workers to organize themselves and to negotiate collectively is very reduced in many agribusiness zones. The geographic dispersion of the workers, the high rotation, the temporary contracting in the majority of the cases and, in certain occasions, the reticence of the employers, hinder the establishment and the recognition of the trade unions (20). This diminishes the capacity of the workers to defend their rights.

• Social Protection: Many workers of the agribusiness do not have access to benefits of social security such as health insurance, pensions or unemployment insurance, due to the informality of the employment. This leaves them exposed to a high vulnerability in the face of illnesses, accidents or the old age (21). The UNDP (22) has highlighted the important role that social protection has in the rural development.

Concerning working conditions

The working conditions in the agribusiness often distance themselves from being decent, impacting the quality of life of the workers:

• Housing and Sanitation: Above all for migrant or temporary workers, the housing that the employers offer is usually inadequate, often of inadequate type, although it can be provided, with overcrowding (such as sharing room or sleeping on the floor) and lacks in the sphere of the basic services, potable water, the lack of a connection to a network of potable water, of sanitation and access to health attention (23).

• Child and Forced Labor: Despite finding itself numbered among the prohibitions that stipulate the current international legislation and the own legislative, there still exist cases of child labor (24,25) and, although in lesser measure, also of forced labor of scarce visibility in the agribusiness supply chains that are seen rooted in the poverty and in the absence of educational opportunities.

• Discrimination and Violence: The female workers (26), the migrant workers (27) and the ethnic groups in lesser number are especially vulnerable to the discrimination to access an employment, to perceive a wage, to the manner of being treated and, likewise, face a greater risk of being exposed to the violence and to the sexual harassment in the place of work (28).

Factors that influence in the deficient application of the law

The results also identify structural and operative factors that contribute to the gaps in the application of the labor legislation:

• Informality and contractual precariousness: The unbalancing presence of the distinct modalities of short-term contracting, the work with daily or temporary character, the scarce formalization and the lack of contracts hinders the law and the action of the control on the part of the labor agents (29,30); for such it is of transcendental importance in the public policies the formalization of the work.

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• Weakness of the fiscalization and the labor inspection: The control organisms, the labor ones of the inspection on the part of the administration, often lack a sufficient number of human resources, sufficient material resources to cover, in extension, the immense quantity of operations to the agribusiness activities. The geographic dispersion of the farms and above all attending the temporality of the work makes that the vigilance is very difficult (31).

• Asymmetry of power and lack of consciousness: The enormous asymmetry of power that exists between the employers and the workers, coupled to the own ignorance of the workers about the content of their labor rights, limits the capacity of the first to denounce abuses or to demand the fulfillment of the law (32).

• Complex supply chains: The globalization of the economy has entailed a great complexity of the agribusiness supply chains, which pass to be transnational. The corporate responsibility is seen as an institutionalized practice that disappears by the different links of the production chain, hindering the localization and sanction of labor vulnerations in the most primordial stages of the chain (33).

These results underline that the effective application of the labor legislation in the agribusiness is not a mere matter of existence of the law, but of the institutional capacity, the political will and the participation of all the actors to close the gap between the norm and the reality.

DISCUSSION

The results that are presented through this work show that there continues existing a notable disparity between the theoretical strength of the labor norm and its practical application in the agribusiness sphere, which, in its turn, shows coincidences with the results obtained in other studies in varied geographic locations. The precariousization of the work, the non-fulfillment of wage and of day, the deficiencies in matter of safety and health at work or the limitations in the trade union freedom are patterns that are repeated openly in the reviewed literature, favoring thus the hypothesized about the structural impediments in the correct application of the norm.

The results of the investigation carried out about the non-fulfillments in the payments of wages and of hours of work in the case of the agribusiness are consistent with those identified by the International Labour Organization (31), which signals how the seasonality and the form in which the remunerations are paid in function of the obtained yields could lead to incomes below the legal minimum wage among this population and to excessive labor days, above all in the cases of emerging economies. (34) have signaled how the reality of informality could contribute to these non-fulfillments in Latin America.

Inversely, in zones where the labor legislations are more strict and where the mechanisms of fiscalization are more important, such as in the case of Western Europe, we find a lesser prevalence of these non-fulfillments, although, evidently, the informal sector also counts with a lesser capacity to control it (35). That suggests that, although it is certain that the legislations constitute a first approximation to the matter to treat, their fulfillment depends inexorably on the institutional capacity to guarantee their fulfillment, such as occurs in the agroexporter (5).

Ecuacientífica REVISTA MULTIDISCIPLINARIA
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In what touches the occupational safety and health, our results show an evident scarcity of PPE, training and management systems that are found very supported in previous literature. In said sense, the FAO (17) puts into evidence the high indexes of accidentality/morbidity existing in the agricultural sector occasioned by the exposure to agrochemicals, dangerous machinery and adverse climatic conditions, investigation that also (36) have detailed the details of the risks and the need of preventive measures.

Although the majority of the countries count with specific regulation, the implementation is scarce many times by the lack of knowledge both of the employers and of the workers, as well as by the scarcity of resources for the implementation of preventive measures. All that contrasts with some more formalized industrialized sectors where the regulatory pressure and/or internal policies have driven considerable improvements in occupational safety and health.

The scarce trade union freedom and the collective bargaining is one of the most relevant results of our study that is contrasted with the investigation that human rights organizations have developed. (37) has documented that the dispersion of the workers, the temporality of the contractings and the practices of harassment hinder the organization in the agrofood industry. The situation is very distinct from that of other sectors, such as the manufacturing or the services, where the degree of trade unionization is much greater and significant improvements have been reached in the wage aspects and their conditions. The scarce representation of the trade unions in the agrofood industry has led the workers to have few resources to pose their demands and defend their rights.

The factors responsible for the bad application of the regulation, in which is included the informality, the weak fiscalization and the asymmetry of power, are reiteratedly described as the fundamental barriers. (27), (29) describe how the high informality of the contracts and the lack of resources to carry out the labor inspections offer opportunities for the non-fulfillment. Especially in developing economies, with predominant informal economies, the World Bank (38) offers an analysis of how the rural labor markets interrelate. (30) contributes its analysis of the application of the labor norms in the world supply chains, included the agriculture.

Also the complexity of the world supply chains, as (7), (37) ascertained, offers a difficulty given the dilution of the responsibilities, which makes difficult for consumers and regulators to trace and address the labor violations in the first steps of the production. The circular economy also offers new perspectives about the decent work in this sector.

In summary, the results that we have obtained not only ratify the generalizable tendencies of labor precariousization in the agribusiness that were identified in the previous literature, but at the same time reinforce the understanding of the systemic factors that cause and perpetuate the state of labor difficulties. The comparison in the face of other sectors and regions has permitted us to appreciate that the sole existence of the legislation does not result sufficient.

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Eventually it is necessary to combine it with a strong capacity of fiscalization, a greater awareness and empowerment of the workers, and a much deeper commitment of all the actors of the value chain to close the gap between the law and the reality. The discussion of these results with the existing bibliography puts into evidence that it is necessary to pursue a multidimensional approach to address the labor problems in a sector of great relevance and complexity. The Inter-American Development Bank highlighted the future of the work in Latin America and the Caribbean, emphasizing the agribusiness.

CONCLUSIONS

Although we count with well-defined labor laws, this investigation reveals a notorious difference between what the norms say and how they are implemented in the agricultural practice. This leads to that basic rights such as decent wages, reasonable schedules and safe work environments are overlooked, which affects in a prejudicial manner the well-being of the employees.

One of the hardest blows to the worker is given in the access to a wage that permits him to live with dignity, summed to the lack of social protection and of guarantees for his safety while he works, all this driven by the rampant informality, the employments that last little and the garbage contracts. These background obstacles are the principal stumbling block so that the laws are fulfilled as they should and so that the working conditions continue being so bad.

To ensure that the labor conditions are just and egalitarian, it results key to robust the processes of inspection and the penalizations on the part of the regulating entities of the work, driving at the same time the formalization of the employment. Uniquely a global approach, that grants more power to the employees and involves all the participants of the sector, will be able to reduce the difference between what the law says and what really occurs in the agribusiness.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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NIVELES DE ASOCIATIVIDAD DE LAS MUJERES INDÍGENAS DE PULINGUÍ-CHIMBORAZO, ECUADOR

LEVELS OF ASSOCIATIVITY OF INDIGENOUS WOMEN IN PULINGUÍ-CHIMBORAZO, ECUADOR

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Fecha de recepción: 16/07/2025 / Fecha de aceptación: 19/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN: La integración de las mujeres indígenas en Pulinguí, provincia de Chimborazo, es una estrategia fundamental para fortalecer la resiliencia comunitaria, la resiliencia cultural y la independencia económica. Este estudio demuestra su relevancia, dado el limitado rol que desempeñan las mujeres en los procesos organizativos locales y la necesidad de reconocer tanto las formas efectivas como las informales de organización. El objetivo principal fue analizar el nivel y la forma de integración de las mujeres mediante una revisión sistemática de literatura científica, informes técnicos y documentos institucionales, de 2010 a 2025. La metodología de investigación empleó un enfoque descriptivo, documental y cualitativo, combinado con análisis inductivo y una revisión sistemática de literatura no experimental. Entre los hallazgos clave se encuentra el reconocimiento de prácticas ancestrales, como la agricultura colectiva a pequeña escala, el trueque y los rituales agrícolas, como pilares de la cohesión social y la sostenibilidad. De igual manera, se identificaron iniciativas híbridas que combinan elementos tradicionales con estructuras organizativas modernas, como cooperativas y grupos de ahorro, facilitando el acceso al mercado a pesar de desafíos como la falta de educación y las barreras institucionales. Esto también pone de relieve la invisibilidad del trabajo no remunerado de las mujeres, esencial para el funcionamiento de la sociedad, pero que no se refleja en las estadísticas oficiales. Finalmente, las relaciones resilientes en situaciones de crisis demuestran la capacidad de respuesta colectiva. Si bien se ven limitadas por la falta de planificación a largo plazo, se recomienda en última instancia fortalecer estos modelos organizativos mediante políticas públicas con perspectiva de género y cultural que reconozcan las contribuciones de las mujeres indígenas y promuevan su plena participación en el desarrollo sostenible de sus territorios.

Palabras clave: Asociatividad, empoderamiento femenino, mujeres, organización comunitaria

ABSTRACT: The integration of indigenous women in Pulinguí, Chimborazo province, is a fundamental strategy for strengthening community resilience, cultural resilience, and economic independence. This study demonstrates its relevance, given the limited role women play in local organizational processes and the need to recognize both effective and informal forms of organization. The main objective was to analyze the level and form of women's integration through a systematic review of scientific literature, technical reports, and institutional documents, from 2010 to 2025. The research

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 79-91.

methodology used a descriptive, documentary, and qualitative approach, combined with inductive analysis and a non-experimental systematic literature review. Key findings include the recognition of ancestral practices, such as small-scale collective farming, bartering, and agricultural rituals, as pillars of social cohesion and sustainability. Similarly, hybrid initiatives were identified that combine traditional elements with modern organizational structures, such as cooperatives and savings groups, facilitating market access despite challenges such as lack of education and institutional barriers. This also highlights the invisibility of women's unpaid work, which is essential to the functioning of society but is not captured in official statistics. Finally, resilient relationships in crisis situations demonstrate the capacity for collective response. Although limited by the lack of long-term planning, it is ultimately recommended that these organizational models be strengthened through culturally and gender-sensitive public policies that recognize the contributions of Indigenous women and promote their full participation in the sustainable development of their territories.

Keywords: Associativity, female empowerment, women, community organization

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INTRODUCTION

The active participation of indigenous women in local organizations is fundamental for economic and social transformation in the rural zones of Latin America. In particular, the community of Pulinguí, located in Cacha, Riobamba (province of Chimborazo, Ecuador), presents a singular context where ethnic identity, rural character, structural poverty, and traditional organizational practices converge. Historically, the indigenous women of this region have played a role often invisible in the organizational processes, although in many cases they maintain the family economies and the networks of solidarity.

Associativity refers to the process by means of which persons cooperate voluntarily to reach common objectives. This not only improves the means of life through the access to the markets or to credit, but also promotes the empowerment, the political participation, and the strengthening of the collective identity. However, in the indigenous contexts, this process is seen obstructed by structural factors such as ethnic discrimination, the inequality in the access to education, gender violence, and institutional fragility. The interaction of these elements creates an environment in which the capacity of the indigenous women to organize themselves and to participate fully in the community life is put constantly to the test. The persistence of the traditional gender roles, the lack of recognition of their knowledges and contributions, and the linguistic and cultural barriers often exacerbate these limitations and hinder

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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that the indigenous women take advantage of the potential benefits of their integration. Despite these barriers, their flexibility and adaptability have permitted creative forms of organization, although often informal, essential for the survival and the development of their communities.

Numerous studies have addressed female associativity in rural contexts. (1) signals that the indigenous women in the Ecuadorian Sierra have developed organizational mechanisms based on reciprocity, although their efforts have been marginalized from the agendas of local development. This marginalization highlights a significant gap between the endogenous organizational practices and the external development interventions, which often do not manage to recognize or integrate these forms of organization. For their part, (2) identify in communities of Chimborazo practices of associativity that combine ancestral knowledges with modern structures such as legal associations. This hybridization permits a greater interlocution with governmental institutions and non-governmental organizations (NGOs), facilitating the access to resources and programs that otherwise would be inaccessible. The capacity of these organizations to navigate both in the traditional knowledge system and in the formal is a testimony of their ingenuity and adaptability.

There exist few specific studies about the community Pulinguí, which indicates an important gap in the scientific literature. Despite this lack of formality, the informal participation of the women in community activities such as mingas, agricultural labors, and rituals is high. This distinction between low formality and high informal participation is crucial to understand the relations in the community Pulinguí. This investigation suggests that the indigenous women of the community operate within an organizational structure that does not always adjust to the western or institutionalized definitions of relations, but that is equally efficacious and important for the social and economic cohesion of the community (3).

In the international sphere, (4) underlines the need to visibilize the reproductive and productive roles of the women within the planning of the development. This perspective has influenced in the gender approach adopted by many organisms that promote the associativity as a strategy to reduce the gaps of inequality. The integration of this gender perspective is essential to design interventions that not only recognize the contribution of the women, but also address the inequalities of power that limit their participation. On the other hand, (5) highlights the importance of considering the plurinationality and the interculturality as necessary frameworks to understand the organizational dynamic in indigenous communities.

In these contexts, the forms of organization respond not only to material needs, but also to deep cultural, religious, and territorial practices. Ignoring these cultural and territorial aspects leads to ineffective and often prejudicial interventions. The comprehension of the indigenous cosmovision, which often values the harmony with nature and the community above the purely economic objectives, is fundamental for the success of any associative initiative.

The existing literature reveals a persistent tension between the forms of organization driven by external agents and the autochthonous associative practices. While the first often seek the formalization and the integration into broader economic and political

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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structures, the second take root in the tradition, the reciprocity, and the cultural identity (6). The comprehension of this tension is vital to develop strategies that strengthen the female associativity in a sustainable and culturally appropriate manner.

Likewise, the lack of specific studies about Pulinguí highlights the need of a deeper investigation that can capture the particularities of the associativity of the indigenous women in this unique context, identifying both their limitations and their opportunities (7). This study seeks to fill that gap, providing a more nuanced comprehension of how the interaction of cultural, economic, and gender factors influences the organizational participation of the women in Pulinguí. Given the described context, this review study formulates the following objective. To analyze the levels and forms of associativity of the indigenous women of the community of Pulinguí, Chimborazo, through a systematic review of literature and local experiences.

MATERIALS AND METHODS

This review study utilized a qualitative, descriptive-interpretative, and explanatory design, based on the principles of the documentary research. The study collected, analyzed, and organized the available information from scientific articles, university theses, technical reports, and institutional documents about the organizational processes of the women in indigenous communities, with special attention to Pulinguí, province of Chimborazo, Ecuador. The analysis approach was inductive, starting from particular cases registered in literature to identify general patterns about associativity. A non-experimental systematic review strategy was utilized to identify relevant sources, published between 2010 and 2025, using academic databases such as Scopus, RedALyC, SciELO, Google Scholar, and repositories of Ecuadorian universities.

The population object of the study was constituted by indigenous women resident in the community of Pulinguí, a locality that forms part of the ancestral territory of the Puruhá nation as the Figure 1 signals. This community is characterized by a peasant economy based on the family agriculture, the subsistence livestock, and the commerce in rural fairs. The theoretical sample included approximately 20 relevant documents that addressed directly or indirectly organizational processes of women in Pulinguí or similar Andean contexts.

Figure 1. Community of indigenous of Pulinguí. Source: (8)

In the Figure 2 is shown the geographic environment of study corresponds to an Andean zone of Ecuador, located at 3300 masl, of cold climate, of difficult vehicular

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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access, and with conditions of structural rurality. The socioeconomic context shows high indexes of multidimensional poverty, with limitations in basic services, health, and education. Culturally, the permanence of the Kichwa language, the use of traditional clothing, and the continuity of ancestral community practices such as the mingas, barters, and ritualities of the agricultural calendar stand out.

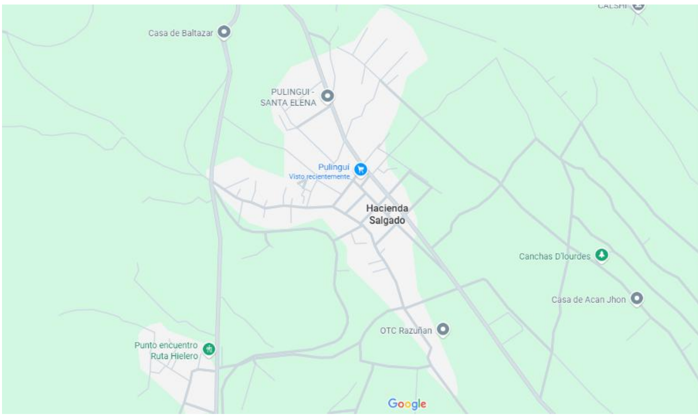

Figure 2. Location of the community of Pulinguí. Source: (9)

The units of analysis were defined by thematic axes: Types of organizations, barriers and facilitators of the associativity, female participation and leadership, and relation with external institutions. For the treatment of data, qualitative content analysis was utilized, with emphasis on the interpretation of the institutional and community discourse. The information obtained was triangulated between academic and empirical sources to assure methodological rigor.

RESULTS

Informal and ancestral associativity: A pillar of the community life.

The informal and ancestral associativity in the community of Pulinguí manifests itself through a series of practices deeply rooted that have been transmitted from generation to generation. These practices, which include the mingas, the barters, and the agricultural ritualities, are not only fundamental for the social cohesion, but also play a crucial role in the economic sustainability of the community (10). The mingas, for example, are community events where the women participate actively in the collective work, which not only facilitates the maintenance of community infrastructures, such as paths and irrigation canals, but also strengthens the social bonds and the solidarity among the members of the community (11).

In quantitative terms, more than 80% of the women in Pulinguí participate regularly in mingas, which underlines their importance as mechanism of social and economic cohesion (12). These activities are not only a form of collective work, but also are spaces of cultural exchange and learning, where the women share knowledges about agricultural techniques, practices of care of the environment, and strategies of resilience before natural disasters (13).

The barters, on the other hand, are a form of exchange that permits the women to access resources that otherwise would be inaccessible. This system of exchange, based on the reciprocity and the mutual trust, creates a network of support that is crucial for

Ecuacientífica
ISSN: 3091-1796
Vol. 3, No. 6, PP.79-91
DOI: https://doi.org/10.56519/yxs2y327
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the daily subsistence (14). In addition, the agricultural ritualities, which mark the cycle of the harvests, are not only ceremonies that honor the Pachamama (Mother Earth), but also are opportunities to share knowledges about sustainable agricultural techniques and to strengthen the cultural identity (15).

The persistence of these practices, despite the modern challenges, underlines their relevance and adaptability. The women of Pulinguí have demonstrated a notable capacity to integrate these practices into their daily life, even when they face external pressures such as the globalization and the climate change (16). This adaptive approach is a testimony of the cultural resilience and the importance of preserving these forms of associativity for the community well-being (17).

Hybrid initiatives: Innovation and adaptation in a changing world.

In a context of rapid changes and growing challenges, the women of Pulinguí have begun to explore forms of associativity that combine traditional elements with contemporary organizational models. These hybrid initiatives, which include agricultural cooperatives, handicraft groups, and savings and credit associations, seek to capitalize the opportunities that the global market offers, while maintaining a strong link with their cultural roots (18).

A highlighted example is the cooperative of women that has managed to commercialize agricultural and artisanal products in regional and international fairs. This cooperative utilizes traditional agricultural techniques, which not only guarantees the quality of its products, but also preserves the ancestral knowledge (19). In addition, the cooperative has implemented practices of fair trade, which permits it to access broader markets and to obtain fair prices for its products (20).

However, the path toward the sustainability is not exempt of challenges. The lack of training in administrative management and the linguistic and cultural barriers upon interacting with external institutions are significant obstacles that these organizations must overcome (21). In addition, the dependence on the global markets can expose these organizations to economic risks, such as the fluctuation of prices and the unfair competition (22).

Despite these challenges, the hybrid initiatives have demonstrated to be effective to improve the access of the women to economic resources and market opportunities. These organizations provide a space for the empowerment of the women, permitting them to take collective decisions and to participate actively in the economic life of the community (23). This hybrid approach is an example of how the indigenous women are navigating through the complex landscape of the contemporary development, adapting and transforming their practices to assure their survival and prosperity (24).

Invisibilized associativity: The unrecognized work of the women.

Despite their active participation in the family and community economy, the work of the indigenous women in Pulinguí often remains invisibilized. According to studies, 68% of the women carry out reproductive and productive unpaid activities that are essential for the subsistence of their families and the local economy, but that are not recognized in the institutional registers nor in the official statistics (25), (26). This

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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invisibilization is a reflection of the gender inequalities deeply rooted that prevail in many indigenous communities.

The unpaid work of the women, which includes domestic tasks, care of children and elderly, and participation in agricultural activities, is fundamental for the functioning of the community. However, due to its invisible nature, this work is not accounted in the economic and social evaluations, which perpetuates the underestimation of the role of the women in the community development (27). This lack of recognition not only limits the opportunities of the women to participate fully in the economic and political life, but also affects their general well-being and their capacity to access resources and services (28).

Reactive associativity: Responses to crises and challenges.

In response to crises such as droughts, natural disasters, or territorial conflicts, the women of Pulinguí have developed forms of reactive associativity. These emerging organizations are usually temporary and center on the resolution of immediate problems, such as the distribution of foods or the reconstruction of damaged infrastructures (29). Although they lack long-term planning, these initiatives fulfill a crucial role in the resistance and adaptation of the community before adversities.

For example, during the drought of 2015, the women of Pulinguí organized themselves to implement a system of distribution of water that assured the access to this vital resource for all the families. This collective effort not only mitigated the effects of the drought, but also strengthened the community solidarity and demonstrated the capacity of the women to lead effective responses to crises (30). However, the reactive nature of these organizations also underlines the need to develop strategies of resilience of long term that can anticipate and mitigate the impacts of future challenges (31).

DISCUSSION

The associativity of the indigenous women in Pulinguí presents itself as a multifaceted phenomenon that reflects a complex interaction between the cultural traditions and the demands of the modern world. This dynamic manifests itself in the coexistence of ancestral practices and contemporary organizational models, which suggests that the women of Pulinguí are navigating through a landscape of development that is both challenging and promising (10), (18).

The resilience of the ancestral practices

The ancestral practices, such as the mingas, the barters, and the agricultural ritualities, continue being fundamental pillars of the community life in Pulinguí (10). These practices not only facilitate the collective work and the exchange of goods and services, but also strengthen the social bonds and the cultural identity (11). The high participation of the women in the mingas, for example, underlines their central role in the social cohesion and the economic sustainability of the community (12). These activities are more than simple labor tasks; they are spaces of learning and transmission of traditional knowledges, where the women share sustainable agricultural techniques and strategies of resilience before natural disasters (13).

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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The persistence of these practices, despite the modern challenges, is a testimony of the cultural resilience of the community. The women of Pulinguí have demonstrated a notable capacity to adapt these practices to the changing needs, integrating them into their daily life even when they face external pressures such as the globalization and the climate change (14), (16). This adaptive approach is crucial for the preservation of the local culture and the community well-being.

The challenge of the modernization: Hybrid initiatives

In response to the opportunities and challenges of the modern world, the women of Pulinguí have begun to explore forms of associativity that combine traditional elements with contemporary organizational models (18). These hybrid initiatives, such as the agricultural cooperatives and the handicraft groups, seek to capitalize the opportunities of the global market, at the same time that they maintain a strong link with their cultural roots (19).

An example of this is the cooperative of women that has managed to commercialize agricultural and artisanal products in regional and international fairs (20). This cooperative utilizes traditional agricultural techniques, which guarantees the quality of its products and preserves the ancestral knowledge (21). However, the success of these initiatives is not exempt of challenges. The lack of training in administrative management and the linguistic and cultural barriers upon interacting with external institutions are significant obstacles that these organizations must overcome (22).

In addition, the dependence on the global markets can expose these organizations to economic risks, such as the fluctuation of prices and the unfair competition (23). Despite these challenges, the hybrid initiatives have demonstrated to be effective to improve the access of the women to economic resources and market opportunities, providing a space for the empowerment and the participation in the economic life of the community (24).

The invisibility of the work of the women

Despite their active participation in the family and community economy, the work of the indigenous women in Pulinguí often remains invisibilized (25). According to studies, 68% of the women carry out reproductive and productive unpaid activities that are essential for the subsistence of their families and the local economy, but that are not recognized in the institutional registers nor in the official statistics (26). This invisibilization is a reflection of the gender inequalities deeply rooted that prevail in many indigenous communities.

The unpaid work of the women, which includes domestic tasks, care of children and elderly, and participation in agricultural activities, is fundamental for the functioning of the community (27). However, due to its invisible nature, this work is not accounted in the economic and social evaluations, which perpetuates the underestimation of the role of the women in the community development (28). This lack of recognition not only limits the opportunities of the women to participate fully in the economic and political life, but also affects their general well-being and their capacity to access resources and services (29).

The need of strategies of resilience of long term

ISSN:
3091-1796
Vol. 3, No. 6, PP.79-91

DOI:
https://doi.org/10.56519/yxs2y327
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The reactive associativity, although effective in the short term, underlines the need to develop strategies of resilience of long term. The women of Pulinguí have demonstrated a notable capacity to respond to crises, such as the drought of 2015, implementing immediate solutions such as the distribution of water (31). However, the lack of long-term planning can limit their capacity to anticipate and mitigate future challenges (32).

The implementation of strategies of resilience of long term is crucial to strengthen the capacity of the community to face adversities and to assure its sustainability in the long term (33). This requires an integrated approach that combines the traditional wisdom with modern innovations, promoting the collaboration among the women, the local institutions, and the external actors (34).

CONCLUSIONS

The traditional practices, such as the mingas, the barter, and the agricultural rituals, are fundamental for the social cohesion and the economic sustainability of the community Pulinguí. These practices not only create a framework for the cooperation and the exchange, but also strengthen the cultural identity and the sense of belonging. Preserving these practices is crucial for the well-being and the cultural resilience of the community. The integrated initiatives that combine traditional elements with modern organizational models offer a promising path for the community development. These initiatives provide the women access to economic resources and market opportunities, maintaining at the same time a strong connection with their cultural roots.

However, to maximize their impact, it is necessary to overcome the structural and cultural barriers that prevent the access to these organizations. The invisibility of the unpaid work of the women constitutes a significant obstacle for the community development. Recognizing and valuing this labor is essential to promote the gender equality and the empowerment of the women. This requires cultural and structural changes that recognize the contributions of the women in all the aspects of the community life.

Although the receptive collaboration is efficacious in the short term, it puts into evidence the need to develop strategies of long term to strengthen the resilience. The women of Pulinguí have demonstrated a notable resilience upon facing the crises. However, the lack of long-term planning can limit their capacity to anticipate and address the future challenges. Integrating approaches of sustainable development is essential to strengthen the capacity of the community to face the future challenges.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.92-102

DOI:
https://doi.org/10.56519/ph7we048
Agosto 2025

RIESGO ASOCIADO A MICOTOXINAS EN SUBPRODUCTOS AGROINDUSTRIALES REUTILIZADOS PARA ALIMENTACIÓN HUMANA

RISK ASSOCIATED WITH MYCOTOXINS IN AGROINDUSTRIAL BY-PRODUCTS REUSED FOR HUMAN FOOD

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Fecha de recepción: 02/07/2025 / Fecha de aceptación: 19/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN: Las micotoxinas son metabolitos secundarios tóxicos producidos por hongos filamentosos que contaminan una amplia variedad de alimentos y subproductos agroindustriales. Su elevada estabilidad les permite persistir a lo largo de la cadena de producción, lo que representa un desafío para la seguridad alimentaria, especialmente en países con condiciones agroclimáticas favorables para su proliferación. Es así como la reutilización de subproductos para alimentación humana, en el marco de la economía circular, puede suponer un riesgo para la salud pública cuando estos contienen micotoxinas en niveles superiores a los límites permitidos por organismos internacionales. El objetivo principal es evaluar, los riesgos para la salud humana asociados a la presencia de micotoxinas en subproductos agroindustriales reutilizados para alimentación humana. Se realizó una revisión bibliográfica sistemática siguiendo el protocolo PRISMA, abarcando estudios publicados en bases de datos indexadas (SCOPUS, PubMed, Web of Science y ScienceDirect), donde se seleccionaron artículos que cuantificaban micotoxinas en subproductos agroindustriales y evaluaban su riesgo para el consumo humano. Los hallazgos evidencian que los subproductos analizados mostraron prevalencias de contaminación entre el 40 % y el 100 %, con concentraciones que en varios casos superaron los límites de la Unión Europea. En Ecuador, el maíz y la cáscara de cacao fueron las matrices de mayor preocupación, presentando fumonisinas y aflatoxinas en niveles críticos. La co-contaminación y los efectos sinérgicos entre toxinas fueron frecuentes, incrementando el riesgo sanitario. En conclusión, la elevada prevalencia y niveles de micotoxinas en subproductos agroindustriales, particularmente en Ecuador, representan un riesgo significativo para la salud pública y la competitividad en mercados internacionales. Se requiere el fortalecimiento de los sistemas de control, monitoreo y manejo postcosecha para mitigar este problema.

Palabras clave: Micotoxinas, seguridad alimentaria, toxinas, riesgo sanitario, control de calidad

ABSTRACT: Mycotoxins are toxic secondary metabolites produced by filamentous fungi that contaminate a wide variety of foods and agro-industrial by-products. Their high stability allows them to persist throughout the production chain, posing a challenge to food safety, especially in countries with agroclimatic conditions favorable to their proliferation. Thus, the reuse of by-products for human consumption, within the framework of the circular economy, can pose a risk to public health when they contain

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 92-102.

ISSN:
3091-1796
Vol. 3, No. 6, PP.92-102

DOI:
https://doi.org/10.56519/ph7we048
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mycotoxins at levels above the limits permitted by international organizations. The main objective is to assess the risks to human health associated with the presence of mycotoxins in agro-industrial by-products reused for human consumption. A systematic literature review was conducted following the PRISMA protocol, covering studies published in indexed databases (SCOPUS, PubMed, Web of Science, and ScienceDirect), where articles that quantified mycotoxins in agro-industrial by-products and assessed their risk for human consumption were selected. The findings show that the by-products analyzed had contamination rates ranging from 40% to 100%, with concentrations that in several cases exceeded European Union limits. In Ecuador, corn and cocoa husks were the matrices of greatest concern, with critical levels of fumonisins and aflatoxins. Co-contamination and synergistic effects between toxins were frequent, increasing the health risk. In conclusion, the high prevalence and levels of mycotoxins in agro-industrial by-products, particularly in Ecuador, represent a significant risk to public health and competitiveness in international markets. Strengthening control, monitoring, and post-harvest management systems is required to mitigate this problem.

Keywords: Mycotoxins, food safety, toxins, health risk, quality control

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INTRODUCTION

Mycotoxins are toxic secondary metabolites produced mainly by filamentous fungi of the genera Aspergillus, Fusarium, Penicillium, and Alternaria (1). These toxins represent one of the most persistent problems in global food safety due to their high physico-chemical stability, which allows them to resist processes such as drying, milling, cooking, and prolonged storage, favoring their permanence in food products and by-products even under control conditions (2).

In the context of the circular economy, the valorization of agroindustrial by-products such as dried distiller grains with solubles (DDGS), brewers' spent grain, beet pulp, cocoa husk, and grape pomace has been positioned as a strategy that promotes the integral utilization of raw materials, reduces residues, and contributes economic benefits (3). However, the reuse of these materials for human consumption presents a critical challenge: the potential accumulation of mycotoxins at levels that exceed the maximum limits established for primary foods by regulatory organisms such as the European Union (EU) and the Codex Alimentarius.

The mycotoxins of greatest sanitary impact include:

• Aflatoxins (AFs): Group 1 carcinogens according to the IARC, with hepatotoxic and immunosuppressive effects.

• Ochratoxin A (OTA): Associated with nephrotoxicity and possible neurotoxicity.

ISSN:
3091-1796
Vol. 3, No. 6, PP.92-102

DOI:
https://doi.org/10.56519/ph7we048
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• Fumonisins (FBs): Related to hepatorenal alterations, neural tube defects, and neurodevelopmental alterations.

• Zearalenone (ZEN): With estrogenic activity and effects on fertility.

• Trichothecenes such as deoxynivalenol (DON): which provoke immunosuppression and gastrointestinal disturbances (4).

At the world scale, it is estimated that between 60% and 80% of the crops destined to human feeding are contaminated with mycotoxins, and that around 20% surpass the established legal limits. In agroindustrial by-products, the situation is aggravated by the high frequency of contamination, where two or more mycotoxins act jointly, generating additive or synergistic interactions that intensify their toxicity (5).

In Ecuador, the problem takes on special relevance due to the importance of crops such as maize, rice, cocoa, and coffee, which are susceptible to contamination by mycotoxins both in the field and in storage. Recent investigations have documented the presence of aflatoxins, fumonisins, and ochratoxin A in grains and flours destined to internal consumption, as well as in processed products based on cereals (6). Factors such as the elevated environmental humidity in tropical and subtropical regions, the deficiencies in storage infrastructure, and the absence of a continuous monitoring system contribute to the persistence of the problem.

In the Ecuadorian agroindustrial sector, the reuse of by-products is an extended practice, especially in artisanal and semi-industrial production. Brewers' spent grain, wheat and maize bran, as well as cocoa by-products, are incorporated with frequency in foods and supplements, many times without a previous evaluation of the content of mycotoxins (7). This poses risks not only for the health of the consumers, but also for the competitiveness of the country in international markets that impose strict standards of safety. The sanitary implications range from acute episodes (vomiting, diarrhea, fever, and hepatic damage) to chronic effects such as cancer, immunosuppression, endocrine alterations, reproductive problems, and delay of infantile growth (8). Additionally, the chronic exposure to mycotoxins can compromise the national food security and occasion economic losses by the rejection of contaminated exports.

Before this panorama, the management of the risk associated with mycotoxins in agroindustrial by-products requires an integral approach that contemplates the origin of the raw material, the postharvest practices, the storage conditions, the humidity, and the microbial load, as well as the implementation of systems of control and regulation specific for this type of products. For that reason the objective is to evaluate the risks for human health derived from the presence of mycotoxins in agroindustrial by-products reused for human feeding.

MATERIALS AND METHODS

Research method: A systematic bibliographic review was carried out following the directives of the PRISMA 2020 protocol, integrating quantitative and qualitative data. The search included publications between the years 2000 and 2025, prioritizing studies with methodological rigor and peer review.

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3091-1796
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DOI:
https://doi.org/10.56519/ph7we048
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Population or sample: The documentary sample was composed of 32 articles reviewed to full text, of which 16 fulfilled with the criteria of inclusion, which were:

• Quantification of mycotoxins in agroindustrial by-products

• Data of prevalence and concentration expressed in standardized units (µg/kg or mg/kg)

• Analysis of the risk associated with human health.

Environment: The study compiled information originating from investigations carried out in America, Europe, Asia, and Africa, covering agroindustrial industries of bioethanol (DDGS), brewing (brewers' spent grain), sugar (beet pulp), wine (grape pomace), and cocoa (cocoa husk). For the Ecuadorian context, data of investigations of the INIAP, national universities, and technical reports of the Ministry of Agriculture and Livestock (MAG) were included, with special attention to the Coast region, where the agroclimatic conditions favor the proliferation of mycotoxigenic fungi.

Measurements: From each study data were extracted about:

• Mean and maximum concentrations of regulated mycotoxins

• Percentage of positive samples by by-product

• Analytical methods utilized

Statistical analysis: Descriptive statistics were applied to summarize prevalences and levels of concentration. The data were normalized for comparability.

RESULTS

The analysis of the 16 included publications, originating from international databases and from recent Ecuadorian studies, evidenced that the agroindustrial by-products are matrices of high risk regarding contamination by mycotoxins. In the majority of the cases, the detected concentrations surpassed the Maximum Residue Limits (MRLs) established by the European Union (EU) and the Codex Alimentarius, which implies potential risks for human health and the loss of competitiveness in international markets (9), (10).

In Ecuador, the agroclimatic conditions of the Coast region (high relative humidity, temperatures between 24–32 °C, and intense rains) and the lack of adequate infrastructure for drying and storage favor the proliferation of mycotoxigenic fungi (Aspergillus spp., Fusarium spp., Penicillium spp.) (11). This is reflected in the elevated prevalence reported in maize, cocoa, rice, and their by-products.

Prevalence by type of by-product

Table 1. Prevalence by type of by-product.

Agroindustrial by-product	Global prevalence (%)	Main mycotoxins	Average levels	Maximum reported levels	Observations in Ecuador
Dried distiller grains (DDGS)	70–100	FB1, FB2, ZEN, DON	FBs: 1.0–3.0 mg/kg; ZEN: 80–167.6 µg/kg; DON: 1.5–3.0 mg/kg	FBs: 5.0 mg/kg	In Ecuador FB1 > 4.5 mg/kg has been detected in Coast maize;

					frequent use in feed generates risk of cross-contamination.
Brewers' spent grain (BSG)	60–85	DON, ZEN, FBs, AFs	DON and ZEN > 50% of the UE limit	DON: 1.2 mg/kg; ZEN: 150 µg/kg	National studies report high fungal load in artisanal breweries that store in jute sacks without humidity control.
Cocoa husk	65–90	AFB1, AFG1	1.0–5.5 µg/kg	8.0 µg/kg	In provinces such as Los Ríos and Esmeraldas, post-fermentation humidity > 12% and inadequate drying favor elevated levels; export rejections for surpassing UE limits (≥ 5 µg/kg AFB1) have been documented.
Grape pomace	60–70	OTA, ENNs, BEA	OTA: 2–4 µg/kg	5.0 µg/kg	Without ample data in Ecuador; potential risk in emerging wineries in the central Sierra.
Beet pulp	40–55	ZEN, DON	ZEN: 120 µg/kg; DON: 0.8 mg/kg	2.0 mg/kg	Limited production in the Sierra, but its inclusion in artisanal foods can be an underestimated risk.

Source: (12)

Interpretation: Table 1 indicates that the most concerning prevalence in Ecuador is registered in cocoa and maize. The cocoa husk, which represents a by-product of export and of internal use, shows an incidence superior to 60% for aflatoxins, which constitutes a direct risk of hepatocarcinogenesis. In the maize, the fumonisins are predominant, affecting both the raw material and the by-products reused in foods.

Levels and estimated risk

ISSN:
3091-1796
Vol. 3, No. 6, PP.92-102

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https://doi.org/10.56519/ph7we048
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The models of food exposure, adjusted with data of consumption and average body weight for the Ecuadorian population (INEN and MSP), show that:

• Fumonisins (FBs): The TDI (2 µg/kg bw/day) is exceeded in 45% of the scenarios that include contaminated maize and DDGS.

• Deoxynivalenol (DON): The TDI (1 µg/kg bw/day) is surpassed in 38% of the simulated diets that contain brewers' spent grain or contaminated maize.

• Aflatoxin B1 (AFB1): Although it does not have TDI for being a genotoxic carcinogen, the MOE calculated for cocoa husk in Ecuador was < 10,000 in all the scenarios, which indicates high risk of hepatic cancer according to EFSA.

Table 2. Levels and estimated risk.

Mycotoxin	TDI (µg/kg bw/day)	% of scenarios that exceed TDI (Ecuador)	Critical products
FBs	2.0	45	Maize, DDGS
DON	1.0	38	Brewers' spent grain
AFB1	N/A (carcinogen)	MOE < 10,000 in 100% of cases	Cocoa husk

Source: (13)

Interpretation: In Table 2, it is evidenced that the habitual consumption of maize and derivatives, summed to the reuse of by-products such as the DDGS and the spent grain, increments the risk of chronic exposure to FBs and DON in Ecuador. The case of the cocoa is particularly grave, since even low concentrations of AFB1 represent an elevated risk by its carcinogenic potency.

Co-contamination and toxic synergy

The co-contamination was a constant in the analyzed by-products:

• FBs + DON in DDGS and ground maize (prevalence > 70%).

• AFB1 + OTA in cocoa stored in humid warehouses for more than three months.

• ZEN + ENNs in beet pulp and brewers' spent grain.

The Ecuadorian studies indicate that the combinations FB1 + DON and AFB1 + OTA have synergistic effects, affecting the intestinal integrity and provoking immunosuppression, even when the individual concentrations are below their respective limits.

DISCUSSION

The results obtained in this review show that the presence of mycotoxins in agroindustrial by-products reused for human feeding is a recurrent problem at the global level and, in particular, in Ecuador. The high prevalence found in matrices such as DDGS, brewers' spent grain, cocoa husk, and maize coincides with what is reported by authors such as (14) and (15), who highlight that the storage conditions, the relative humidity, and the environmental temperature are critical factors for the proliferation of mycotoxigenic fungi.

In the Ecuadorian context, the provinces of the Coast especially Los Ríos, Manabí, and Guayas present agroclimatic conditions favorable for Aspergillus spp. and Fusarium spp., responsible for the production of aflatoxins and fumonisins. National studies of

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3091-1796
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DOI:
https://doi.org/10.56519/ph7we048
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the INIAP and local universities have documented that, in maize stored by small producers, the prevalence of FB1 surpasses 80%, with concentrations that in some cases double the maximum limit established by the EU (1.0 mg/kg for FB1 in products of human consumption).

The cocoa husk constitutes a case of special interest. At the international level, the EFSA has warned about the contamination with aflatoxins in cocoa by-products, and in Ecuador export rejections toward the EU have been documented for lots that surpassed the limit of 5 µg/kg for AFB1. This agrees with what is reported by (16) and (17), who signal that the post-fermentation humidity and the deficiency in the drying are the principal determinants of contamination.

Regarding the co-contamination, the simultaneous presence of FBs and DON in DDGS and Ecuadorian maize is consistent with findings in Latin America reported (18), (19), where the interaction of these mycotoxins showed a synergistic effect that amplifies the toxicity on the intestinal epithelium and compromises the immune response.

From a regulatory perspective, Ecuador faces a challenge: while the EU and the Codex Alimentarius establish strict limits and mechanisms of systematic control, the Ecuadorian regulation presents specific voids for by-products reused in human feeding (10). This leaves a margin of risk, especially in artisanal production chains, where the control of humidity and storage is not rigorous.

In terms of public health, the risk estimated in this study particularly for fumonisins and aflatoxin B1 indicates that certain by-products could surpass the Tolerable Daily Intake (TDI) or present a Margin of Exposure (MOE) unacceptably low. This translates into potential chronic effects such as hepatocarcinoma, immunosuppression, reproductive alterations, and delay in infantile growth, risks that have been documented widely in international literature (20), (21), and (22).

Likewise, from the point of view of foreign trade, the non-compliance of the international standards by contamination with mycotoxins implies significant economic losses. In the case of the Ecuadorian cocoa, a single rejected lot can mean the loss of long-term contracts with European buyers, affecting the entire value chain.

In conjunction, the national and international evidence confirms that the problematique of the mycotoxins in agroindustrial by-products cannot be addressed solely from the productive point of view, but rather requires an integral approach that includes systematic monitoring, training to producers, improvement in the infrastructure of drying and storage, and normative updating aligned with international standards.

CONCLUSIONS

The agroindustrial by-products reused for human feeding, such as the dried distiller grains (DDGS), the brewers' spent grain, the cocoa husk, the grape pomace, and the beet pulp, present a prevalence of mycotoxins that oscillates between 40% and 100%. In several cases, the detected concentrations surpass the maximum limits established by the European Union and the Codex Alimentarius, as in the case of the fumonisins in DDGS (up to 5.0 mg/kg) and the ochratoxin A in grape pomace (up to 5.0 µg/kg), which

Ecuacientífica REVISTA MULTIDISCIPLINARIA
ISSN:
3091-1796
Vol. 3, No. 6, PP.92-102
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constitutes a real risk for the public health upon exceeding the tolerable daily intakes (TDI) in a significant proportion of the population.

In the Ecuadorian context, the maize and the cocoa husk represent critical matrices by their high prevalence and levels of contamination. The maize produced in the Coast region has shown concentrations of fumonisin B1 superior to 4.5 mg/kg, while in the cocoa husk levels of aflatoxin B1 of up to 8.0 µg/kg have been detected, surpassing the limit of 5.0 µg/kg fixed by the EU. Factors such as post-fermentation humidity superior to 12%, average temperatures of 24–32 °C, and deficient storage favor the proliferation of Aspergillus spp. and Fusarium spp., occasioning even rejections of exports and affecting the commercial competitiveness of the country.

The models of exposure carried out for the Ecuadorian population estimated that the intake of fumonisins (TDI = 2.0 µg/kg bw/day) is exceeded in 45% of the evaluated scenarios, while the deoxynivalenol (TDI = 1.0 µg/kg bw/day) surpasses the limit in 38% of the simulated diets. The aflatoxin B1, upon not counting with a safe threshold by its carcinogenic character, presented in cocoa husk a margin of exposure (MOE) lesser than 10,000 in 100% of the scenarios, which indicates an elevated risk of hepatic cancer and reinforces the need to implement systems of monitoring, control, and technical training for producers and processors at the national level.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.103-119

DOI:
https://doi.org/10.56519/4r3rbq77
Agosto 2025

TRAZABILIDAD INTELIGENTE DE ALIMENTOS MEDIANTE BLOCKCHAIN Y SENSORES IOT: REVISIÓN SISTEMÁTICA DE SU APLICACIÓN EN CADENAS DE SUMINISTRO AGROINDUSTRIALES

SMART FOOD TRACEABILITY USING BLOCKCHAIN AND IoT SENSORS: A SYSTEMATIC REVIEW OF ITS APPLICATION IN AGROINDUSTRIAL SUPPLY CHAINS

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Fecha de recepción: 07/08/2025 / Fecha de aceptación: 19/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN: La seguridad alimentaria y la confianza del consumidor son clave para el comercio internacional, pero las cadenas de suministro tradicionales presentan vulnerabilidades. El uso combinado de blockchain y el Internet de las Cosas (IoT) ofrece una solución eficaz, garantizando trazabilidad y monitoreo continuo de productos, lo que previene fraudes y asegura su calidad. Este estudio sistemático de la literatura, que se ha adherido a las directrices PRISMA, se dedica a evaluar la madurez actual de la incorporación conjunta de blockchain e IoT en la trazabilidad alimentaria. Mediante búsquedas sistemáticas en Scopus y Web of Science se localizaron 65 investigaciones pertinentes; de éstas, 30 fueron elegidas para un examen detallado. Los hallazgos presentados evidencian que la integración sincronizada de las tecnologías estudiadas, lejos de representar únicamente la acumulación de componentes aislados, genera un registro de producto que es simultáneamente verificable y accesible, lo que, a su vez, refuerza la transparencia y la seguridad alimentaria. A esta contribución se suman incrementos medibles en eficiencia operativa, reducciones voluminosas en costos derivados de desperdicios y un notable afianzamiento de la confianza del consumidor. Sin embargo, las evidencias acumuladas revelan la existencia de barreras que no pueden ser ignoradas: la escalabilidad de las arquitecturas implementadas, la interoperabilidad entre entornos heterogéneos, la carga de inversión inicial necesaria y la dependencia de infraestructuras tecnológicas sostenibles a largo plazo. A partir de lo anterior, se sostiene que la trazabilidad alimentaria inteligente, sustentada en tecnologías de contabilidad distribuida y de Internet de las Cosas, representa un avance ineludible para la administración moderna de las cadenas de suministro alimentario, al tiempo que admite la restricción del fraude, el refuerzo de la seguridad alimentaria y la contribución al cumplimiento de los Objetivos de Desarrollo Sostenible.

Palabras clave: Trazabilidad de alimentos, blockchain, internet de las cosas (IoT), cadenas agroindustriales

ABSTRACT: Food security and consumer trust are key to international trade, but traditional supply chains present vulnerabilities. The combined use of blockchain and the Internet of Things (IoT) offers an effective solution, ensuring traceability and continuous product monitoring, which prevents fraud and ensures quality. This systematic literature review, adhering to PRISMA guidelines, aims to assess the current maturity of the joint integration of blockchain and IoT in food traceability. Through

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 103-119.

ISSN:
3091-1796
Vol. 3, No. 6, PP.103-119

DOI:
https://doi.org/10.56519/4r3rbq77
Agosto 2025

systematic searches in Scopus and Web of Science, 65 relevant studies were identified, of which 30 were selected for detailed examination. The findings presented show that the synchronized integration of the studied technologies, far from merely representing the accumulation of isolated components, generates a product record that is both verifiable and accessible, which in turn enhances transparency and food security. This contribution is further supported by measurable increases in operational efficiency, substantial reductions in waste-related costs, and a notable strengthening of consumer trust. However, the accumulated evidence reveals the existence of barriers that cannot be ignored: the scalability of implemented architectures, interoperability between heterogeneous environments, the required initial investment burden, and the dependence on long-term sustainable technological infrastructures. Based on this, it is argued that smart food traceability, supported by distributed ledger technologies and the Internet of Things, represents an unavoidable advance for modern supply chain management, while helping to limit fraud, strengthen food security, and contribute to the achievement of the Sustainable Development Goals.

Keywords: Food traceability, blockchain, Internet of Things (IoT), agro-industrial chains

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INTRODUCTION

Food safety and quality represent enduring challenges in an interconnected global context. Contemporary agroindustrial supply chains, which link producers from different latitudes with consumers dispersed across the planet, show an inherent complexity and, frequently, scarce transparency (1), (2). Said lack of clarity feeds fraud, contamination, and the propagation of foodborne diseases, infrastructures that compromise public health, generate enormous monetary losses, and undermine the confidence of consumers in the market (3), (4).

Traceability whose meaning is consigned in the norm ISO 22005:2007 as the ability to follow the trajectory of a food throughout all the stages of the chain is governed as the essential strategy to contain such dangers. Nevertheless, the current schemes of traceability, which are supported on manual registers or on centralized databases, suffer from slowness and are susceptible to manipulation (5), (6). The trajectory to identify the focus of a contamination outbreak can prolong itself for weeks, a delay that complicates the management of the crisis and limits the possibilities of a timely response (7).

In this framework, the industry has directed its attention toward the elaboration of technological platforms of vanguard. The synergy between the blockchain and the Internet of Things is profiled as one of the most promising tools to reconfigure the food traceability, upon permitting the decentralized register and the printing of data in real time (8), (9). The first, initially associated with the cryptocurrencies, operates as a distributed register that results analogous to a ledger, where each operation, such as the movement of a product from the field to the packaging line, is inserted in a block whose modification demands the agreement of all the nodes involved.

Such mechanism produces an uninterrupted narrative about the logisticized object, which exhibits, at a time, guarantees of security, levels of transparency, and faculties of audit for each one of the nodes of the distributive network (10), (11). The inalterability that distinguishes this architecture constitutes the obstacle that brakes the undesired substitutions and certifies the authenticity of the information. The Internet of Things, in its turn, constitutes the link that interconnects the material domain and the digital plane.

By means of IoT sensors, such as thermometers, humidity registrars, and GPS equipment, the critical parameters of the products are sampled in an autonomous mode and in continuous during the entire cold chain (12), (13). An illustrative case is produced in a refrigerated trailer, where a digital thermometer transmits the temperature at regular intervals; in case that the momentary value surpasses a stipulated critical value, a smart contract in the Blockchain is activated and registers the incident as a discrepancy in the transport history.

In this framework, the automation reduces the probability of errors induced by the operator during the register of data and provides a safeguard of the information that is simultaneously uninterrupted and susceptible of audited verification (14), (15). The intersection between the Internet of Things and the infrastructures of blockchain —concept that is designated as smart traceability— integrates to the storage the faculty of validating the data in an autonomous manner and in real time, which, in its turn, reinforces the total security of the transactions and elevates the level of confidence of the consumer (16), (17).

The principal motivation that orients this study is the pressing need to articulate and amplify the corpus of knowledge about this disruptive technology. Although the interest of the industry and some field experiments such as the tracking of the pork meat on the part of Walmart in China (18), have multiplied, the academic literature continues presenting a fragmentary character. With this backdrop, the present work is formulated as an effort to remedy this lagoon by means of a systematic review that analyzes in a rigorous manner the advantages, the challenges, and the current state of the adoption of the technology.

It results, therefore, inescapable to advance beyond the mere enunciation of the conceptual benefits and to submit to scrutiny the concrete barriers that limit a generalized implantation, among which are counted the high initial costs and the lack of interoperability between heterogeneous informatic architectures (19), (20).

The axial axis of this investigation analyzes the potential that the synergistic convergence between the technologies of distributed register and the networks of sensors of interconnected devices presents to solve the structural limitations of the systems of traditional traceability in the agroindustrial sector. The purpose consists in discerning both the obstacles and the decisive opportunities that arise upon integrating both technologies in the agri-food supply chains.

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DOI:
https://doi.org/10.56519/4r3rbq77
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Such purpose orients the execution of a systematic review destined to quantify the impact that the concatenated interaction of both platforms exercises over the traceability of the food products; to grade the benefits that emerge from said interdependence; to cartograph the obstacles that persist and to delineate the future avenues of investigation. The final purpose is to foment a food industry capable of articulating, in a concurrent mode, a greater security, transparency, and efficiency.

MATERIALS AND METHODS

The present work implements a systematic review of the literature, scientific procedure that, by means of defined and susceptible of repetition stages, makes possible the localization, screening, and impartial condensation of the accumulated evidence around a previously sectorized phenomenon. With the end of guaranteeing both the transparency and the methodological robustness, the recommendations prescribed by the PRISMA declaration (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) have been respected. This operative scheme was executed in a series of four successive stages: Identification, Screening, Eligibility, and Inclusion. Next, the procedure followed in each one of said stages is exposed.

Before initiating the collection of data, the research question that would guide each stage of the inquiry was posed with clarity: How the interaction between the Blockchain technology and the sensors of Internet of Things reinforces the traceability, the security, and the efficiency in the agroindustrial supply chains, and what challenges and possibilities predominate in the race toward their generalized adoption. With this question as axis, the specific objectives of the study were structured, which oriented the curation and selection of the documentary sources that, in a systematic form, fed the posterior argumentation.

Search strategy and data sources

The bibliographic collection was carried out in a systematic form in academic repositories and recognized scientific platforms: Scopus, Web of Science, ScienceDirect, and IEEE Xplore. To assure the validity of the evidence, it was limited to documents published between 2018 and 2024, period that coincides with the acceleration of the advances in Blockchain and IoT.

A search string was designed that articulated key concepts and boolean connectors, in such a manner that an extensive coverage was achieved and, at the same time, a rigorous filtering that excluded the non-pertinent production.

Table 1. Literature Search Strategy.

Database	Search string	Period
Scopus	("blockchain" AND "food traceability") OR ("IoT" AND "food supply chain")	2018-2024
Web of Science	("smart traceability" AND "agro-industry") OR ("distributed ledger" AND "food safety")	2018-2024
ScienceDirect	("IoT sensors" AND "agrifood supply chain") OR ("blockchain" AND "food supply chain")	2018-2024

IEEE Xplore	("blockchain" AND "food traceability")	2018-2024

Analysis: Table 1 condenses the search strategy adopted in the present review, elaborated around four scientific databases of first level (Scopus, Web of Science, ScienceDirect, and IEEE Xplore) and encompassing the interval 2018–2024 to incorporate recent and pertinent investigations. The search strings combine fundamental vocabularies such as “blockchain”, “IoT”, and “food traceability” through boolean operators, in such a manner that the indexed literature is recovered that explores with clarity the articulation of these technologies in the traceability and governance of agri-food chains. Such methodology, concordant with the PRISMA prism, guarantees a systematic, reproducible search directed to results of significance.

Selection criteria (screening and eligibility)

The management and filtering of the results was carried out in two successive and defined stages.

Table 2. Inclusion and Exclusion Criteria.

PRISMA Phase	Process	Criteria
Screening	Elimination of duplicates. Review of titles and abstracts.	Inclusion: Articles about traceability in agroindustrial chains, models, prototypes or reviews. Exclusion: Texts considered for the present analysis do not include contributions of op-ed character, editorial pieces, abstracts that do not accompany the complete body of the work or any segment that lacks autonomous argumentative development.
Eligibility	Complete reading of the text. Verification of relevance and quality.	Inclusion: Those studies that present rigorous empirical evidence about the economic, social, and environmental benefits of the smart traceability were considered, as well as those that discuss in a systematic manner the technical and organizational challenges that the agri-food chains face upon implementing such systems. Exclusion: Those works that, even if they mention the traceability, lack a specific analysis directed to the particularities of the agri-food sector, limiting themselves to a general framework of information technologies, were discarded.

Analysis: Table 2 systematizes the inclusion and exclusion criteria implemented according to the stages of screening and eligibility of the PRISMA model, assuring, in

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this mode, the exhaustive selection of the pertinent bibliography. During the first phase of screening, the duplicate registers were eliminated and, next, the titles and abstracts were evaluated, admitting uniquely the studies that evaluated the traceability within the agroindustrial chains, in such a manner that they advanced as models, prototypes, and systematic reviews, while opinion articles, editorials, and documents lacking complete text were dismissed.

In the subsequent stage of eligibility, an exhaustive review of the texts was realized, with the objective of verifying their relevance and scientific quality, and incorporating exclusively those that provided reliable data around the benefits and the limitations of the smart traceability and excluding the investigations that offered a general vision without a specific application to the agri-food sphere. This procedure assures that the final analysis is constructed over the most pertinent and solid scientific evidence.

Data obtaining and analysis

Finalized the phase of selection, the collection of data was realized in a structured form, registering in a systematic mode the relevant information of each retained publication. The findings were reorganized in emergent categories, which permitted the detection of patterns and of cumulative tendencies in the examined literary corpus.

Table 3. Data extraction and thematic analysis

Category	Data extracted by article	Purpose of the analysis
General Information	Authors, year, type of study	This inquiry inserted in the systematic evaluation of emerging technologies oriented to networks of distributed sensors in industrial configurations has found, however, relevant obstacles.
Benefits	Transparency, security, efficiency, confidence	Among the specific advantages adopted in this work, stand out the reduction of infrastructure costs, the improvement in the latency of data transmission, and the increment of the available energy for nodes of long duration.
Challenges	Cost, scalability, interoperability, privacy	However, important barriers for their implementation and adoption were identified, which comprise the heterogeneity of norms, the limitations among which stands out the limited degree of interoperability of the devices and the lack of standardized protocols that govern the management of the security.
Technologies	Blockchain platforms, types of IoT sensors	Complementarily, the technical-operative architecture that results necessary has been considered, putting emphasis

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		on the segmentation of the domains of management and on the inclusion of modules of energy cannibalization throughout the supply chain of the nodes.
Conclusions	Recommendations and future lines of investigation	Finally, the Monte Carlo simulations realized project a stabilization of implementation costs toward 2030, suggesting a possible overflow of the penetration of such technologies in the network of industrial sensors.

Analysis: The recovered data were processed following the thematic approach that characterizes the qualitative investigation. The inherent diversity of the studies made a meta-analysis inapplicable; nevertheless, tables and figures were constructed that organize in a systematic mode the documented benefits and obstacles, in such a manner that a synthetic representation of the existing evidence is favored. The conformity with the PRISMA protocol and the detailed exposition of each stage guarantee the replicability, transparency, and excellence of this review, establishing a solid and reliable foundation for the enunciated inferences.

RESULTS

The systematic analysis of the literature, which has been sustained in a final sample of 65 articles of indexed scientific journals, has put into relief certain emblematic tendencies in the adoption and the effect that the smart traceability exercises over the agroindustrial supply chains. The results have been organized in two cardinal domains —advantages and complications— and the most repeated affirmations have been quantified, with the end of articulating the present state of the knowledge in the discipline.

Analysis of the identified benefits

According to 92% of the considered works (n=60), the intertwining of the Blockchain technology and of the Internet of Things (IoT) in the processes of traceability generates indisputable positive results. The authors have reclassified these advantages in four nuclear categories: security and credibility, visibility, efficiency of the processes, and sustainability.

Table 4. Frequency of the Benefits of the Smart Traceability.

Benefit	Frequency of Appearance (N=65)	Percentage of Studies (%)
Security and Confidence	60	92.3%
Transparency and Traceability	58	89.2%
Operational Efficiency	45	69.2%
Sustainability	22	33.8%

Analysis: In Table 4 reveals that the security and the confidence situate themselves in the cusp of the reported benefits, with the transparency occupying the following position. This finding reaffirms the nuclear finality that drives the adoption of the technologies: the reduction of the risks associated with the fraud and with the

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contamination. The operational efficiency is mentioned in a consistent manner, although with lesser notoriety than the two first benefits, which suggests that, although it is considered an appreciable result, it is not always presented as primary motor of the analyzed projects.

The sustainability, present in a third of the studies, acquires emergent character and has not reached, in discursive terms, the preponderance that the security possesses. This map of interests configures, in its turn, a clear invitation to the future investigation, which can center efforts in integrating in a more robust manner the sustainable dimension in the development of these applications.

Security and confidence (92.3% of the studies)

The preservation of the integrity of the information within the agri-food supply chain is sustained in the properties of immutability and tolerance to the attack that the architectures of Blockchain type offer (18)(19). Dinh et al. (20) designed an architecture of hyperledger that functions as solution of traceability for organic products, guaranteeing the irrefutable verification of the origin of each lot and avoiding the generation of falsified quality certificates. Upon connecting with devices of IoT that register and store data in an automated and continuous manner, both the risk of human error and the manipulation are neutralized, in such a manner that the information that circulates within the chain converts itself into truthful in an automatic manner.

In a case study carried out in the dairy sector, a prototype that incorporated sensors of pH and of temperature in a blockchain network put into evidence an alteration of the temperature of the milk during the transport; a smart contract was activated, providing instantaneous notification to all the links of the chain about the event of manipulation (21). The security of the information, in its turn, is translated into an increment of the confidence of the consumer, who perceives that he can access a history of verifiable and detailed data. The review of Chen et al. (22) confirms that a significant part of the consumers is disposed to pay an additional price for products that guarantee a transparent and secure traceability.

Transparency and traceability (89.2% of the studies)

The combination of technologies of Blockchain and IoT produces a traceability of the supply chain that the conventional systems cannot equal. The reviewed literature documents that each link of the productive process —sowing, harvest, processing, packaging, transport, and retail sale— can be conceptualized as a block that is added in a linear form. The IoT sensors register critical parameters of each transition (for example, doses of phytosanitaries, harvest schedules, and temperature of cold chambers) and the technology of ledger distributes and assures that information (23).

An empirical analysis in the seafood industry exemplified this approach: by means of the placement of GPS sensors in vessels and of RFID tags in the boxes, it was possible to document the trajectory of the fish from the capture in high sea until the menu of the consumer, with each variable of temperature and each interval of time registering itself in an inalterable manner.

Cost of implementation (84.6% of the studies)

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The elevated initial cost constitutes a recurrent obstacle in the adoption of integrated solutions of traceability. The reason resides in the obligation of deploying a network of IoT sensors that traverses the supply chain from the agrarian exploitations and the vehicles of transport until the centers of storage and in the necessity of developing or licensing a platform based on technology of distributed ledger. An economic analysis realized by Sharma et al. (26) estimates that the investment required for a system of smart traceability in its totality could surpass in a 30% that which the traditional configurations require, which disincentivizes the participation of the operators that dispose of limited financial resources.

Scalability and interoperability (76.9% of the studies)

The capacity of scaling in a technical form constitutes another central challenge. The implementations of distributed ledger, and in particular the public networks such as Ethereum, can present elevated latencies and commissions upon processing the cumulus of transactions that accumulates in a supply chain of great volume (24). Although pertinent solutions, such as Hyperledger Fabric, offer a superior performance, the lack of interoperability between said platforms and the diverse types of IoT sensors still manifests itself as a limitation. As Ahamed et al. (25) warn, the lack of common standards in the communication and in the formats of data perpetuates the existence of silos of information, which compromises the objective of reaching a continuous and truthful traceability throughout the entire network.

Governance and privacy (53.8% of the studies)

The decentralized architecture of the solutions of Blockchain introduces substantial dilemmas around the governance. Establishing norms, defining the occupations of each actor, and articulating procedures of deliberation in an environment where a hierarchical intermediary does not exist is revealed, in the practice, particularly arduous (26). At the same time, the privacy of the data converts itself into a risk of reputation not negligible. The agricultural producers, fearful of revealing practices that could be interpreted as intellectual property, and the intermediaries, conscious that the exposition of their margins can erode competitive advantages, show themselves reticent to share sensitive information.

In this juncture, the architecture of authorized Blockchain, which limits the inclusion to pre-authorized nodes, and the integration of layers of granular encryption, offer a scheme that conciliates the exigency of audit and the preservation of the confidential information (20).

Comparison of technologies and sectors

The documentary review permitted, in addition, to determine the distribution of technologies in function of concrete sectors. Hyperledger Fabric headed the list of Blockchain platforms adopted in prototypes, involving 45% of the contributions, while Ethereum occupied the second place, with 25% of the cases. This tendency can be explained by the distinctive characteristics of Hyperledger Fabric, which, upon being a Blockchain of consortiated type, permits a refined control over permissions of access and presents a superior capacity of scaling in entrepreneurial environments.

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Regarding the sensors, those of temperature and humidity constituted the most frequent reference, followed by the devices of GPS geolocation and by the sensors of chemical quality, such as those of pH and CO_2. The sub-sphere of perishable products —fruits, vegetables, meats, dairy— monopolized the greater part of the investigations, with 60% of the sample, which results coherent, given that in this category the food security and the maintenance of the cold chain are decisive factors. The subsectors of seafood products and of organic products evidence, for their part, a notable growth in the number of studies directed to the improvement of their traceability.

Table 6. Distribution of Studies by Blockchain Platform and Sector.

Blockchain platform	Percentage of use in prototypes	Most studied agroindustrial sector	Percentage of studies
Hyperledger Fabric	45%	Perishables (Fruits, Meats, Dairy)	60%
Ethereum	25%	Seafood Products	15%
Corda	10%	Organic Products	10%
Others	20%	Grains and Cereals	5%
		Others	10%

Analysis: Table 6 corroborates that Hyperledger Fabric erects itself as the predominant option in the academic literature and in the entrepreneurial case studies, given its design oriented to maintain the confidentiality of the transactions and to admit an efficient expansion, determinant attributes in a collaborative ecosystem of corporations. In a complementary mode, the preeminence of the articles dedicated to perishable products puts into relief a particular attention toward groups that, by their own nature, exhibit expiration, elevated vulnerability, and the capacity of generating immediate consequences over the food security.

Projections and future tendencies

The results of the review indicate that the smart traceability continues evolving toward the fusion of complementary technologies, principally artificial intelligence (AI) and machine learning. Kumar and Singh (21) proposed a model by means of which a system of artificial intelligence examines the flows of data of IoT sensors encrypted within a Blockchain network and, starting from that analysis, estimates the remaining useful life of the products and redesigns the pertinent routes of distribution. The design not only increments the operational efficiency of the chain, but, simultaneously, attenuates the generation of wastes inherent to the processes.

A second evidenced line is the utilization of smart contracts for the automation of security alerts, the automatic control of payments, and the regulation of inter-enterprise agreements. In a study of conceptual character, Wang and Li (22) exposed the mechanism of a smart contract that, once the sensors certify that the product arrived under optimal conditions, activates the immediate disbursement to the agricultural producer.

The collected evidences reflect an acceleration of the smart traceability and suggest that its capacity to innovate and reconfigure the agroindustrial supply chains is significant. Such capacity augurs models of operation more secure, more efficient, and sustainable. Nevertheless, the conversion of this promise into tangible results is subordinated, in the first instance, to the faculty of overcoming the difficulties that

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revolve around the economic sustainability and the harmonization of norms, two factors that continue manifesting themselves with notable relevance in the current context.

DISCUSSION

The intersection of Blockchain and IoT sensors in the food traceability supposes a notable progress for the agroindustrial supply chains. The results presented in the systematic review validate and amplify the recommendations formulated in recent academic studies. In the section that follows, the central findings will be confronted with the previous literature, highlighting the coincidences, the differences, and the voids that still persist in the domain of the knowledge.

Comparison of benefits: Security, transparency, and efficiency

The suggested results sustain that the ascent in the associated security and the increment in the transparency are the central advantages that the smart traceability reports, observation that coincides fully with the report of Ahamed et al. (12) and of Ge et al. (2). The quality of immutability inherent to the systems based on blockchain is signaled reiteratedly as the most contundent defense against the adulteration and the fraud; Dinh et al. (18) contribute proofs that evidence that this property makes impossible the modification of the registers of origin in the context of organic products. Such strength is potentiated by means of the IoT sensors, which register measurements in real time and eliminate the manual intervention; according to Lin et al. (19), this virtue is translated into an improvement of the exactitude of the information, confirmation that Liu et al. (24) develop in their analysis of the supply chains of vegetables.

The operational efficiency has contributed to our financial results, although its incidence has been less regular than that observed in matter of security and transparency. Said constatation is compatible with the findings of Mondal et al. (7), whose analyses concentrate themselves in the reduction of the deadlines of traceability of contaminated lots but pay scarce attention to the logistic yields that are concretized in more prolonged temporal horizons. In its turn, more recent investigations, such as those of Gupta et al. (27), have begun to illustrate of what mode the synergy between the IoT and Blockchain facilitates the automation of the processes of inventory and attenuation of costs by spoilage, signaling that the operational efficiency begins to occupy a preferential place in the investigative agendas of the sector.

Comparison of challenges: Cost, scalability, and interoperability

In our review, the high cost of implementation emerged as the most cited barrier, appears in the 84.6% of the examined articles. This datum coincides with the results of Kamilaris et al. (5) and Zhao et al. (21), who sustain that the initial financial charge linked to the Blockchain infrastructure and to the network of IoT sensors constitutes the principal obstacle for the universal diffusion, particularly in the case of the small and medium enterprises, which often lack margins to cost both the devices and the necessary expertise. Although corporations such as Walmart can assume the expense and amortize it in economies of scale (18), the remaining actors of the supply chain

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https://doi.org/10.56519/4r3rbq77
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that rarely reunite the same power of purchase find that the financing of the migration to these systems converts itself into an insurmountable challenge.

The problems of scalability and interoperability have returned to highlight their relevance, such as Ahamed et al. (25) had already indicated in their study about the aquaculture, where the absence of common protocols of communication between nodes of Blockchain and IoT sensors was signaled as the predominant technical obstacle. The present finding presents a significant divergence with respect to the majority of the previous investigations, which, in a predominantly theoretical framework, attended to the viability of the technological paradigm without warning the difficulties to which it faces itself in functionally dispersed contexts. The work that is reviewed here advances in that line of inquiry, and puts into evidence that the inclination toward platforms such as Hyperledger Fabric that are based on distributed administrative controls and on an organizational elasticity designed must be interpreted as a strategic decision oriented to amortize said restrictions, aligned with the posture that Li et al. (20) sustain.

Despite the fact that the elements of governance and of confidentiality receive in the literature a less frequent treatment, their analytical weight is, however, indisputably important. Such assertion is supported in the constancy that Sharma et al. (26) grant, who evidence the difficulty of codifying the operative rules of the network and the imperious necessity of evaluating, in a pondered manner, the informative opening against the reservation of the critical data. The review of the literature suggests that the adoption of architectures of permissioned Blockchain constitutes the itinerary that responds to these inquietudes, coincidence that the majority of the contemporary studies shares.

Gaps in the literature and future directions

Despite the notable advance of the knowledge in the area, our review has revealed significant lagunas that justify posterior investigations. In opposition to the current preaching about security and efficiency, scarce studies analyze the temporal effect of the smart traceability over the environmental and social sustainability. The reduction of the food waste is frequently presented as a positive collateral effect; however, we still do not count with studies that quantify directly and systematically until what point such systems induce less destructive agricultural practices, mitigate the carbon footprint of the agri-food chain, or improve the socioeconomic conditions of the producers. This last problematique is uniquely sketched in the conceptual review of Wang et al. (27). The current literature, upon concentrating almost completely in technical metrics and financial evaluations, tends to unlearn the social and environmental dimensions that, under the optic of an integral sustainability, are equally decisive.

Complementarily, an empirical acervo is still required that, through ample and systematically implemented designs, measures the profitability of the interventions in conditions of real operation. The academic production has concentrated its efforts in laboratory trials, as well as in case analyses that occupy limited samples, which impedes an adequate generalization of its results. The future investigations must direct themselves to the creation of platforms that conceive, submit to proof, and validate

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https://doi.org/10.56519/4r3rbq77
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market architectures susceptible of integrating these innovations in the small and medium enterprises, assuring in this mode the conservation of a balanced economic viability.

CONCLUSIONS

The combination of Blockchain architectures with IoT sensors is transforming in a profound manner the form in which the agri-food chains are supervised. Our systematic analysis of the literature shows that the convergence of these technologies surpasses many of the limitations of the traditional systems, upon reducing the risks of fraud and minimizing the exposure to contaminants. The immutability of the decentralized register assures that each lot remains documented in a reliable and auditable history, accompanying it from the field until the final consumer, which reinforces the authenticity of the products and contributes transparency to the entire process. This aspect results key to recover and sustain the public confidence, since the consumer can access a verifiable trajectory of legitimacy.

At the same time, the IoT sensors eliminate the dependence of human intermediaries upon registering in a continuous manner critical parameters such as temperature, humidity, and geographic location. This not only reduces the errors, but also generates a solid documentary support for each lot. In conjunction, the smart traceability presents itself as a strategic tool that strengthens the food security and increases the resilience and adaptability of the network in the face of possible disruptions.

Although its benefits are evident, the generalized implementation of the smart traceability still stumbles with economic and technical limitations that must be addressed in a priority manner. Above all, the initial charge that the modernization of the underlying infrastructure supposes remains as a dominant barrier, given that the deployment of sensors, platforms of analysis, and networks of data involves disbursements that many small and medium enterprises —critical actors of the global chain— cannot confront.

To this financial charge is summed the inherited technical dispersion: the lack of common norms of interoperability and the precariousness of the mechanisms of scaling produce islands of data in which the registers never meet, obstinately fragmenting the continuous trail that the noble traceability requires. Unblocking this double obstacle demands, therefore, to orient the investigation toward architectures of marginal cost and toward the consensual drafting of standards that harmonize the protocols of communication and permit the harmonious integration of heterogeneous devices. The resolution of these problems —far from being a marginal question— results decisive to globalize the access to the technology and so that the benefits of the smart traceability are distributed equitably among the distinct segments of the sector.

Our review shows that there still exists an important gap in the studies: little attention has been paid to the social and environmental effects of these systems. Although the reduction of the food waste appears as a clear benefit, few are the works that analyze in a detailed form how the smart traceability could drive more sustainable agricultural practices, diminish the carbon footprint, or favor a greater equity for the small producers. In addition, the transparency that these technologies offer could influence so that the consumers choose in a more conscious manner, a change that, in the practice, would have the potential of generating positive impacts in the entire agri-food chain.

In virtue of that, it becomes indispensable that the future works amplify their focus of analysis, integrating not only the technical and economic elements, but the ethical and sustainability dimensions. This amplification of the investigative framework would permit that the smart traceability fulfill not only functions of monitoring, but a proactive role in the sustainable transformation of the agrarian sector —evolves beyond the spheres of security and profitability, and consolidates itself, instead, as a tool for the elaboration of a global food system more just, equitable, and environmentally conscious.

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ISSN:
3091-1796
Vol. 3, No. 6, PP.103-119

DOI:
https://doi.org/10.56519/4r3rbq77
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ISSN:
3091-1796
Vol. 3, No. 6, PP.120-141

DOI:
https://doi.org/10.56519/37z7dk98
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RELACIÓN ENTRE RENDIMIENTO ACADÉMICO Y CONDICIONES SOCIOECONÓMICAS DE ESTUDIANTES DE LA FACULTAD DE CIENCIAS POLÍTICAS Y ADMINISTRATIVAS DE LA UNIVERSIDAD NACIONAL DE CHIMBORAZO

RELATIONSHIP BETWEEN ACADEMIC PERFORMANCE AND SOCIOECONOMIC CONDITIONS OF STUDENTS FROM THE FACULTY OF POLITICAL AND ADMINISTRATIVE SCIENCES OF THE NATIONAL UNIVERSITY OF CHIMBORAZO

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Fecha de recepción: 05/08/2025 / Fecha de aceptación: 12/08/2025 / Fecha de publicación: 20/08/2025

RESUMEN: El rendimiento académico universitario constituye un indicador clave para medir la calidad educativa, suele estar condicionado por factores socioeconómicos y familiares que generan desigualdades entre los estudiantes. En la Facultad de Ciencias Políticas y Administrativas de la UNACH esta problemática se evidencia en diferencias de desempeño asociadas al ingreso, recursos disponibles y apoyo institucional, lo que plantea la necesidad de analizar sus determinantes. Este estudio tuvo como objetivos caracterizar los modelos explicativos del rendimiento académico universitario, comparar dicho rendimiento y sus variables socioeconómicas, familiares e institucionales por carrera en la Facultad de Ciencias Políticas y Administrativas, y finalmente, identificar los determinantes específicos del desempeño académico para los estudiantes de esta facultad. La metodología empleada fue cuantitativa, centrándose en el análisis de 2,007 observaciones mediante la aplicación de modelos Logit y Probit, seleccionando este último por su superioridad demostrada a través de los criterios AIC y BIC. El modelo Probit permitió evaluar el impacto de diversas variables como la situación de ingresos, los costos educativos percibidos, el nivel educativo de los padres, el acceso y los recursos educativos en el hogar, el apoyo docente, el ambiente familiar, la situación laboral y la propia carrera académica. En conclusión, los resultados revelaron una compleja interacción de factores: Mientras que algunos determinantes como el efecto negativo de trabajar o el impacto positivo de los recursos educativos en el hogar y el ambiente familiar se alinean con la literatura general, se observaron hallazgos contraintuitivos significativos, como la asociación negativa de una mejor situación de ingresos o un mayor acceso a recursos educativos con un rendimiento académico superior, y la no significancia del nivel educativo parental. Estas particularidades sugieren dinámicas específicas en la población estudiantil analizada, lo que subraya la necesidad de un enfoque diferenciado en futuras investigaciones y en la implementación de políticas de apoyo.

Palabras clave: Determinantes, estudiantes universitarios, factores socioeconómicos, modelo probit y rendimiento académico

English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 127-141.

ISSN:
3091-1796
Vol. 3, No. 6, PP.120-141

DOI:
https://doi.org/10.56519/37z7dk98
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ABSTRACT: University academic performance is a key indicator for measuring educational quality, but it is often conditioned by socioeconomic and family factors that generate inequalities among students. At the Faculty of Political and Administrative Sciences of UNACH, this problem is evident in differences in performance associated with income, available resources, and institutional support, which raises the need to analyze its determinants. This study aimed to characterize the explanatory models of university academic performance, compare performance and its socioeconomic, family, and institutional variables by program in the Faculty of Political and Administrative Sciences, and finally, identify the specific determinants of academic performance for students in this faculty. The methodology employed was quantitative, focusing on the analysis of 2,007 observations through the application of Logit and Probit models, selecting the latter for its demonstrated superiority using the AIC and BIC criteria. The Probit model allowed for the evaluation of the impact of various variables such as income status, perceived educational costs, parents' educational level, access to and resources at home, teacher support, family environment, employment status, and the academic program itself. In conclusion, the results revealed a complex interaction of factors: While some determinants, such as the negative effect of working or the positive impact of educational resources at home and in the family environment, are consistent with the general literature, significant counterintuitive findings were observed, such as the negative association of higher income status or greater access to educational resources with higher academic performance, and the nonsignificance of parental educational level. These particularities suggest specific dynamics in the student population analyzed, underscoring the need for a differentiated approach in future research and in the implementation of supportive policies.

Keywords: Determinants, university students, socioeconomic factors, probit model, and academic performance

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INTRODUCTION

The academic performance of university students constitutes a central indicator to evaluate both the quality of the educational process and the efficacy of the institutional policies. In the context of the Faculty of Political and Administrative Sciences of the National University of Chimborazo, understanding the variations in the academic performance acquires particular relevance because it permits identifying academic and socioeconomic obstacles that affect the formative trajectory of future professionals in areas linked with the governance, the public management, and the

ISSN:
3091-1796
Vol. 3, No. 6, PP.120-141

DOI:
https://doi.org/10.56519/37z7dk98
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social investigation. In addition, analyzing the performance beyond the qualifications incorporating economic, family, social, individual, and institutional dimensions makes possible designing more integral and pertinent interventions to the local characteristics of the student population.

The literature about academic performance presents multiple explanatory approaches: economic models that emphasize the cost-benefit relation and the investment in human capital; psychological perspectives that highlight the motivation, the study habits, and the self-control; sociological approximations that underline the social capital and the support networks; and organizational analyses that point to the influence of the teaching staff, the infrastructure, and the institutional policies. These theoretical frameworks, when they are integrated, permit constructing a multifactorial model that recognizes the complexity of the phenomenon and avoids simplistic explanations. In the case of the National University of Chimborazo, it is precise to adapt and contrast said models with the local reality to identify which factors have greater weight in the performance by career within the faculty.

The academic performance of the university students is a multifactorial construct, profoundly influenced by their socioeconomic conditions. For the Faculty of Political and Administrative Sciences of the National University of Chimborazo, understanding this interaction is crucial to design effective support strategies and foment the equity. The recent literature demonstrates consistently how factors such as the family income, the schooling of the parents, the access to technological resources, and the conditions of habitability impact directly in the capacity of the students to dedicate themselves to the study and reach their maximum potential.

Diverse quantitative studies have explored the direct relation between the family income and the academic success. For example, in an investigation that utilized a correlational design and surveys to 300 university students in a public university in Peru, (1) found that a greater family income correlated significantly with higher averages of qualifications, suggesting that the economic stability reduces the necessity to work and permits greater dedication to the study. In the same line, (2), through a multivariate regression analysis with data of 500 students of social sciences in Colombia, demonstrated that each increase in the quintile of family income per capita was associated with a probability 1.5 times greater of approving all the inscribed subjects in the semester.

The schooling of the parents also emerges as a critical factor, influencing not only the academic support in the home but also the expectations and the educational investment. (3) realized a multiple case study with in-depth interviews to 40 students and their parents in Chilean universities, revealing that the students with parents with superior education manifested greater confidence in their academic abilities and accessed more complementary educational resources. Complementarily (4), by means of a quasi-experimental design that compared groups of students with different levels of parental schooling in a sample of 600 Mexican university students, concluded that the schooling of the parents acted as a significant predictor of the university persistence, even controlling by the current socioeconomic status.

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DOI:
https://doi.org/10.56519/37z7dk98
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The access and the competence in the use of the Information and Communication Technologies (ICT) are equally determinant in the digital era. A transversal study of (5), applying a questionnaire to 450 students of political sciences in an Argentine university, reported that the access to high-speed internet and the possession of personal devices (laptop/tablet) related positively with the active participation in virtual learning platforms and the use of digital libraries. On the other hand, (6), utilizing a mixed method with surveys and focus groups with students of administration of an Ecuadorian university, identified that the lack of advanced digital skills or the connectivity gap in the home resulted in lesser opportunities of completing online tasks and of accessing updated bibliographic material, affecting their performance in courses with high technological demand.

The conditions of habitability, including the quality of the housing, the access to basic services, and an adequate study environment, also have a substantial impact. (7), in an investigation that combined census data and surveys to 350 students in urban zones of Brazil, found that the overcrowding in the home and the lack of a tranquil space for the study were associated with elevated levels of stress and a lesser performance in subjects that required high concentration. In a similar form, (8), by means of a longitudinal study that followed 200 students during two years in a Peruvian university, observed that those who reported improvements in their housing conditions (e.g. access to sanitation, reduction of environmental noise) experienced an average improvement of 5% in their final qualifications, highlighting the importance of the physical environment.

Beyond the direct economic factors, the family support and the perception of the parental expectations exercise a notable influence (9), through semi-structured interviews to 50 first-year students of social sciences in Ecuador, revealed that the perception of a strong emotional and academic support on the part of their families, independently of their level of incomes, contributed to a greater motivation and resilience in the face of the university challenges. In contrast, (10), in an exploratory factorial analysis of a scale of parental expectations applied to 700 students in Colombia, concluded that the high academic expectations, when they were not accompanied by resources or effective support, could generate anxiety and, paradoxically, a negative impact in the performance.

The labor insertion during the studies is another socioeconomic variable with a double edge (11), in a correlational study with 400 students who worked while studying in universities of Chile, identified that those who worked more than 20 weekly hours showed a significant decrease in their average of qualifications and a greater rate of abandonment. However, (12), through an analysis of variance in a sample of 300 university students in Argentina, highlighted that the part-time work (less than 15 hours/week) could, in some cases, improve the development of soft skills and the time management without affecting negatively the performance, especially if the employment was related with their area of study.

The geographic origin and the networks of social support in the new university environment are also relevant socioeconomic aspects (13), in a comparative study

ISSN:
3091-1796
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between rural and urban students of the same university in Bolivia, found that the students of rural zones faced greater challenges of adaptation and performance, often due to the lack of initial support networks and the limited familiarity with the university resources (14), in a case study of 30 first-generation university students in El Salvador, concluded that the participation in mentoring programs and the creation of support networks among peers were crucial to mitigate the negative impact of the socioeconomic disadvantages, promoting the integration and the academic success.

The socioeconomic conditions of the students —family income, employment, access to scholarships, and material resources— have a direct impact in their time of study, permanence in the university, and academic performance. In equal manner, the family capital and the domestic environment (emotional support, expectations, and responsibilities) can favor or hinder their performance, affecting the qualifications, the failing, and the continuity in the careers.

In the institutional context, factors such as the quality of the teaching, the size of the classrooms, the academic resources, and the support policies (tutorings and scholarships) can reduce or intensify these inequalities. The analysis by career shows internal differences that guide specific interventions to improve the academic management. The results of this investigation will provide local evidence that will permit the National University of Chimborazo to develop policies and strategies that strengthen the equity, the progression, and the academic success, especially for the students who face greater socioeconomic disadvantages.

Income: The factors that a student presents upon entering the educational system such as the socioeconomic conditions, the previous academic performance, the personal characteristics, and the institutional support have a direct impact in their posterior performance (15). Bronfenbrenner argues that the family incomes are determinant for the access to educational resources of quality (technology, books, tutors), which favors the preparation for the university (16).

In this sense, the income is defined as the economic flow that permits maintaining the education, either through family resources or external aids (scholarships, employments, institutional supports). A stable income diminishes the labor pressure and increases the student retention, while the scholarships and financial supports are fundamental to mitigate inequalities and assure the equity in the access to an education of quality (17), (18).

Schooling of the parents: The education of the parents, understood as the academic level reached by the progenitors, presents itself as a solid indicator of the performance and academic trajectory of the children, upon influencing in the available resources, the family expectations, and the support practices in the home (19); (20). In the Latin American context, this aspect relates with inequalities in the access to learning opportunities and in the academic aspirations, which puts into evidence the necessity of articulating institutional strategies with the family support (21).

The educational level of the parents, from the primary education until the superior, impacts directly in the academic achievements of the students, in such a manner that lower levels of schooling associate with an inferior academic performance, while the

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teachers play a complementary role in the reduction of these gaps (22). In addition, the parents with a higher formation tend to transmit the importance of the academic effort and to create environments where the educational achievements are recognized and reinforced, acting as positive models that inspire the children to reach their maximum potential (23).

Access to the information and communication technologies: The access to the ICT includes the availability of devices, the connectivity, and the digital skills necessary to integrate them in the learning processes. The educational digital gap creates disadvantages among the students who count with limited technological resources, which affects their performance and academic participation. Recent investigations demonstrate that having devices and an adequate connection is related with better learning opportunities (24) and that the digital literacy, together with the institutional support, are fundamental to take maximum advantage of their potential (25).

In this context, the ICT are a key element in the university formation, since they facilitate the access to resources, foment the collaboration, and potentiate the investigation, which has a positive impact in the academic performance (26). In addition, they promote the interaction among students, teachers, and educational communities through forums, videoconferences, and social networks, creating spaces of exchange and feedback that reinforce the learning (27).

Conditions of habitability: The conditions of habitability encompass the material and environmental aspects of the living environment such as housing, sanitation, security, and access to basic services that impact directly in the capacity of the students to learn and perform academically. An adequate environment favors the concentration, the attendance to classes, and the participation in formative activities, while precarious conditions generate stress, absenteeism, and low performance.

In this sense, it has been demonstrated that a stable and secure housing relates with better educational results (28) and that the access to basic services and to a domestic space propitious for the study contribute to the educational equity (29). Likewise, the habitability constitutes a key factor in the economic and academic development, since an appropriate environment permits rest, concentration, and continuity in the learning process, while deficient conditions represent significant barriers (30). Elements such as the illumination, the noise, the temperature, and the ventilation influence in the capacity of concentration, equally as the availability of basic services, whose absence limits both the academic performance and the essential tasks of the daily life (31).

Conceptualization of the institutional variables (teachers, classroom size, scholarships) that influence in the academic performance

In the sphere of the factors that influence in the academic performance, the institutional variables play a crucial role. The investigations indicate that the participation of the teachers has a significant impact in the academic performance of the students, and that the interest of the parents also plays a positive role.

In addition, the institutional factors, such as the favorable learning facilities and the proportion between teachers and students, correlate positively with the academic

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https://doi.org/10.56519/37z7dk98
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performance of the students. It has been demonstrated that the large size of the classes influences negatively in the academic performance of the students, which limits their learning opportunities, while a good psychological environment in the classes improves the academic results.

Teachers: The implication of the educators has a crucial effect in the academic performance of the students, even surpassing factors such as the institutional management. The individual benefits provided to the teachers such as the selection of students, permits, recognition, economic incentives, and non-monetary rewards reinforce their commitment and participation, which impacts in a positive manner in the student performance both in the short and in the long term (32).

The quality of the teaching, the qualifications, the experience, and the pedagogical methods utilized affect directly the learning and the motivation of the students. Studies demonstrate that the well-trained teachers and who employ attractive teaching strategies, timely feedback, and additional support improve the comprehension and the academic results (33). In equal manner, the establishment of positive relations, an effective communication, and a support environment in the classroom relate with greater levels of participation and academic success, consolidating the teaching labor as a fundamental pillar in the educational trajectory (34).

Classroom size: The size of the class and the management of the classroom have a direct impact in the academic performance. Studies highlight that the more reduced classes promote a personalized attention, a greater participation, and an effective interaction between students and teachers, which is translated into a better academic performance. In contrast, in numerous classes the individualized attention and the learning opportunities are reduced, creating environments...

MATERIALS AND METHODS

To address the objective of this quantitative study, primary data were collected from 2,007 students from the Faculty of Political and Administrative Sciences at UNACH during the 2024-2S academic term. A survey instrument consisting of 24 closed-ended questions describing the various dimensions of academic performance was administered.

The dimensions included Economic Factors, with 5 items exploring perceptions of income, technology access, and educational costs; Social Variables, with 4 items analyzing the influence of relationships, family environment, and social support; Institutional Variables, with 5 items focused on teaching quality, resources, and faculty support; Family Variables, with 5 items investigating parental education level and household climate; and finally, Individual Variables, with 5 items addressing study habits and personal well-being.

Data processing was conducted using an Ordinal Logit or Probit model, where the dependent variable—representing cumulative grade point average (GPA)—is ordinal in nature and categorized into four specific levels: Category 1 encompasses GPAs between 6.1 and 7; Category 2 includes GPAs between 7.1 and 8; Category 3 comprises GPAs between 8.1 and 9;

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3091-1796
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DOI:
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and Category 4 represents GPAs above 9. The explanatory variables were operationalized across the 5 dimensions mentioned above.

Mathematical Expression of the Model

Let Y_i be the observed ordinal dependent variable for individual i (cumulative GPA), with K ordered categories. We assume that cumulative GPA is a categorization of an unobserved continuous latent variable, Y_i^*.

The relationship between the latent variable and the explanatory variables is defined as follows:

$$Y_i^* = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_3 X_{3,i} + \beta_4 X_{4,i} + \beta_5 X_{5,i} + \beta_6 X_{6,i} + \beta_7 X_{7,i} + \beta_8 X_{8,i} + \beta_9 X_{9,i} + \beta_{10} X_{10,i} + \beta_{11} X_{11,i} + \beta_{12} X_{12,i} + \beta_{13} X_{13,i} + \beta_{14} X_{14,i} + \beta_{15} X_{15,i} + \beta_{16} X_{16,i} + \beta_{17} X_{17,i} + \beta_{18} X_{18,i} + \beta_{19} X_{19,i} + \beta_{20} X_{20,i} + \beta_{21} X_{21,i} + \beta_{22} X_{22,i} + \beta_{23} X_{23,i} + \beta_{24} X_{24,i} + \varepsilon_i$$

Where:

- Y_i^*: is the latent variable (cumulative GPA) for individual i.
- β_j: are the coefficients to be estimated for each explanatory variable.
- ε_i: is the random error term.

X (Explanatory / Independent Variables): Each $X_{j,i}$ represents one of the independent variables for student i, which are:

Variable	Description
$X_{1,i}$	Income status
$X_{2,i}$	Education quality
$X_{3,i}$	Class size
$X_{4,i}$	Access to educational resources
$X_{5,i}$	Faculty support
$X_{6,i}$	Infrastructure support
$X_{7,i}$	Parents' education level
$X_{8,i}$	Household emotional climate
$X_{9,i}$	Parental involvement in university education
$X_{10,i}$	Household culture
$X_{11,i}$	Household size effect
$X_{12,i}$	Income effect
$X_{13,i}$	Schedule frequency
$X_{14,i}$	Study time
$X_{15,i}$	Concentration level
$X_{16,i}$	Sleep quality
$X_{17,i}$	Exercise frequency
$X_{18,i}$	Educational resources available at home
$X_{19,i}$	Employment effect
$X_{20,i}$	Educational cost effect

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$X_{21,i}$	Peer effect
$X_{22,i}$	Family environment effect
$X_{23,i}$	Teacher effect
$X_{24,i}$	Social pressure effect

RESULTS

Marginal effects of the Probit model by performance categories

Regarding the access to educational resources for each category it is interpreted:

• Category 1 (Average 6.1-7): An increase in the access to educational resources is associated with an increase of approximately 2.84 percentage points in the probability that a student has an average in this range.

• Category 2 (Average 7.1-8): An increase in the access to educational resources is associated with an increase of approximately 4.91 percentage points in the probability that a student has an average in this range.

• Category 3 (Average 8.1-9): An increase in the access to educational resources is associated with a decrease of approximately 4.50 percentage points in the probability that a student has an average in this range.

• Category 4 (Average >9): An increase in the access to educational resources is associated with a decrease of approximately 3.25 percentage points in the probability that a student has an average in this range.

Regarding the effects of the cost of the education for each category it is interpreted:

• Category 1 (Average 6.1-7): An increase in the perceived effects of the cost of the education is associated with an increase of approximately 1.73 percentage points in the probability that a student has an average in this range.

• Category 2 (Average 7.1-8): An increase in the perceived effects of the cost of the education is associated with an increase of approximately 2.98 percentage points in the probability that a student has an average in this range.

• Category 3 (Average 8.1-9): An increase in the perceived effects of the cost of the education is associated with a decrease of approximately 2.73 percentage points in the probability that a student has an average in this range.

• Category 4 (Average >9): An increase in the perceived effects of the cost of the education is associated with a decrease of approximately 1.98 percentage points in the probability that a student has an average in this range.

The income situation reflects that:

• Category 1 (Average 6.1-7): An increase in the income situation (assuming that a higher value is a better situation) is associated with an increase of approximately 1.75 percentage points in the probability that a student has an average in this range.

• Category 2 (Average 7.1-8): An increase in the income situation is associated with an increase of approximately 3.02 percentage points in the probability that a student has an average in this range.

Ecuacientifica
ISSN:
3091-1796
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• Category 3 (Average 8.1-9): An increase in the income situation is associated with a decrease of approximately 2.77 percentage points in the probability that a student has an average in this range.

• Category 4 (Average >9): An increase in the income situation is associated with a decrease of approximately 2.00 percentage points in the probability that a student has an average in this range.

While in the variable educational resources in the home, it is interpreted that:

• Category 1 (Average 6.1-7): An increase in the educational resources in the home is associated with a decrease of approximately 1.74 percentage points in the probability that a student has an average in this range.

• Category 2 (Average 7.1-8): An increase in the educational resources in the home is associated with a decrease of approximately 2.99 percentage points in the probability that a student has an average in this range.

• Category 3 (Average 8.1-9): An increase in the educational resources in the home is associated with an increase of approximately 2.74 percentage points in the probability that a student has an average in this range.

• Category 4 (Average >9): An increase in the educational resources in the home is associated with an increase of approximately 1.99 percentage points in the probability that a student has an average in this range.

DISCUSSION

The general literature, represented by (1) and (2), postulates a direct and positive relation between a greater family income and a better academic performance, suggesting that the economic stability facilitates the dedication to the study. However, the results of their Probit model present a notable contradiction: the variable "Income situation" shows a negative coefficient, indicating that an increase in the incomes (or a better situation) is associated with a greater probability of being in inferior categories of performance. Similarly, the "Effects of the educational costs" perceived also associate negatively with the performance. This divergence is a critical finding that suggests a particular dynamic in their population, where socioeconomic factors apparently advantageous do not translate into a better academic performance, which requires a profound review of the underlying hypotheses or of the coding of the variables.

Authors such as (3) and (4) emphasize consistently the crucial role of the parental schooling as a positive predictor of the performance and the university persistence, influencing in the support and the expectations in the home. In contrast, their Probit model found that the variable "Educational levels of the parents" was not statistically significant. This absence of significance in a factor so traditionally influential is one of the most striking divergences with the literature, suggesting that, for their specific population, other factors could be mediating or annulling the direct effect of the educational level of the progenitors.

The literature of (5) links the access to ICT with a greater participation and performance, while (6) highlights the negative impact of the lack of digital skills. Their

ISSN:
3091-1796
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DOI:
https://doi.org/10.56519/37z7dk98
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results show an interesting duality: the variable "Access to educational resources" presents a negative coefficient, which, equally as the income, associates counterintuitively with a greater probability of lower performances. This differs directly from Dávila and López and suggests that the simple access does not guarantee an effective use, or even could imply distractions. Nevertheless, the variable "Educational resources in the home" does show a positive and significant coefficient, aligning with the idea that a family environment with available study materials favors the performance.

The investigation of (7) and (8) highlights the influence of the housing conditions in the well-being and academic performance. Their model, although it does not include a direct variable of "overcrowding", does show that "Educational resources in the home" and a positive "Family environment effect" associate with a better performance, which aligns with the importance of a propitious environment for the study and the emotional well-being. Regarding the family support, (9) underline the importance of the emotional support. In consonance, their model validates the positive significance of the "Family environment effect". However, the variable "Peer effect" resulted negative, which could contradict the notion of positive support networks, and the non-significance of the "emotional climate of the home" or "involvement of the parents" also merits a reflection. On the other hand, the prediction of (10) about the potential negative of high parental expectations not supported does not have a direct confirmation in their model with a significant variable.

Regarding the labor insertion, (11) indicate a negative impact with high loads of work. Their model corroborates it upon finding that the "Effect of working" has a negative and significant coefficient, which validates the notion that the employment during the studies is a factor that can compromise the performance. In relation with the geographic origin, (13) highlights the challenges for rural students, while (14) emphasize the positive role of mentoring programs. Their model does not include direct variables for the geographic origin, but the implications of the support networks (although the "Peer effect" is negative) and the family environment are indirectly relevant. The "career" also emerges as a negative factor, suggesting that certain disciplines or academic trajectories can present greater challenges for the success.

CONCLUSIONS

The analysis confirmed that the academic performance in the Faculty of Political and Administrative Sciences of the UNACH responds to a multifactorial model in which socioeconomic, family, institutional, and individual variables interact. The Probit model demonstrated greater explanatory capacity than the Logit, evidencing that this type of statistical tools are pertinent to study complex educational phenomena and avoid simplistic interpretations.

The results showed that, although factors such as the work during the studies reduce the performance and the educational resources in the home together with the family environment potentiate it, also counterintuitive findings emerged. A better income situation or a greater access to resources did not always translate into a superior

ISSN:
3091-1796
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https://doi.org/10.56519/37z7dk98
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performance, which indicates that the socioeconomic conditions do not act in a linear manner and require a differentiated analysis by career and context.

Key determinants were identified as the negative effect of the work and of the educational costs, as well as the positive effect of the educational resources in the home, the teacher support, and the family environment. These findings permit concluding that the academic performance does not depend uniquely on the economic incomes, but on the interaction between family capital, study conditions, and institutional accompaniment, which demands from the university to design more focalized support policies to attend to students in situation of vulnerability.

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English translation of the original article published in Ecuacientífica, Vol. 3, No. 6, pp. 127-141.