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SPECIAL ISSUE

Sustainable finance: The role of savings and credit cooperatives in Ecuador

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Abstract

The current world situation leads us to consider that sustainable development needs to be a global priority to ensure the future of the planet and improve the quality of life. There is a need for sustainable finance to support this. Savings and credit cooperatives could help to achieve this impact as they serve the microfinance and microlending market. They facilitate the financial inclusion of the most vulnerable people, most of whom live in rural areas and are members of organizations, such as agricultural cooperatives and associations. Previous studies have focused exclusively on overall profitability, so this paper contributes to extending the literature by analyzing the whole population of savings and credit cooperatives in Ecuador (510 institutions), focusing on their profitability in two ways: the overall profitability necessary for the viability of the business and, in addition, the microcredit portfolio profitability, as a specific measure of its contribution to sustainability and social value creation. Another novelty is that the analysis has been carried out using several machine learning techniques for the wider generalization of the results. These

show that size is the most relevant variable for predicting the ROE and that the microcredit portfolio profitability is conditioned by the credit variables.

KEYWORDS
machine learning, microcredits, savings and credit cooperatives

1 | INTRODUCTION

The current world situation leads us to consider that sustainable development, based on the three basic pillars of economic, social and environmental development, needs to be a global priority. All this has encouraged the adoption of new economic approaches and there is growing demand and interest in moving towards a more inclusive form of capitalism and making a transition to a stakeholder-based corporate governance model (Parmar et al., 2010). The basic principle of this model, the maximization of wealth for all stakeholders and not just owners, combined with environmental, social, and governance (ESG) issues, could create a new economic paradigm. In fact, the so-called social economy and social enterprises such as cooperative societies have provided ample evidence of their important role in the international economy and their capacity to combine the three objectives mentioned, namely economic, social, and environmental development (Bernardi et al., 2021; Hudon & Huybrechts, 2017; Kim et al., 2020). Cooperatives are enterprises whose identity is based on their values and cooperative principles that enable and facilitate the new social and entrepreneurial contract, necessary to achieve sustainability and overcome the unprecedented challenges. The cooperative identity is naturally aligned with the objectives of the 2030 Agenda for Sustainable Development, there being an important consensus about the essential and decisive role cooperative societies play in sustainable development (Novkovic, 2022). In critical situations, this can create, manage, and enable a fairer, more inclusive and more resilient recovery in times of crisis, especially after COVID-19, largely due to its principles of solidarity and community care.

As a result, there is a need for sustainable finance to form the backbone of sustainable development. Defining sustainable finance in an exhaustive manner is not an easy task and this means that there is currently no consensus and universal definition of what sustainable finance is. According to Migliorelli (2021), sustainable finance should be understood today as "finance for sustainability". In this sense, sustainable finance would include two interconnected issues. The first is the identification of the possible dimensions of sustainability (preservation of the environment and ecosystems, conservation of biodiversity, the fight against climate change and the eradication of poverty and hunger). The second is the evaluation of the contribution of each sector or economic activity to the achievement or improvement of at least one of the dimensions of sustainability, which would involve identifying the areas that merit sustainable financing. Based on these two aspects, a definition of sustainable finance could be determined in accordance with the current context: "finance to support sectors or activities that contribute to the achievement of, or the improvement in, at least one of the relevant sustainability dimensions" (Migliorelli, 2021).

It has become evident that over the long-term this will optimize the social and environmental impact while providing financial value (Schoenmaker & Schramade, 2018) and that savings and credit cooperatives could be one type of economic organization capable of achieving this

impact (Cornée et al., 2023). A critical aspect of savings and credit cooperatives' activity, especially in developing countries, is precisely their focus on the microfinance and microlending market. This is because such financing is the most requested by their members and customers, as it is commonly used for investing in small enterprises who will repay the loan (Zavala et al., 2020). Therefore, microlending managed by cooperative societies has a strong impact on local populations as it can contribute to their development in three ways: access to financial services that would otherwise be more difficult, improvement in infrastructures and microenterprises. Therefore, savings and credit cooperatives are a key channel for promoting financial inclusion and an essential element of both sustainable development and microenterprises by providing access to and delivering microlending (Maia et al., 2019).

This is particularly relevant in Ecuador, where the excluded population is found largely in rural areas. The savings and credit cooperatives (COACs, in Ecuador) finance rural activities and enterprises, contributing to poverty reduction. The cooperative financial sector is recognized for its importance in the country's financial system, indicating user confidence and sector establishment (SEPS, 2022). The importance of COACs has led to legislation for the larger ones that is considered rigid, the aim being to avoid the high systemic risk that poor management would imply. The economic impact of financial cooperatives is of the utmost importance to their economic and social development. So, based on the characteristics and type of activity and services of savings and credit cooperatives in these countries (Orellana & Rodríguez, 2021), analyzing them allows us to draw generalizable conclusions about the behavior patterns of these institutions in countries where the presence of cooperatives is being strengthened, and thus contribute to their economic viability. Nevertheless, despite the importance of this sector in Ecuador, only limited and partial research has been conducted on savings and credit cooperatives and their profitability. Although there is some more extensive research (Cadena Tomalo, 2018; Luque & Peñaherrera, 2021; Torres-Inga et al., 2022), this is very scarce despite the importance of this sector. Consequently, a broader study of the entire cooperative credit sector is needed, focusing on profitability as a guarantee of the fulfilment of the social purposes of cooperatives.

Bearing in mind all these issues, the objective of this paper is to analyze the whole population of savings and credit cooperatives in Ecuador, focusing on their profitability from two points of view: the overall profitability (using ROE) of the company necessary for the viability of the business and the profitability of the microlending portfolio, as a specific measure of their contribution to sustainability and the creation of social value. Microcredit is one of the products that cooperative institutions offer to provide the population with more income for financing and thus enable them to carry out their entrepreneurial and innovation projects. In this way, they would be contributing to reducing income inequality and the poverty index could be lowered. Savings and credit cooperatives are the institutions within the Ecuadorian financial system that offer the highest proportion of microcredits. According to the Central Bank of Ecuador, in 2018, 66% of the credit granted by COACs was accounted for by microcredits (Morales, 2018). In this way, this research improves the understanding of how these institutions can be better managed and contribute effectively to the strengthening of an inclusive financial system.

In addition, this paper presents the novelty of the way in which the proposed analyses will be carried out. Despite the popularity of parametric models, such as the commonly used logit regression model for the analysis of profitability, another research approach currently being used to examine financial problems is based on non-parametric techniques, such as artificial intelligence. As a result, this study will use several methods, namely a decision tree, Random Forest and Gradient Boosting Machine learning (it should be noted that much of the empirical research on savings and credit cooperatives uses data envelopment analysis, DEA, (McKillop & Wilson,

2011)). The combination of several machine learning techniques results in a comprehensive analysis of the problem from several points of view, that is, a combination of methods allows us to generalize the usefulness of individual predictor variables more widely.

The results show that size is the most significant variable in predicting the ROE of the COACs, while the prediction of the profitability of the microlending portfolio is conditioned by the credit variables (that is, the implicit lending rate and credit spread). Consequently, it can be concluded that the viability of savings and credit cooperatives is closely related to the cooperative principle of open doors and the economic participation of their members in the cooperative activity (asset, equity, and interest income) and their commitment and trust in the services they offer. This leads to greater penetration in the community. In addition, the particular behavior of the microlending portfolio is highlighted, since in this case, the fundamental variable for its viability is the relationship between the credit variables. This analysis shows that there must be a neutral behavior in this portfolio, or in other words, there must be a balance between depositors and borrowers.

The main contributions of the paper to the existing literature are as follows. First, to the authors' knowledge, it is the first study to analyze the whole savings and credit cooperative sector in Ecuador in depth, focusing on profitability. This ensures that the paper is free from the sampling errors and reporting biases that are features of survey data. Second, given the importance of microlending as a tool for achieving financial inclusion and sustainable development, we analyze which variables are most significant for predicting the profitability of the microlending portfolio. This is all bearing in mind that savings and credit cooperatives must meet two simultaneous objectives: a social, economic and environmental impact and economic-financial viability, the second being required to produce the first. To the extent that the business of cooperatives is conducted with their members, and their members are in turn the owners, savings and credit cooperatives face a potential conflict between borrowing members (who want access to low-cost credit) and saving members (who want a high rate of return on invested funds) (Mercer et al., 2019). In this way, analyzing the microlending portfolio and its viability will show whether cooperatives are an effective vehicle for poverty alleviation and sustainable development or whether improvements need to be made to ensure that these programmes work. Furthermore, considering that the loan portfolio is the one most closely linked to the social impact of their activities, we intend to analyze whether there is a dominant group, depositors or borrowers, in savings and credit cooperatives. The literature on member group dominance in savings and credit cooperatives outside the United States remains scarce especially in emerging market economies. In this context, the investigation of such behavior in Ecuador enriches the discussion due to the idiosyncrasies of its financial system. Finally, the paper validates the usefulness of a variety of machine learning tools in solving the task of predicting the profitability of a specific type of financial institution, in this case savings and credit cooperatives.

The paper starts with a literature review. In the next sections, information is provided about the dataset, variables, and methods applied in this study. After that, the main results of the study are presented. The paper ends with some conclusions and policy implications.

2 | LITERATURE REVIEW

2.1 | Sustainable development and cooperatives: special focus on farmers' organizations

A revision and rethinking are taking place about how social and solidarity economy enterprises, including cooperatives, can and must play a key role (Guzman et al., 2020) in the achievement of sustainability. This is not only in terms of business sustainability specifically, but also in terms of the more demanding and broader sustainable development goals related to the planet, prosperity and people (Utting, 2018). Cooperatives have characteristics allowing them to become a differentiating element in the achievement of these challenges (Novkovic, 2022; Organización Internacional del Trabajo, 2022). There are several reasons for this enormous potential to contribute to sustainable development.

First, sustainability requires transformations in all spheres. There is a need to promote business organizations that create economic value, but above all that are oriented towards people and their needs, and, therefore, have a social impact that can extend beyond the communities in which they operate (Doherty et al., 2014). This orientation requires the involvement, motivation and active participation of the individuals who make up these organizations and the values on which they are based (Guzman et al., 2020; Novkovic, 2022). Cooperatives have this social approach precisely because they have two aspects that are different from other organizations: why they do things and how they do them. The first is related to their business objectives, which instead of being based on maximizing the benefit to capital contributors (Novkovic, 2022), are based on meeting the unsatisfied needs of their members through participation in cooperative activity and democratic governance (active participation). This is what provides the economic rights and constitutes the basis for the rights to the surpluses generated (Novkovic, 2018).

Second, the concept of sustainable development expressed in the 17 SDGs requires business organizations to accelerate the sustainability process. This acceleration, from the business level, can occur if there are companies trained in this formulation, that do not require major transformations and that have sufficient volume and presence to generate an impact. Both conditions are met by social economy enterprises, especially cooperatives. It can be argued that cooperatives are trained in this approach and do not require very relevant transformations since they are organizations whose principles are aligned with this stream of the SDGs (Bretos & Marcuello, 2017).

Third, sustainable development will only be real if it is inclusive at all levels (individual, local, regional, national, and transnational) and, therefore, it is not just multinationals that will have a key role in achieving it. This will require organizations that are present in other areas, since high poverty rates are often found in small, vulnerable, and conflict-affected countries. In this sense, social economy enterprises provide a model in which changes occur especially through local, regional and national action, making a significant contribution to regional development. In fact, the literature has widely recognized that cooperatives have a positive influence in socio-economic terms on the people involved in the business and the region in which they are located (Guzman et al., 2020).

Fourth, another essential factor for the achievement of sustainability is the need to promote entrepreneurship and social entrepreneurship, so that citizens can meet their needs through business initiatives, since the creation of enterprises is a driver of employment and economic growth. There is evidence of how certain factors present in cooperatives promote entrepreneurship, rang-

ing from the perception of the cooperative model as favouring equality to its social orientation or its governance. The identification of these factors provides, in turn, a tool for designing more effective public policies aimed at promoting the social economy (Bastida et al., 2022).

The fifth element, the presence of an ecosystem and a collaborative institutional context that supports cooperatives can create an adequate framework for the development of sustainable business initiatives (Rosati & Faria, 2019). Many countries have recognized their great potential and have already included cooperatives in their plan for medium and long-term growth. In the case of Ecuador, the cooperative and associative sector has experienced substantial growth, especially since the Montecristo Constitution (2008), as the economic system has gone from being social market to social and solidarity and the national financial system is now composed of public, private and social and solidarity sectors. Thus, between 2007 and 2016, the percentage of people with multidimensional poverty decreased from 51.5% in 2009 to 35.1% in 2016; that is, 1.8 million people improved their conditions of access to a decent life (SNPD, 2017). In 2020, the popular and solidarity economy (PSE), including associations and cooperatives, had more than 5 million members, of which 28.03% were women linked to the sector and 21.75% were young people (SEPS, 2020). This context also influences the ability to maintain the cooperative essence and therefore whether there is a greater or lesser impact on development. Thus, in a region where people are more aware of this movement and its philosophy, cooperatives run their business activity in a way that is more oriented towards the cooperative nature and even with higher business quality (Guzman et al., 2020). However, this potential may be obscured if cooperative principles and values in practice are not present or become diluted due to institutional isomorphism with other conventional business organizations, i.e. when the cooperative essence disappears (Mori, 2014; Novkovic, 2022). So, there are some obstacles in fulfilling this role and they are associated partly with capitalisation and agency issues, and partly with the possibility of not utilising the principles and values to their full potential (Novkovic, 2008).

Sixth, sustainable development also requires business organizations that not only accelerate change, but also sustain it over time and across generations, thus being flexible and resilient organizations with a long-term vision. They have an economic and financial regime that allows them to adjust in a different way to conventional enterprises in times of crisis (Novkovic, 2008). In addition, the link between agricultural cooperatives and associations and the SDGs is remarkable. The goals where the agri-food sector could have a special impact are: producing food (Goal 2), facilitating economic structure and activity (Goals 8 and 9) in a more responsible way and respecting the environment (Goals 7, 12, and 13) and contributing to stop the deterioration of the planet (Goals 5, 15), doing so through cooperation (Goal 17) and education (Goal 4).

An agricultural associative and solidarity movement exists in almost every country in the world, being well represented in developed countries as well as in emerging and developing ones, contributing to meeting essential needs, such as the alleviation and reduction of hunger and poverty, as well as food security in different areas of the world. Smallholder farmers could gain benefits such as bargaining power in purchasing inputs or product sales, resource sharing, and securing farmers' rights from agricultural cooperatives (Moon & Lee, 2020). Through their close relationships with farmers, agricultural cooperatives/associations can be key players in supply chains, helping farmers to change their farming practices and encouraging the adoption of more sustainable practices. Cooperatives can also promote the adoption of these practices by reducing farmers' perceived risks and making investment more feasible. Through joint action, they can occupy a relevant strategic position in the agri-food chain by acting as a link with the industrial or service sector, allowing participation in processing and marketing. (FAO, 2022; Inter-Agency Task Force on Social & Solidarity Economy, 2022). Agricultural systems not only provide food, they also gen-

erate income and employment. Their activity generates economic growth that can increase the well-being of the rural world and is a mechanism for reducing unemployment, poverty, social exclusion and inequality.The way cooperatives help reduce poverty is important: they identify economic opportunities for their members; empower the disadvantaged to protect their interests; provide security to the poor by allowing them to convert individual risks into collective risks; and mediate members' access to assets that they use to earn a living (Moral, 2019). So, it is a movement that contributes especially to rural development because they are enterprises that are necessarily linked to that environment and geographic area, providing stability and structure for the rural world, offering a local and regional response to global needs. They help farmers and their environment to increase their incomes and yields by pooling their resources (Chekmarev et al., 2022). They are essential to prevent depopulation and ageing in rural areas, slowing down depopulation and ageing through the creation of job opportunities, promoting education and training, as well as collaboration among different stakeholders to achieve objectives (FAO, 2022).

In the case of Latin America and the Caribbean, two aspects are important to highlight. First, there is a movement of associations, groupings, and committees of agricultural producers which, although they do not have the cooperative legal form, follow the cooperative philosophy as social economy enterprises and their principles of solidarity and mutual aid. Second, these agricultural associations are smaller in size and therefore also have greater weaknesses due to a lack of resources and capabilities. In these cases, there is a need for support not only from the state with its public policies, but also from financial institutions specialized in microcredit, which will facilitate the production or marketing of agricultural products by the members of these small associations and cooperatives.

2.2 | Sustainable finance and savings and credit cooperatives

The role of sustainable finance has become an essential part of sustainable development because sustainable finance is the nexus between sustainable development and finance (Kumar et al., 2022). We can identify three characteristics that may be present in sustainable finance: considering society and the environment as core elements in financial and investment decisions; a long-term horizon that addresses the challenges of global sustainability; and measurable results. Financial institutions play a fundamental role since they are the ones that can not only provide the savings and credit solutions that make these objectives possible, but also facilitate access to these solutions through two key tools: financial inclusion and microcredit. In this context, savings and credit cooperatives can become a normative model of sustainable finance. Regarding the former, savings and credit cooperatives are a key channel for promoting financial inclusion, which is included in eight of the 17 SDGs. Financial inclusion contributes to more stable financial systems and economies and makes economic growth possible, as it reduces poverty by facilitating access to the financial services and education that enable productive investment and increased productivity. Furthermore, through this improved access to financial services, access to other basic and sustainable services such as education and health care, clean water and clean energy, sustainable infrastructure (transportation, communication), affordable housing and disaster prevention is also made possible (Cunha et al., 2021). It is necessary to establish not only a common language for sustainable finance (UN Global Compact, 2022), but also a more extensive language considering the limitations of traditional concepts related to sustainable finance (Ren et al., 2023), integrating, among others, micro, small and medium-sized enterprises in the field of sustainable finance as well as financial cooperatives.

Financial cooperatives fill market gaps, offering sustainable business models to serve customers in need of financial services. They rely on sound financial management, credit discipline, and local knowledge to address credit and banking access issues. Savings and credit cooperatives play a vital role in supporting low-income individuals by delivering individual financial loans based on collective savings, contributing to poverty alleviation (Adusei et al., 2021; Manko & Watkins, 2021) and the differences in structure, incentives, and objectives between savings and credit cooperatives and conventional banks, which constitute the cooperative essence, that can lead to sustainability goals (Van Rijn et al., 2023). In addition, a critical aspect of the activity of savings and credit cooperatives, especially in developing countries, is their attention to the microfinance and microlending market. It should be noted that the microcredit portfolio makes up around 50% of the cooperative system's total portfolio in Ecuador (SEPS, 2019), which is an indicator of the significant contribution cooperatives make to the development of microfinance and to supporting microentrepreneurs. They are an essential element of sustainable development and microenterprises through providing access to and delivering microlending, especially for micro, small and medium-sized enterprises, which can improve investment levels, employment generation and productivity growth (Maia et al., 2019).

Considering that sustainable development can only be achieved by orienting finance towards sustainability, it is a necessary condition for the financial institutions that make this possible to be sound and solvent and, therefore, financially sustainable (Adusei et al., 2023; Bayai & Ikhide, 2018). The challenge of remaining solvent and competitive in the financial market is a means, not an end, to achieving their social and solidarity objectives, etc., (Westrup & Camilo, 2022). The achievement of their economic and social function can only occur through the fulfilment of the necessary and essential profitability of the institution. The savings and credit cooperatives, despite having a social conception, must be profitable and economically efficient in the same way as any other sector of the economy. Their profitability and economic efficiency will enable them to create a capital foundation for future expansion and to mitigate negative shocks and ensure their long-term survival. Yeon & Kim (2013) find that financial profitability is an appropriate tool for policymakers to predict business failure, set management strategies and dictate policies to ensure the health of the financial sector.

Some barriers that credit and savings cooperatives may face in developing their role as a major player in sustainable finance is the impact on their viability, efficiency and results and, certain elements related to their governance. Regarding their economic performance, there is a need to consider the intrinsic duality of their members and, also, that their effectiveness as a tool to promote financial inclusion and alleviate poverty depends on their ability to mobilize more members, which is referred to as credit cooperative outreach. Therefore, it is important to understand the factors that drive their penetration in different economic environments. We will analyze both factors: the duality of members and savings and credit cooperatives outreach.

Focusing on the duality of their members, given that saving and credit cooperatives do not seek to maximize profit, one of the most relevant difficulties pointed out by the literature is the establishment of their objective. This must consider that credit and savings cooperatives have to benefit all their members and that these may have different financial needs and requirements since they include both savings and borrowing members. Members with deposits will want high interest rates, while members with loans will want lower interest rates. These objectives lead to a reduction in spreads (McKillop & Wilson, 2011; 2015). Both groups are essential to performance, as borrowers are the providers of loanable funds through their deposits and lenders are essential to generate income. Borrowers prefer lower interest rates on loans, while savers seek higher interest rates on savings (McKillop et al., 2020).

If the objectives of both groups of members are of equal importance, the cooperative will attempt to pay the highest rates of return on savings and to charge the lowest interest rate on loans (McKillop & Wilson, 2011). This situation, linked to the fact that the cooperative must be viable, may generate a governance problem. This possible principal–principal agency conflict can occur precisely because both types of members can influence the decision process (Unda et al., 2019. Given these potential principal–principal tensions, many investigations have tried to analyze the behavior of credit and savings cooperatives in terms of their pricing policy (rates), to determine whether there is a bias towards savers or borrowers. Most theoretical economic models for savings and credit cooperatives claim that the most efficient configuration to satisfy members' competing objectives is to adopt a balanced approach in the distribution of monetary benefits to the two main groups. In this way, savings and credit cooperatives that seek to satisfy the preferences of only one group of members move away from their theoretically neutral orientation, i.e. being neutral by dividing monetary benefits between the two groups (Siudek & Zawojska, 2015), since improving the position for one particular group means worsening it for the other. To reduce (increase) the interest rate on loans, it is also necessary to reduce (increase) the interest rate on savings. Therefore, agency conflicts between savers and borrowers arise when the profits of one member group increase at the expense of the other, generating such a conflict that could compromise the viability of the cooperative. The outcome of these conflicts may determine the dominance of a member group (McKillop et al., 2020)

There is some evidence that cooperatives are characterized by the dominance of a member group. In this regard, Mercer et al. (2019), point to the empirical contributions of several papers that find a certain tendency whereby in savings and credit cooperatives, the objective of offering low-cost credit prevails, even if this entails a possible loss of income (Catturani & Venkat, 2014; Siudek & Zawojska, 2015). These models argue that if the cooperative were to be dominated by either of these groups, this could affect its efficiency and result in situations such as a lack of new members joining or the existing members leaving, since they are not seeing their needs satisfied. Thus, neutrality is less likely to generate incentives for credit and savings cooperatives to discourage the entry of new members and, therefore, helps to keep the institution active (McKillop & Wilson, 2011). So, the way for a dominated credit and savings cooperative to function would be with membership restrictions (Bressan et al., 2012), This dominance may affect the level of competitiveness of cooperatives, as saver-dominated cooperatives tend to set higher interest rates on loans, while lower rates are observed in borrower-dominated cooperatives. Consequently, there are several reasons to assume that savings and credit cooperatives that maintain their cooperative values should behave neutrally. It is worth noting that the dominance of one group over another is limited by the functioning of the cooperative. On the one hand, by the threat of withdrawal of members whose preferences are not met. On the other hand, the democratic voting structure, based on the principle of one member, one vote, leads to interest rate decisions being approved by its members, thus considering the interests of both savers and borrowers. In addition, there are other elements to be considered, such as the fact that the members have rights to the surplus, which means that they can be savers and borrowers at the same time.

However, the method for balancing the objectives of savers and borrowers may not be simple, as there may be other conditions that could lead savings and credit cooperatives to end up being characterized by some degree of dominance, even if they are not profit-driven entities. Within these potentially unbalancing elements, research has analyzed how certain endogenous variables (such as the age of the credit and saving cooperative, its size, the average monetary volume of loans and savings per member, net income distribution, etc.) can affect whether the credit and saving cooperative is neutral or not (Bressan et al., 2012). In addition to these factors, there are also exoge-

nous variables that may affect this equilibrium. McKillop & Wilson (2015) point out that savings and credit cooperatives may be forced to behave as constrained profit maximizers when exposed to intense competition from other financial institutions or if prudential regulation designed to ensure the survival of financial institutions force credit unions down the path of achieving profit (Worthington, 2004). The dominance of one group over the other may also be related to the interest rate situation in the credit and saving cooperative environment. In a high-rate environment, there may be dominance of those who borrow, who want to borrow at lower rates, while in a low-rate environment the contrary may occur (Mercer et al., 2019). In addition, the fact that a credit and saving cooperative can carry out operations with non-member third parties may introduce new and competing interests (McKillop et al., 2020). Finally, another issue relates to the fact that cooperative financial institutions may be subject to interest rate ceilings on borrower loans that offered them access to credit at fair and reasonable interest rates. In the case of Ecuador, there are limitations on interest rates and they are obligatory for all financial institutions.

The second key element is the outreach of these financial institutions to the population to meet their social objectives and the financial sustainability of savings and credit cooperatives. Various authors have pointed out that there is some debate about the link between financial sustainability and outreach (Duguma & Han, 2018; Meyer, 2019**)**. Bearing in mind that the outreach indicators are on the depth (types of clients reached and level of poverty) and breadth (number of clients served) of outreach (Duguma & Han, 2018), we understand, after a review of various research papers, that cooperatives can only have this social impact if they are financially sustainable, that is, outreach and financial sustainability are complementary (Meyer, 2019). Moreover, saving mobilization and credit provision are key elements in the relationship between outreach and financial sustainability (Yitayaw, 2021). In fact, deposit mobilization, is the most stable and affordable funding source that ensures their financial sustainability. So, an appropriate saving product allows financial institutions to generate low-cost deposits that contribute sustainable funding for lending activities (Duguma & Han, 2018)

Another interesting issue concerns the homogeneity or heterogeneity of members, which can generate difficulties in the governance of the cooperative and lead to failures in benefiting all members, thus compromising its future viability. Member heterogeneity has been an issue studied especially in agricultural cooperatives, although it may affect all cooperatives. Cooperative members participate in the decision-making process on the issues of financing, strategy and distribution of results and members with different characteristics and conflicting preferences are inclined to compete for rents (Kalogeras et al., 2009). In contrast, cooperatives with a highly homogeneous membership have been associated with good functioning of the cooperative, at all levels: financial commitment to the cooperative as well as greater economic and social commitment and participation in decisions that benefit all members. There are multiple heterogeneity dimensions that can affect the members of a savings and credit cooperative. First, those related to the geographical dispersion of its members and how they participate in the cooperative activity (savers/borrowers). Second, those related to the attributes and characteristics of the members: personal, temporary, risk aversion and countercultural. These personal features may imply different preferences and interests that may hinder cooperative decisions, and their monetary and non-monetary outcomes, although not all of the dimensions may prove to be relevant for cooperative performance (Höhler & Kühl, 2018).

From a sustainable finance point of view, a certain degree of heterogeneity among members could have a positive effect, both on their financial sustainability and on the development of two key functions of credit and savings cooperative, namely financial inclusion and microcredit. In relation to the first, they may be excessively exposed to systematic risk due to the homogeneity of members (Marwa & Aziakpono, 2015). Regarding the latter, inclusion and microcredit require a

greater diversification of financial services to serve people with different characteristics and needs, and especially low-income groups who tend to be socially and economically excluded. These collectives may have more difficulty in repaying their loans and live in disparate geographic areas. In other words, it requires not only broadening scope but also deepening it.

2.3 | Savings and credit cooperatives in Ecuador

In Ecuador, the Constitution (2008) and the Organic Law of the Popular and Solidarity Economy, known as LOEPS (2011, last amended in 2018) are the legal texts governing social economy organizations. According to them, the economic system is social and solidary and, basically, will be made up of public, private, mixed, popular and solidarity-based forms of economic organization. The popular and solidarity economy includes the cooperative, associative and community sectors. These entities will receive different and preferential treatment from the State to the extent that they promote the development of the popular and solidarity-based economy. Their importance is evidenced by the fact that these entities, in the exercise of the activities inherent to their corporate purpose, do not constitute tax-generating events (but the operations they carry out with third parties and that are not reinvested in the organization are subject to the common tax regime). Therefore, the savings and credit cooperatives may be partially exempt from paying income tax if they decide to reinvest, through the same institution, the surpluses generated during the fiscal year, resulting in the granting of credit to small and medium producers either to expand their market, innovate in new technologies or even create more human resources positions.

The Superintendency of the Popular and Solidarity Economy (commonly known as SEPS, by their initials in Spanish), acts as a technical body for the supervision and control of institutions in the popular and solidarity financial sector (PSFS), promoting their sustainability, development and proper functioning. In this sense, COACs have developed strategies to maintain an adequate level of liquidity and mitigate risk. They play a positive role in the banking sector by contributing to institutional diversity and they are mostly focused on retail banking and assume less risk, thus contributing to the stability of the system (Perilleux & Nyssens, 2017). In this scenario, there are several elements of the COACs (which represent 99% of the PSFS) that contribute to the strengthening of the inclusive financial system: their coverage (points of attention, i.e. service points, throughout their geography), credit structure and type of credit (SEPS, 2020).

The coverage is linked to the fact that the largest number of popular and solidarity economy organizations in the real sector corresponds to agricultural organizations (cooperatives and associations), which represent about 33% and is one of the largest generators of employment in the country (29.4% of workers). Other relevant data are related to poverty due to unsatisfied basic needs reached 33% at the national level. Poverty is prevalent in rural areas, so the COACs play a significant role in supporting social inclusion. World Bank (2020) and SEPS (2020) reports show the strength of the cooperative credit system, as 94.6% of the cantons have at least one service point. This demonstrates that the social and cooperative movement has a high presence throughout the country, particularly in rural areas (54% of service points) and in areas of high poverty (37%), and approximately one out of every five institutions (17%) works with the indigenous population. This implies that most of the institutions are specialized in microcredit (41% of their loan portfolio is dedicated to microcredit), hence the interest of this research. In addition, 49% of the portfolio is dedicated to consumer credit, with agriculture, livestock, forestry, and fishing activities being the third largest in terms of the volume of credit granted by savings and credit cooperatives.

Consequently, the role of the COACs is fundamental (Buendía-Martínez et al., 2020), since they allow for the inclusion in society of certain vulnerable groups that were traditionally outside the financial system, while at the same time being agents that revitalize the economy with a notable social impact. The triple vocation of cooperatives (economic, entrepreneurial, and social) acquires true significance in the rural environment, showing its full solidarity and integrating vocation as its most characteristic feature.

Comparing to the private banking, an essential element of the COACs as a means of sustainable finance in Ecuador is their role in the outreach of the financial services they offer, as well as their depth (Jácome, 2021). Firstly, the COACs have a greater physical presence in the Ecuadorian territory (cantons), significantly in those with medium and low socio-economic status. Secondly, when analyzing the structure of their credit portfolio, it is evident that microcredit is more prevalent in the COACs with the objective of financing MSEs and small producers and generating greater inclusion. The COACs used microcredit to finance a greater number of cantons whose socio-economic conditions are medium or low. A similar situation is observed when comparing the balances of deposits. Finally, it is considered that the COACs perform better in financial intermediation processes as they contribute to the transformation of savings resources in the territories where they are generated into financing for those same territories or channelling these to cantons with medium or low socio-economic conditions.

However, only some partial research has been conducted on COACs and their profitability. Thus, some studies analyze the economic and financial profitability or liquidity risk of a single cooperative (Jumbo Narváez, 2013; Tierra Chacha, 2015). Other studies only focus on one area of the country and/or segment (Criollo, 2017; Sisalema, 2017; Cadena Tomalo, 2018; Trujillo, 2013). One of the most extensive studies is that of Luque & Peñaherrera (2021), but this mainly analyzes the evolution of the COACs. Finally, the most recent research is that by Torres-Inga et al. (2022), which evaluates the technical efficiency and the factors that influence it over the years 2009 to 2020 applying the DEA, with a production and intermediation focus, to 19 COACs. Consequently, more research about the role of the COACs is needed.

3 | METHODOLOGY

3.1 | Data: Population of savings and credit cooperatives in Ecuador

The financial information has been obtained from the monthly financial statement published by SEPS dated December 2020. The data set is composed of all the COACs that are part of the popular and solidarity financial sector and were active on 31 March 2021, resulting in a database with 510 institutions. A total of 28 financial indicators (26 independent variables and two dependent variables) were calculated for this set of institutions.

3.2 | Variables

3.2.1 | Dependent variables: ROE and profitability of the microcredit portfolio

The variables to be used as dependent variables will be return on equity (ROE) and the profitability of the microcredit portfolio (RCM).

TABLE 1 Number of cooperatives with data on the dependent variables

VARIABLE	ROE	RCM
PROFIT	339	311
NON-PROFIT	171	199
TOTAL	**510**	**510**

Source: Own elaboration.

The ROE variable measures the return on the capital provided by investors in terms of the net profit obtained in the year. The ROE variable has been codified as 1 for a positive return and 0 otherwise, to help our models. This ratio is a key variable for investors because it measures the creation of additional value (Burja, 2011; Charles et al., 2018). In fact, by using ROE it is possible to analyze the global efficiency rate, so investors can assess the profitability of their investment. It is also a variable commonly used in previous studies in the credit sector (see for example, Erdal & Karahanoglu, 2016; Lapo & Tello, 2021; Popa & Ciobanu, 2014). Therefore, ROE will be used as a measure of the overall profitability of the company, necessary for the viability of the business. Moreover, the use of ROE as the dependent variable is in line with the premises used in this paper. Firstly, we consider that this variable better captures the dual nature of the members, since, although profit maximization is not their main objective, members do not only participate in the cooperative activity by lending or borrowing, but must also participate in the financial flow, i.e. as owners. Secondly, the legislation on COACS in Ecuador allows them to operate with third parties (in this case, as we have mentioned before, this type of operations do not have tax benefits). So ROE, as a residual variable, also better captures the formation not only of the surplus but also of profits. Finally, all these arguments are based on the idea that maximum service provision is impossible without being profitable (Almehdawe et al., 2020).

Regarding the other dependent variable, RCM, we can define the microcredit portfolio as that granted to an individual or legal entity with annual sales less than or equal to USD 100,000.00, or to a group of borrowers, intended to finance small-scale production and/or marketing activities, whose main source of payment is from the sales or income generated by such activities. Therefore, RCM refers to the return on the microcredit portfolio, subject to a maturity band, i.e. depending on the range of the future maturity of the transactions (SEPS, 2017). In common with ROE, the dependent variable RCM has also been discretized into the values 1 and 0, but in this case considering the distribution of the variable (Gonzales Pérez et al., 2002). We should mention that we analyze the profitability of the microcredit portfolio as a specific measure of its contribution to sustainability and the creation of social value.

Table 1 shows the number of institutions with data on the two dependent variables.

3.2.2 | Independent variables

The independent variables in this study are summarised in Table 2.

The selection of variables was carried out considering their importance for the profitability of credit institutions in general (Bakar & Tahir, 2009; Erdal & Karahanoglu, 2016; Uddin et al., 2022), and savings and credit cooperatives in particular (SEPS, 2017 and 2021). In addition, the selected ratios reflect the basic financial dimensions (growth, solvency, efficiency and liquidity) that are important according to empirical research on profitability (Balcaen & Ooghe, 2006; Laitinen et al., 2014). Moreover, we would like to point out that the variables used are those employed by the

TABLE 2 Independent variables

VARIABLE	DEFINITION	CODE
SOLVENCY		
Equity adequacy	Equity + Net income/Net Non-Current Assets	SOL1
Equity vulnerability	Unproductive Portfolio/Equity + Net Income	SOL2
Equity losses	Accumulated Losses—Reserves/Shareholders' Equity	SOL3
Solvency 4	Equity/Assets	SOL4
Solvency 5	Equity/Liabilities	SOL5
OPERATING EXPENSE EFFICIENCY		
Operating expense efficiency 1	Operating Expense/Net Financial Margin	EFG1
Operating expense efficiency 2	Operating Expense/Assets	EFG2
QUALITY OF ASSETS		
Quality of assets 1	Productive Assets/Liabilities With Cost	CAA1
Proportion of productive Assets	Productive Assets/Total Assets	CAA2
Proportion of non-productive Assets	Net Non-Productive Assets/Total Assets	CAA3
CREDIT		
Portfolio default	Unproductive Portfolio/Total Portfolio	CR1
Portfolio hedging	Portfolio Provisions/Unproductive Portfolio	CR2
Net interest margin	Interest Earned—Interest Paid	CR3
Implicit lending rate	Portfolio Interest/Total Portfolio	CR4
Implicit deposit rate	Deposit interest/Deposits—Repo Operations	CR5
Spread	Implicit Lending Rate—Implicit Deposit Rate	CR6
Credit 7	Loan Provision/Total Loans	CR7
Credit 8	Provision for Consumer Credit/Consumer Loans	CR8
Performance of microcredit portfolio	Microcredit Portfolio/(Maturing Microcredit Portfolio + Maturing Refinanced Portfolio + Maturing Restructured Portfolio)	CR10
FINANCIAL EFFICIENCY		
Financial Efficiency 1	Brokerage Margin/Productive Assets	EFF1
Financial Efficiency 2	Brokerage Margin/Equity	EFF2
LIQUIDITY		
Liquidity 1	Liquid Funds/Short-Term Deposits	LIQ1
Liquidity 2	Gross Portfolio/Assets	LIQ2
Liquidity 3	Gross Portfolio/Total Deposits	LIQ3
SIZE		
Size 1	Logarithm of Assets	T1
Size 2	Logarithm of Equity	T2
Turnover	Logarithm of Interest Income	T3

Source: SEPS (2017).

Superintendency of the Popular and Solidarity Economy, the supervisory body of the COACs (SEPS, 2017)

Regarding the independent variables, the summary statistics for our companies are provided in Table 3, while Table 4 shows the correlation matrix.

As can be seen, the correlation coefficients of the independent variables show that many of the independent variables used in the analysis are highly correlated. Therefore, a principal component analysis (PCA) was performed for the 26 independent variables in order to reduce the dimensions of the database and present more standardised variables. The principal component analysis is one of the best known and most effective multivariate techniques to reduce the dimension of a high-dimensional data matrix. In it, the principal components are obtained as a linear combination of the original variables. This means the existing relationships between the different variables are used and it deals with the problem of the correlation of independent variables, avoiding the loss of information and thus being able to better explain the variability of the data. In this sense, the concept of a greater amount of information is related to that of greater variance, which means that the greater the variability of the data, the greater the amount of information (Jolliffe, 2002).

In our study, the objective will be to start from the 26 independent variables and obtain a smaller number of components that cover the greatest amount of information. For the selection of the components, the criteria followed was that their eigenvalue should be greater than or equal to 1 and that the set of components chosen should explain more than 70% of the variance of the data. As a result, a total of 10 components were obtained, which explain 78.10%. The results were obtained using Rstudio software.

When performing a principal component analysis, one of the objectives is to see which variables have the greatest influence on each component. In this way, the composition of each component can help us to identify each dimension of the concept we are creating and thus understand more clearly the key variables in classifying institutions as profitable or unprofitable. To explain the grouping of each dimension with each variable used, we rotated the factors using the varimax method to obtain a solution that is easier to interpret. The advantage of using this method is that it allows each component to have high correlations with a few of the variables and low correlations with the rest of them. The following table indicates the grouping of the variables in each component (Table 5).

3.2.3 | Machine learning techniques and their applications

To predict the profitability of savings and credit cooperatives, we have developed three models applying different well-known machine learning techniques: the CART decision tree, Random Forest and Gradient Boosting Machine. The combination of several machine learning techniques results in a comprehensive analysis of the problem from several points of view, that is, a combination of methods allows us to generalize the usefulness of individual predictor variables more broadly, meaning that the most relevant variables can be selected for further comparison. The selection of these methods is based on their good performance in solving classification problems (Ariza-Garzón et al., 2021; Campillo et al., 2018). In fact, all these approaches have also been tested previously in assessing the performance of credit firms (Ariza-Garzón et al., 2020; Erdal & Karahanoglu, 2016; Golbayani et al., 2020; Hartini et al., 2021; Uddin et al., 2022).

Due to the well-known nature of these methods, their detailed descriptions are not provided. In fact, this paper does not seek to introduce new classification methods or modify existing ones. Instead, its novelty lies in being the first paper to apply several machine learning techniques to

TABLE 3 Summary statistics for the independent variables

CODE	MINIMUN	MAXIMUM	MEAN	DESVIATION	VARIANCE	ASYMMETRY	KURTOSIS
SOL1	−411707.37	42256.40	−592.15	18562.78	344576741.57	−21.42	475.36
SOL2	−351.43	2206.49	20.77	117.70	13852.57	13.36	237.27
SOL3	0.00	9452.04	21.19	418.67	175286.48	22.54	508.79
SOL4	−2.77	0.88	0.24	0.21	0.04	−5.18	82.84
SOL5	−0.67	8.01	0.45	0.72	0.52	5.90	47.19
EFG1	−2455.04	4372.47	108.20	297.77	88668.24	4.27	104.76
EFG2	0.00	84.90	8.13	6.39	40.89	6.17	59.02
CAA1	0.00	1378.87	127.49	100.08	10016.68	8.12	85.22
CAA2	0.00	136.20	81.80	19.76	390.53	-1.94	4.11
CAA3	-36.20	100.00	18.20	19.76	390.53	1.94	4.11
CR1	0.00	100.00	12.85	17.89	320.07	2.85	8.91
CR2	0.00	175233.00	582.76	8190.82	67089463.04	19.87	413.39
CR3	0.00	614.54	35.75	35.48	1258.93	9.75	144.98
CR4	0.00	50.03	14.49	5.35	28.57	0.96	7.15
CR5	0.00	56.88	5.64	3.70	13.71	5.18	71.12
CR6	−26.09	42.90	8.85	5.08	25.85	1.16	13.34
CR7	0.00	3.37	0.10	0.24	0.06	11.14	139.95
CR8	0.00	19.45	0.15	1.13	1.29	13.52	201.92
EFF1	−2229.91	48.35	−6.95	100.43	10085.68	−21.46	474.37
EFF2	−649.40	834.56	−2.62	54.44	2963.55	2.63	157.16
LIQ1	0.00	709.98	38.45	48.77	2378.44	7.57	84.78
LIQ2	−1.63	0.94	0.64	0.19	0.04	−4.58	43.20
LIQ3	−2.23	15.99	1.11	0.95	0.91	9.14	126.18
T1	7.62	21.65	14.75	2.17	4.73	0.31	0.22
T2	0.00	19.38	13.13	2.20	4.86	−0.90	6.66
T3	0.00	19.37	12.43	2.54	6.43	−0.51	1.98

Source: Own elaboration.

TABLE 4 Correlation matrix

	SOL1	SOL2	SOL3	SOL4	SOL5	EFG1	EFG2	CAA1	CAA2	CAA3	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	EFF1	EFF2	LIQ1	LIQ2	LIQ3	T1	T2	T3
SOL1	1,00	0,02	0,00	0,02	0,02	0,00	0,03	0,01	−0,04	0,04	0,02	0,00	−0,01	0,01	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,01	0,02	−0,07	−0,06	−0,06
SOL2	0,02	1,00	0,00	−0,04	−0,04	0,01	0,00	−0,14	−0,42	0,42	0,48	−0,01	0,11	−0,18	−0,10	−0,12	0,07	0,00	0,00	0,56	0,00	−0,09	−0,03	−0,21	−0,23	−0,26
SOL3	0,00	0,00	1,00	−0,20	−0,05	0,20	0,22	−0,05	−0,10	0,10	−0,02	0,00	−0,04	−0,08	−0,07	−0,03	0,01	0,00	−0,04	0,05	−0,04	−0,08	−0,05	−0,10	−0,28	−0,11
SOL4	0,02	−0,04	−0,20	1,00	0,67	0,08	−0,11	0,47	−0,06	0,06	0,01	0,03	−0,17	0,06	−0,11	0,14	0,09	−0,02	0,01	−0,04	0,16	0,06	0,36	−0,24	0,07	−0,22
SOL5	0,02	−0,04	−0,05	0,67	1,00	0,04	0,11	0,82	−0,12	0,12	0,11	0,06	−0,16	−0,06	−0,12	0,02	0,04	−0,03	0,00	0,00	0,25	−0,09	0,55	−0,32	−0,12	−0,34
EFG1	0,00	0,01	0,20	0,08	0,04	1,00	−0,06	0,00	−0,04	0,04	−0,01	0,00	−0,04	−0,11	0,01	−0,12	−0,10	−0,01	0,13	0,11	0,07	0,06	0,09	−0,03	−0,03	−0,04
EFG2	0,03	0,00	0,22	−0,11	0,11	−0,06	1,00	0,04	−0,30	0,30	0,32	0,05	−0,11	0,30	−0,12	0,40	0,46	0,01	−0,61	−0,36	0,03	−0,29	−0,01	−0,44	−0,45	−0,37
CAA1	0,01	−0,14	−0,05	0,47	0,82	0,00	0,04	1,00	0,27	−0,27	−0,22	0,04	−0,18	0,02	0,15	−0,10	−0,06	−0,04	0,08	0,04	0,41	0,04	0,58	−0,13	0,01	−0,11
CAA2	−0,04	−0,42	−0,10	−0,06	−0,12	−0,04	−0,30	0,27	1,00	−1,00	−0,81	0,04	−0,18	0,10	0,22	−0,06	−0,26	−0,09	0,26	0,11	−0,01	0,45	0,06	0,44	0,42	0,53
CAA3	0,04	0,42	0,10	0,06	0,12	0,04	0,30	−0,27	−1,00	1,00	0,81	−0,04	0,18	−0,10	−0,22	0,06	0,26	0,09	−0,26	−0,11	0,01	−0,45	−0,06	−0,44	−0,42	−0,53
CR1	0,02	0,48	−0,02	0,01	0,11	−0,01	0,32	−0,22	−0,81	0,81	1,00	−0,05	0,16	−0,15	−0,21	0,00	0,44	0,12	−0,30	−0,12	0,00	−0,45	−0,09	−0,41	−0,40	−0,50
CR2	0,00	−0,01	0,00	0,03	0,06	0,00	0,05	0,04	0,04	−0,04	−0,05	1,00	−0,04	0,02	−0,05	0,06	−0,02	−0,01	0,00	0,01	−0,01	0,01	0,03	−0,02	−0,01	−0,01
CR3	−0,01	0,11	−0,04	−0,17	−0,16	−0,04	−0,11	−0,18	−0,18	0,18	0,16	−0,04	1,00	−0,07	0,24	−0,25	0,04	−0,04	−0,22	−0,19	−0,04	−0,06	−0,14	0,14	0,06	0,06
CR4	0,01	−0,18	−0,08	0,06	−0,06	−0,11	0,30	0,02	0,10	−0,10	−0,15	0,02	−0,07	1,00	0,42	0,75	0,14	−0,01	−0,26	−0,12	0,09	−0,04	−0,13	0,13	0,16	0,30
CR5	0,00	−0,10	−0,07	−0,11	−0,12	0,01	−0,12	0,15	0,22	−0,22	−0,21	−0,05	0,24	0,42	1,00	−0,29	−0,09	−0,07	0,01	−0,03	0,38	0,18	0,08	0,31	0,27	0,38
CR6	0,01	−0,12	−0,03	0,14	0,02	−0,12	0,40	−0,10	−0,06	0,06	0,00	0,06	−0,25	0,75	−0,29	1,00	0,21	0,04	−0,28	−0,10	−0,19	−0,17	−0,19	−0,09	−0,03	0,03
CR7	0,00	0,07	0,01	0,09	0,04	−0,10	0,46	−0,06	−0,26	0,26	0,44	−0,02	0,04	0,14	−0,09	0,21	1,00	0,11	−0,63	−0,45	−0,03	−0,65	−0,22	−0,15	−0,13	−0,16
CR8	0,00	0,00	0,00	−0,02	−0,03	−0,01	0,01	−0,04	−0,09	0,09	0,12	−0,01	−0,04	−0,01	−0,07	0,04	0,11	1,00	−0,01	−0,07	−0,03	−0,14	−0,05	−0,04	−0,05	−0,05
EFF1	0,00	0,00	−0,04	0,01	0,00	0,13	−0,61	0,08	0,26	−0,26	−0,30	0,00	−0,22	−0,26	0,01	−0,28	−0,63	−0,01	1,00	0,40	0,04	0,24	0,08	0,12	0,12	0,14
EFF2	0,00	0,56	0,05	−0,04	0,00	0,11	−0,36	0,04	0,11	−0,11	−0,12	0,01	−0,19	−0,12	−0,03	−0,10	−0,45	−0,07	0,40	1,00	0,01	0,30	0,08	0,03	0,00	0,01
LIQ1	0,01	0,00	−0,04	0,16	0,25	0,07	0,03	0,41	−0,01	0,01	0,00	−0,01	−0,04	0,09	0,38	−0,19	−0,03	−0,03	0,04	0,01	1,00	−0,08	0,46	−0,19	−0,13	−0,17
LIQ2	0,01	−0,09	−0,08	0,06	−0,09	0,06	−0,29	0,04	0,45	−0,45	−0,45	0,01	−0,06	−0,04	0,18	−0,17	−0,65	−0,14	0,24	0,30	−0,08	1,00	0,29	0,15	0,16	0,21
LIQ3	0,02	−0,03	−0,05	0,36	0,55	0,09	−0,01	0,58	0,06	−0,06	−0,09	0,03	−0,14	−0,13	0,08	−0,19	−0,22	−0,05	0,08	0,08	0,46	0,29	1,00	−0,20	−0,08	−0,21
T1	−0,07	−0,21	−0,10	−0,24	−0,32	−0,03	−0,44	−0,13	0,44	−0,44	−0,41	−0,02	0,14	0,13	0,31	−0,09	−0,15	−0,04	0,12	0,03	−0,19	0,15	−0,20	1,00	0,91	0,95
T2	−0,06	−0,23	−0,28	0,07	−0,12	−0,03	−0,45	0,01	0,42	−0,42	−0,40	−0,01	0,06	0,16	0,27	−0,03	−0,13	−0,05	0,12	0,00	−0,13	0,16	−0,08	0,91	1,00	0,88
T3	−0,06	−0,26	−0,11	−0,22	−0,34	−0,04	−0,37	−0,11	0,53	−0,53	−0,50	−0,01	0,06	0,30	0,38	0,03	−0,16	−0,05	0,14	0,01	−0,17	0,21	−0,21	0,95	0,88	1,00

Source: Own elaboration.

TABLE 5 Summary of the components

COMPONENT	Definition	Variables	% of explained variance
COMP.1	Vulnerability	SOL2; CAA2; CAA3; CR1	19,85%
COMP.2	Size	T1; T2; T3	12,97%
COMP.3	Solvency	SOL4; SOL5; CAA1; LIQ3	10,40%
COMP.4	Financial Efficiency	EFG2; CR7; EFF1; EFF2; LIQ2	6,97%
COMP.5	Credit 1	CR4; CR6	6,06%
COMP.6	Liquidity	CR5; LIQ1	5,75%
COMP.7	Management	SOL3; EFG1	4,47%
COMP.8	Credit 2	CR3; CR8;	4,15%
COMP.9	Portfolio hedging	CR2	3,85%
COMP.10	Equity adequacy	SOL1	3,66%

Source: Own elaboration.

the analysis of the profitability of a specific type of credit institution, namely savings and credit cooperatives, focusing not only on the global profitability needed to operate a business (ROE) but also on profitability related to creating social value through microcredits (RCM).

Decision trees are one of the most widely used machine learning models for the analysis of bank performance as this approach combines interpretability and predictive capability. It produces a hierarchical tree representation to visualise the classification, where nodes represent rules about features and leaves represent categories. From among the numerous decision tree composition approaches, we have used CART (Classification and Regression Tree), which is one of the most popular (Breiman, 2001).

Random forest (RF) is a type of ensemble technique that combines a large number of independent decision trees estimated for random data sets. The method used by the Random forest algorithm to re-sample (i.e. to select random data) is called Bootstrap. This technique consists of inferring a given distribution through repeated samples drawn from the sample itself, with replacement. Thus, in Random forest, a model is created for the training sample with the subset of data selected using the Bootstrap method. A Random Forest prediction corresponds to an aggregation of the independent predictions of each of the single trees via averaging, or voting for the classification case (Breiman, 2001; Hartini et al., 2021).

Gradient boosting machine (GBM) is a type of algorithm based on different individual models (decision trees) whose results are aggregated (Friedman, 2002). This way, the final result (ensemble classifier) is formed by a model that is a combination of the previous ones (weak classifiers), but with a very superior predictive capacity, far superior to that of the individual models on which it is based. GBM, in its successive iterations, learns from and minimises the errors of the previous models, and adjusts the decision trees to the residuals or errors in order to keep updating and minimising the residuals. Precisely, one of the most significant characteristics of this boosting-based algorithm is that it learns from the errors of the multiple models while it generates them (Chambers & Dinsmore, 2015).

All the models were run using RStudio (Boehmke & Greenwell, 2019; Kassambara, 2018). In addition, it should be noted that machine learning methods suffer from the overfitting problem. Therefore, they are usually applied by dividing the dataset into training and test sets, which provides a more realistic understanding of the model's performance (Segovia-Vargas et al., 2004). In our study, 80% of the total database was randomly assigned to *training data* and 20% to *test data*.

We measured the performance of the proposed models using several well-known measures frequently used in evaluating the performance of credit firms: the classification accuracy rate (Acc) and the area under the receiver operating characteristic curve (AUC—the maximum accuracy would be associated with an AUC value closer to 1 and the minimum with a value of 0.5). We analyzed the performance of each class, using three performance metrics: accuracy (Acc), specificity (Sp) and sensitivity (Se) (Drzewiecki, 2017; Gu et al., 2009). These measures can be obtained from the confusion matrix, in which the diagonal represents the correctly classified examples and the off-diagonal represents the classification errors. Accuracy (Acc) is the rate of correctly classified observations. Specificity (Sp) and sensitivity (Se) identify the two possible error types in a binary classification problem: type I errors and type II errors. A type I error is associated with the specificity of the model (Type I error $= 1 - \text{Sp}$). A higher Sp indicates a lower probability of type I misclassifications. In contrast, a type II error is related to the sensitivity (Se) of the model (Type II error $= 1 - \text{Se}$). A higher Se implies a lower probability of type II misclassifications. In our study, a type I error indicates that a COAC is classified as profitable when it is not.

In our study it is important to analyze misclassifications due to their economic significance and to validate the evidence in our models. Therefore, for various economics problems, some errors are more important than others (a clear example is business failure prediction misclassifications where the error resulting from failed companies about to go bankrupt being considered financially healthy is considered more costly than the contrary (Gutiérrez et al., 2010; Hernandez Tinoco & Wilson, 2013).

4 | RESULTS AND DISCUSSION

4.1 | Decision tree (CART) results

We have developed a classification tree for the two dependent variables. The performance of the tree generated for the ROE variable shows an ACC of 84.38% and AUC of 0.8153, while the performance of the tree generated for the RCM shows an ACC of 77% and AUC of 0.8360. The measurements for both models are quite satisfactory which allows us to interpret them (see Figure 1 for analysis of the ROE and Figure 2 for analysis of the RCM).

For the ROE variable tree, it can be observed that it is easier to predict profitable COACs than unprofitable COACs (the predictive performance of profitable companies, class 1, is 72%). The most important rule corresponds to terminal node 7. This rule indicates that 67% of COACs are classified as profitable if $\text{COMP\_2} < -0.6$ and $\text{COMP\_1} < 0.73$.

On the other hand, the RCM variable tree also shows the strongest rule that classifies profitable firms (class 1). This rule corresponds to terminal node 7 and indicates that a COAC belongs to the profitable class if $\text{COMP\_5} < -0.3749$ and $\text{COMP\_6} < -0.4909$.

One of the objectives of the study is to test which variables have the greatest influence on the COAC sector in Ecuador when it comes to predicting profitability. Figure 3 shows the most significant variables for both decision tree models, to differentiate between profitable and non-profitable COACs.

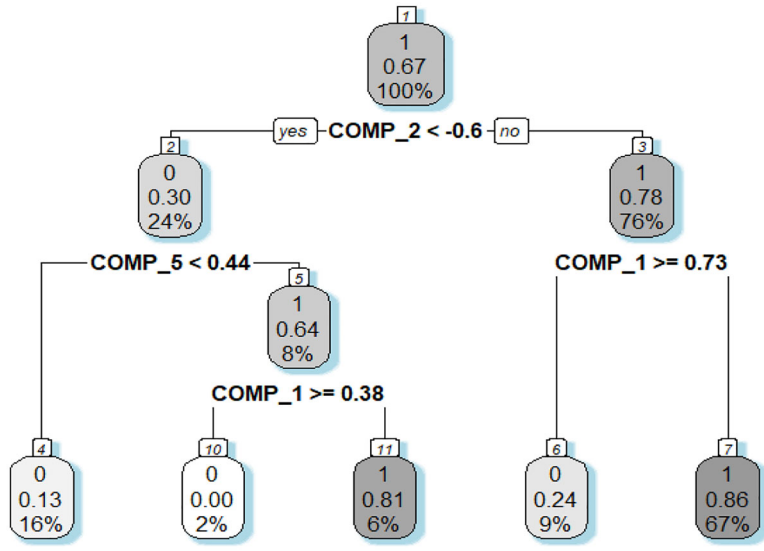

FIGURE 1 CART results for ROE variable. *Source*: Own elaboration. [Colour figure can be viewed at wileyonlinelibrary.com]

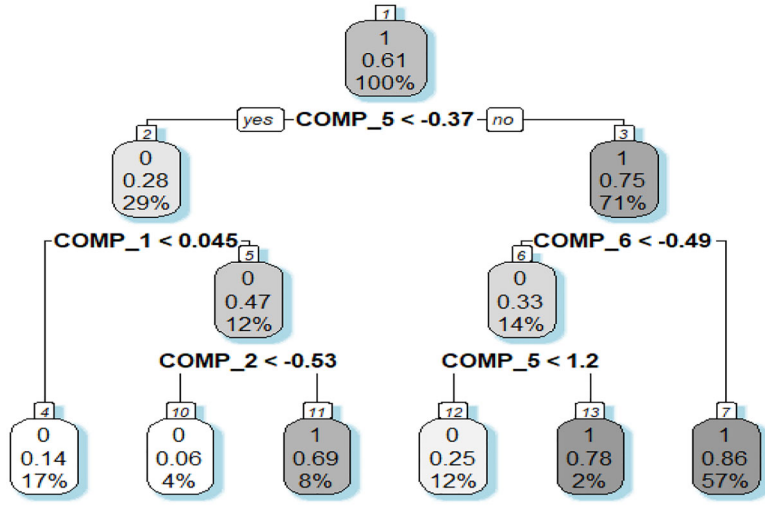

FIGURE 2 CART results for RCM variable. *Source*: Own elaboration. [Colour figure can be viewed at wileyonlinelibrary.com]

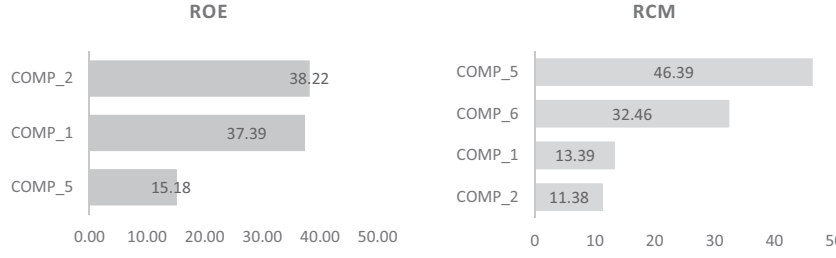

FIGURE 3 Relevant variables in CART for ROE and RCM variables. *Source*: Own elaboration.

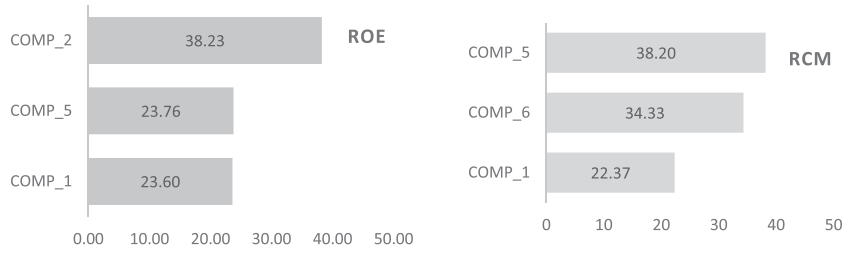

FIGURE 4 Relevant variables in Random Forest Algorithm for ROE and RCM variables. *Source*: Own elaboration.

4.2 | Random forest results

As mentioned in the methodology section, the Random Forest is generated from different decision trees using Bootstrapping subsamples. Thus, to obtain the Random Forest for the ROE and RCM variables, a base model was created and this model was then adjusted to find the optimal parameters (number of trees and number of variables used in each division) to obtain a better classification and minimise the error. The interpretation of the Random Forest results is performed from the importance of the variables in the classification and also from statistics showing the goodness of fit of the model.

As for the ROE Random Forest algorithm, to choose the optimal parameters, the model started to stabilise from 300 trees onwards. Therefore, with this result, the model estimated using the optimal parameters showed an accuracy of fit of 87.88% and the AUC value is 0.8824. Similarly, for the RCM Random Forest algorithm, the model started to stabilise from 300 trees onwards, but in this case the accuracy of the model was 85.25% and the AUC value 0.8742. Consequently, the measurements for both models are quite satisfactory.

The importance of the variables will also be linked to model error, so the importance of the variables is given in the sense of how much not including a variable would affect the model fit. For both Random Forest algorithms, Figure 4 shows the most significant variables to differentiate between profitable and non-profitable COACs.

4.3 | Gradient boosting machine results

As has been previously explained, the idea of GBM is to train different models sequentially, so that each model adjusts for the errors of the previous models. In this case, for the modelling of the GBM, we started by calculating a base model with 6000 trees so that from this model we could adjust the hyperparameters and thus obtain an optimal number of trees to minimise the estimation error. For the prediction of the ROE variable, the GBM required 78 iterations to obtain an optimal model, in which the accuracy of the data fit was 95.16% and the AUC value 0.9241. Similarly, for the prediction of the RCM variable, the GBM required 81 iterations to obtain an optimal model, in which the accuracy of the data fit was 82.26% and the AUC value 0.9227. These results demonstrate that the measurements for both models are quite satisfactory.

In the GBM algorithm, the measure of the importance of variables is based on the improvement of the model by including or removing variables. For both Random Forest algorithms, Figure 5

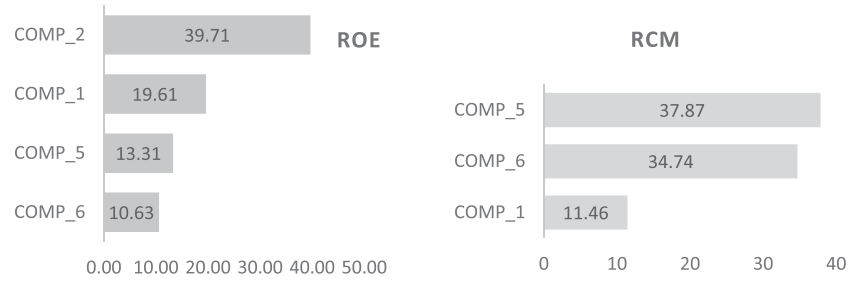

FIGURE 5 Relevant variables in GBM for ROE and RCM variables. *Source*: Own elaboration.

TABLE 6 Summary of the metrics

MODEL	METRIC	ROE	RCM
CART	Sp	68.75%	63.16%
	Se	85.71%	89.47%
	Acc	84.38%	77.00%
RANDOM FOREST	Sp	80.00%	77.50%
	Se	93.55%	83.87%
	Acc	87.88%	85.25%
GBM	Sp	90.63%	70.27%
	Se	84.29%	78.46%
	Acc	95.16%	82.26%

Source: Own elaboration.

shows the most significant variables to differentiate between profitable and non-profitable COACs.

4.4 | Metrics comparison and discussion of the results

First, the performance of each class was analyzed using three performance metrics: accuracy (Acc), specificity (Sp) and sensitivity (Se), as explained in the methodology section. Table 6 shows the summary of all the metrics for both dependent variables, ROE and RCM.

According to these data, the type 1 error (that is, classifying COACs as profitable when in fact they are not) is much smaller for the Random Forest (Sp = 90.63%). Nevertheless, the decision tree approach offers the best level of interpretation, as the decision rules obtained can easily discriminate the sample from the database. Despite this, it suffers from problems of bias and variance, because building a small tree will result in a model with low variance and high bias. However, as the complexity of the methodology increases, a decrease in prediction error will be found because a lower bias is obtained in the methodology as its difficulty increases. Therefore, an optimal model must maintain a balance between these two types of error. This is known as the trade-off between bias and variance errors.

Regarding the prediction of the ROE variable, in all three models the most important variables are component 2, consisting of the size variables (the logarithm of interest income; the logarithm of equity and the logarithm of assets), and components 5 and 1 formed by variables referring to

credit and vulnerability, respectively. It is worth noting that the GBM model also gives some importance to component 6, which is made up of liquidity variables. However, component 2 is the most important in all the different models. One justification for a direct relationship between profitability and the size of an institution is that larger institutions may have greater technical market opportunities at their disposal and may benefit from economies of scale. In addition, they have greater bargaining power with customers and better funding prospects (Almehdawe et al., 2020; Goddard & Wilson, 2005; McKillop et al., 2020).

For the RCM prediction, the most important variables in the three models are: component 5, made up of credit variables, and components 6 and 1, made up of liquidity and vulnerability variables, respectively. Of the three variables, component 5 (made up of credit variables, that is, implicit lending rate and credit spread) is the most important. As a justification for the result obtained, it can be argued that as their portfolio is mainly composed of microcredit, COACs should have an interest rate that generates a certain level of profitability and allows for more deposits for the institution since in this way, through financial intermediation, they can generate more resources. In the same way, the difference between the asset and liability rate maintained by COACs must be in line with them generating profitability so that they have good financial health. So, the results show the particular behavior of the microcredit portfolio in which the fundamental variable for viability is the relationship between the credit variables. The relevance of this analysis lies in the fact that there must be neutral behavior for this portfolio: there must be a balance between depositors and borrowers.

Therefore, the variables selected and the results obtained show the need to have viable financial cooperatives playing their essential role in sustainable finance, financial inclusion and microfinance, thus connecting with the social objectives of sustainable development. Therefore, the fact that the most relevant variables for predicting the viability of the COACS and RCM are size (represented by equity, assets and interest income) and the variables related to credit, allows us to affirm that the importance of the COACs in the real economy is determined by their capacity to meet the real needs of individuals and companies, especially through microcredit and financial inclusion. This requires strong capital positions and institutions of a certain size.

Thus, only viable institutions will be able to achieve their social objectives, such as the scope and the balance in their operations (shown by the implicit lending rate and credit spread), supporting the idea that viability and scope are complementary conditions. Moreover, COACS in Ecuador carry out their activity in numerous markets and serve diverse needs, with an important presence in rural areas and smaller population centres. This fact may mean that COACS are subject to specific economic environments, such as sparse population, separation from large cities and greater difficulties in accessing resources such as supplies and skilled labour, which could affect their viability. So, the larger the institutions, the more likely they are to be subject to increasing returns to scale, and the greater their ability to optimize the social outcomes of their operations. Moreover, size will allow COACS to achieve greater efficiency and social inclusion, as their network of services will be larger both for their members and for families and businesses in the small towns where they are often located. These results also seem to be consistent with the life cycle of financial cooperatives, where growth and development are positively influenced by the size of the institutions (Goddard & Wilson, 2005).

Consequently, the viability of savings and credit cooperatives is closely related to the cooperative open door principle and the economic participation of their members in the cooperative activity (assets, equity and interest income), along with their commitment to and trust in the services they offer, which generates greater penetration in the community.

5 | CONCLUSIONS AND POLICY IMPLICATIONS

5.1 | Conclusions

Financial cooperatives can become key organizations in sustainable finance on the world stage by creating a virtuous circle in communities, including the most vulnerable ones. This is due to the convergence and similarity of their principles, such as equity, inclusion, co-operation, solidarity and democracy, with several of the elements identified in the SDGs. Moreover, these economic organizations can enrich sustainable development because of the way they manage the combination of economic, social and environmental elements. In this way, financial cooperatives can constitute a model that enhances the stakeholder model, since in cooperatives these parties are based on solidarity and the pursuit of common but heterogeneous objectives and links. Moreover, the way cooperatives do business is based on their values and principles and democratic decision-making constitutes a tool for generating value and social cohesion, both for members and the environment, by generating income and contributing to job creation.

Savings and credit cooperatives have a dual nature. This balance is sometimes difficult to find. Consequently, this paper has tested whether savings and credit cooperatives are sustainable over time from an economic and social perspective. To achieve our objective, we have analyzed the whole population of savings and credit cooperatives in Ecuador, focusing on their profitability from two points of view, the overall profitability of the company (necessary for the viability of the business) and the profitability of the microcredit portfolio (necessary to contribute to sustainability and the creation of social values). The analysis has been carried out using a combination of several methods and this allows us to generalize the results. According to these, COACs are profitable and size is the most relevant variable to predict the ROE whilst the prediction of the profitability of the microcredit portfolio is conditioned by the credit variables (that is, the implicit lending rate and credit spread).

To conclude, sustainable development needs sustainable finances, and these require financial institutions with a social orientation, i.e. managed by social values. Consequently, we believe that it will be necessary to prevent the savings and credit cooperatives from losing their specific characteristics. These differences in structure, incentives, and objectives between the savings and credit cooperatives and the conventional banks constitute the cooperative essence, which is precisely what can lead to sustainability objectives. Therefore, the credit unions are essential as they focus on long-term goals and resilience, and have a stronger connection with real productive activities, especially through the financial inclusion and microcredit.

Given that savings and credit cooperatives have to maintain the required balance between their own financial sustainability and their social objectives, we propose novel techniques to determine the key determinants of efficiency in their operations that are particularly relevant for sustainable finance, such as microcredit. In addition, as previous studies have done, we suggest that the savings and credit cooperatives should assess periodically the determinants of their efficiency. This study is not free of its limitations. The population only covers one country and future studies are needed to corroborate our conclusions. Therefore, an enlargement of the data to other countries is our task for future research to obtain more robust results (for instance, a multinational study about savings and credit cooperatives focused on sustainability issues). We also propose to use more advanced artificial intelligence techniques that allow us to use algorithms that optimize social and environmental objectives, subject to the achievement of a minimum financial return, but sufficient to allow their own sustainability.

Thus, in line with other studies focusing on social banking the academia and policy makers have to contribute to the fact that the savings and credit cooperatives can have a substantial impact on the development of finance and sustainable development through a number of tools. First, using the resources at their disposal for the common good, applying their open-door principle. Second, using their resources transparently in the real economy, where the microcredit and the financial inclusion are a central element of this connection. In this respect, they should continue to promote the sustainable development of rural areas, through their support for the key organizations in these areas, such as the agricultural cooperatives and associations. Third, the savings and credit cooperatives should not only support the social economy but also social entrepreneurship. This is a major challenge as it can have a multiplier effect on sustainable development by combining the entrepreneurial nature with their social orientation. Finally, fourth, reinvesting cooperative surpluses in line with social objectives.

5.2 | Policy implications

Our paper makes a clear contribution to sustainability by showing the important role of savings and credit cooperatives in providing sustainable finance, considering that they have a dual nature. Due to the financial services they provide, they are regulated and act like banks, but following their management philosophy and cooperative principles, they must also maintain their social efficiency. This balance is sometimes difficult to find and they are criticised for their treatment of and concern about social indicators. However, many of the large savings and credit cooperatives already report specifically on measures taken to achieve the Sustainable Development Goals. These establish an active policy on financing and investing in sustainable energy generation, increasing the number of products linked to sustainability, financing sustainable housing solutions, supporting large-scale sustainable agriculture as well as creating discussion forums on the circular economy.

Cooperatives undoubtedly also face significant challenges. One of these is the scaling up or growth of these enterprises needed to meet the global needs. This is because many of these organizations remain limited in scope and it can be difficult to replicate the model when moving from a local to a global scale. Scaling up is clearly a major bottleneck for social enterprises and for 'social innovation' more generally. In this area, the World Council of Credit Unions (WOCCU) states that the four challenges to financial self-sustainability are: credit cooperative governance, delinquency, entrepreneurial orientation and innovation, and lack of external supervision or authorising legislation. Therefore, it can be concluded that their limit on potential growth relates to their specific characteristics, which is also one of their comparative advantages. We refer to the fact that their participatory governance or democratic management can be an element that slows down their growth Thus, it is necessary to strike a balance between participation and growth in accordance with the social issues that exist today and the economic and environmental challenges.

Finally, regarding the situation in Ecuador, it is worth highlighting the attention paid by savings and credit cooperatives to rural communities, which are those with the highest levels of poverty and therefore exclusion. They do this by facilitating access to credit and using microcredits as an essential channel. Although the degree of informality in the Ecuadorian economy is very high, the implementation of a financial system in which savings and credit cooperatives have increased their presence has encouraged a better relationship with excluded social sectors. Thus, more people and entities in rural areas have been able to access financial services and products, contributing to the development of rural areas and creating work for disadvantaged people.

So, some important implications for two main stakeholders can be highlighted: governments and international regulators. Given our results, we encourage national, regional and local governments to invest in and financially support these firms for their strong contribution to the SDGs. Thus, policy makers should provide the appropriate the support and the legal environment that facilitates the social impact of financial institutions by placing people (and environment) at the centre of their financial operations. Ecuador is an example to follow in this regard. In fact, Ecuador represents an exception because the process of institutionalization has been carried out, having integrated the sector in the national policy.

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