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SOCIAL EFFICIENCY OF THE SICREDI CENTRO-SUL MS COOPERATIVE: A DETERMINISTIC FRONTIER AND *MALMQUIST* INDEX APPROACH

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Abstract

This article analyzes the social efficiency of 24 service units of the Sicredi Centro-Sul MS cooperative between 2019 and 2021, focusing on the impacts of the COVID-19 pandemic on the performance of branches located in border municipalities between Brazil and Paraguay. The objective is to assess the relative performance of these units based on socioeconomic, financial, and demographic indicators, highlighting the cooperative's role as a driver of local development and social inclusion in areas historically overlooked by the traditional financial system. The research adopts a quantitative approach with a theoretical-deductive framework. Three methodological criteria were employed. The first pertains to the logical method, grounded in deductive reasoning from the theory of productive efficiency, emphasizing Data Envelopment Analysis (DEA). The second involves data collection, which included primary data from the cooperative and secondary data from public sources such as IBGE and RAIS. The third criterion relates to the analysis procedures, which applied the DEA model with variable returns to scale (DEA/VRS), output-oriented, to measure the relative efficiency of the units, along with the *Malmquist Index*, which assesses changes in efficiency over time, distinguishing between technological change and scale components. The results revealed a decline in the average efficiency of the units in 2020 due to the pandemic's effects. In 2021, efficiency scores showed recovery, signaling economic rebound and increased demand for credit. Only four units were efficient across all three years analyzed, indicating significant room for improvement. The *Malmquist Index* pointed to progress in scale efficiency, even in 2020, and relatively homogeneous technological adaptation among the units. However, nine branches experienced declines in technological change, suggesting specific challenges. The study concludes that Sicredi Centro-Sul MS demonstrated resilience during the health crisis and achieved advancements in technological and organizational efficiency. Nevertheless, opportunities for improvement remain, particularly in digital transformation and enhancing social efficiency in less efficient units. The study underscores the novelty of its approach and reinforces the strategic role of credit cooperativism in regional development and achieving the Sustainable Development Goals (SDGs).

Keywords: Benchmark; Brazil-Paraguay Border Local Development; Solidarity Practices; Sustainable Development Goals.

Resumo

Este artigo analisa a eficiência social de 24 unidades de atendimento da cooperativa Sicredi Centro-Sul MS, entre 2019 e 2021, com foco nos impactos da pandemia de COVID-19 sobre o desempenho das agências localizadas em municípios de fronteira entre Brasil e Paraguai. O objetivo é avaliar o desempenho relativo dessas unidades com base em indicadores socioeconômicos, financeiros e demográficos, ressaltando o papel da cooperativa como agente de desenvolvimento local e inclusão social em áreas historicamente negligenciadas pelo sistema financeiro tradicional. A pesquisa é de natureza quantitativa, com abordagem teórico-dedutiva. Três critérios metodológicos foram utilizados. O primeiro refere-se ao método lógico, baseado na dedução a partir da teoria da eficiência produtiva, com ênfase na Análise Envoltória de Dados (DEA). O segundo diz respeito ao levantamento de dados, que incluiu informações primárias da cooperativa e secundárias de fontes públicas, como IBGE e RAIS. O terceiro critério envolve os procedimentos de análise, que aplicaram o modelo DEA com retornos variáveis à escala (DEA/VRS), orientado a output, para medir a eficiência relativa das unidades, além do Índice de Malmquist, que avalia a variação da eficiência ao longo do tempo, separando os componentes de mudança tecnológica e de escala. Os resultados mostraram retração da eficiência média das unidades em 2020, relacionada aos efeitos da pandemia. Em 2021, houve recuperação nos scores, sinalizando retomada econômica e aumento da demanda por crédito. Apenas quatro unidades foram eficientes nos três anos analisados, indicando margem significativa para melhorias. O Índice de Malmquist apontou evolução na eficiência de escala, mesmo em 2020, e adaptação tecnológica relativamente homogênea entre as unidades. No entanto, nove agências apresentaram queda na mudança tecnológica, o que sugere desafios específicos. A pesquisa conclui que a Sicredi Centro-Sul MS demonstrou resiliência diante da crise sanitária e avanços em eficiência tecnológica e organizacional. Ainda assim, persistem oportunidades de melhoria, especialmente quanto à transformação digital e à ampliação da eficiência social nas unidades menos eficientes. O estudo destaca o ineditismo da abordagem e reforça o papel estratégico do cooperativismo de crédito para o desenvolvimento regional e o alcance dos Objetivos de Desenvolvimento Sustentável (ODS).

Palavras-chave: Benchmark; Desenvolvimento Local Fronteira Brasil/Paraguai; Objetivos de Desenvolvimento Sustentável; Prática Solidária.

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INTRODUCTION

Credit cooperativism has played an increasingly significant role in promoting economic development and social inclusion in territories historically characterized by low economic density and financial exclusion. In border regions, where structural challenges are exacerbated by institutional fragility and distance from major decision-making centers, credit cooperatives present themselves as viable alternatives to the traditional financial system, particularly due to their ability to foster local development, associative practices, and credit circulation.

In this context, this research is justified by the need to understand the social efficiency of cooperative organizations operating in small municipalities along the border between Brazil and Paraguay. Such an analysis is particularly timely, given the impacts of the COVID-19 pandemic, which significantly altered the economic behavior of local populations, the consumption patterns of financial services, and the performance of cooperative institutions in terms of innovation, scale, and territorial integration.

The central problem of this study can be formulated as follows: how has the social efficiency of Sicredi Centro-Sul MS service units evolved between 2019 and 2021, especially in light of the pandemic's effects and the territorial specificities of their operational area? Answering this question is important not only for the cooperative's managers but also for policymakers and scholars of regional development and solidarity economy.

The conceptual framework of this research is based on the notion of social efficiency, defined as the ability of cooperative units to generate positive impacts for their members and local communities through the provision of accessible financial services and the promotion of economic development. The analysis relies on quantitative approaches to measuring relative efficiency using non-parametric methods, specifically Data Envelopment Analysis (DEA) and the *Malmquist Index*.

Methodologically, the research adopts a quantitative approach and a theoretical-deductive logical method. It utilized primary data provided by the cooperative and secondary data from public databases (IBGE, RAIS, and other official sources). The DEA/VRS output-oriented model was applied to measure the relative efficiency among the 24 service units, complemented by the *Malmquist Index*, which evaluates efficiency variations over time, considering the components of technological change and scale.

The article is structured into six sections. The first introduces the context, objectives, and relevance of the study. The second section comprises the theoretical framework, addressing credit cooperativism and its relationship with social development, cooperativist principles vis-à-vis the

Sustainable Development Goals (SDGs), the fundamentals of social efficiency, Data Envelopment Analysis (DEA), the *Malmquist Index*, and two-stage efficiency evaluation.

The third section details the methodological procedures, including the study area, variables, and data collection and analysis stages. The fourth section presents the results and discussions, highlighting the main findings and their implications. Finally, the fifth section concludes the study, indicating its contributions, suggestions for future research, and strategies for cooperative management.

CREDIT COOPERATIVISM AND SOCIAL DEVELOPMENT

Cooperativism stands out as one of the most advanced forms of social organization, as noted by Büttenbender (2008), rooted in values and principles aimed at building an improved quality of life for millions of people worldwide.

Recognized as the largest global non-governmental organization (MEINEN, 2012), cooperatives emerge in response to the shared needs and objectives of the working class across various professional categories (BÜTTENBENDER, 2008).

Among their key characteristics is a focus on people, assigning capital an operational role. In this dynamic, individual interests give way to collective prosperity, with gains from joint efforts equitably distributed based on contributions to the initiative (MEINEN, 2012).

As highlighted by Sierra-Fernández, Martínez-Campillo, and Fernández-Santos (2019), credit cooperatives fulfill a direct social role for members and indirectly benefit public authorities, private investors, and other stakeholders linked to financial systems. This approach integrates a social commitment with economic goals, promoting fair resource allocation and citizenship, positioning the cooperative movement at the forefront of new entrepreneurship (MEINEN, 2012).

In a society increasingly seeking conscious and inclusive solutions, moving beyond profit maximization for shareholders, the cooperative model, as emphasized by Meinen (2022), inherently embodies these characteristics. Historically, this socio-economic organization model, based on self-management, has proven effective in generating employment, organizing communities, equitably distributing income, fostering inclusion, and promoting development.

Thus, it is crucial to recognize that the potential application of cooperative principles transcends legal and formal boundaries, offering essential contributions to transforming labor relations and improving the population's quality of life (BÜTTENBENDER, 2008).

Consequently, cooperative societies, as social organizations, should direct their financial resources and capabilities toward implementing social strategies, thereby enhancing trust in their

operations (AMONARRIZ; LANDART; CANTIN, 2017). However, it is important to note that social sustainability in their performance does not equate to philanthropy or artificially improving contributions through profit redistribution. Instead, it constitutes a deeper ethical core essential for social sustainability (HARRIS, 2006).

This ethical approach positions cooperatives strategically, given their heightened commitment to social responsibility. The foundations of these organizations' responsible behavior are firmly rooted in their specific cooperative principles and values. Thus, cooperatives are expected to act responsibly toward their members and society at large while maintaining economic viability (AMONARRIZ; LANDART; CANTIN, 2017).

Cooperativism Principles versus Sustainable Development Goals

In September 2015, the United Nations General Assembly approved the 2030 Agenda for Sustainable Development, which incorporates 17 Sustainable Development Goals (SDGs) (UN, 2015). These SDGs establish connections between the major challenges of our time, providing a framework for implementing sustainable development on a global scale.

By adopting a universal approach, the SDGs allow each country to develop its implementation methodology, as highlighted by Niestroy *et al.* (2019) in a study conducted in the European Union to identify best practices in SDG implementation.

The adoption of the SDGs implies a pragmatic conception of development across all societal domains. It represents a transformation in perspectives on national and international development, as well as interactions between the economy, environment, and society, steering them toward sustainability (NIESTROY *et al.*, 2019).

This perspective has led thinkers, influencers, collectives, governments, and multilateral organizations worldwide to increasingly focus on the cooperative movement. Cooperatives are regarded as the enterprises of the future, where economic activity aligns with human purpose. Consequently, the UN acknowledges the cooperative model's contribution to achieving the Sustainable Development Goals and, by extension, the pursuit of social peace a macro-objective of the United Nations (MEINEN, 2022).

The correlation between cooperative principles and SDG targets can be observed in Chart 1 below:

Chart 1 – Application of Cooperativist Principles to the Sustainable Development Goals

Cooperativist Principles	Linked goals or SDGs
1. Voluntary and Open Membership: The first principle of cooperatives emphasizes openness to all individuals willing to participate without discrimination. It reinforces values such as equity, freedom, and impartiality, promoting integration and equal opportunities.	Goals 8.10 and 10.2
2. Democratic Management: The second principle highlights the democratic management of cooperatives, emphasizing self-management, transparency, and equal participation in decision-making. This occurs through member control, adhering to the principle of "1 person, 1 vote" in assemblies such as AGMs, special meetings, council meetings, and committees. The election of members to specific roles is crucial to maintaining the cooperative identity, ensuring equitable participation in strategic decisions.	Goals 5.5 and 16.7
3. Member Economic Participation: The third principle addresses the formation and remuneration of capital in cooperatives according to the guidelines of their bylaws. Members are compensated based on their participation in the cooperative. A portion of the capital is allocated to the organization's development, promoting its sustainability and improving the services provided to members. This principle promotes values of responsibility and solidarity.	-
4. Autonomy and Independence: The fourth principle underscores the independence and autonomy of cooperatives from other organizations. Cooperatives are considered autonomous and controlled by their members. If they establish agreements with other entities, including public institutions or acquire external capital, they must do so in a way that preserves democratic member control and the cooperative's autonomy.	Goals 2.1, 2.a, and 17.17
5. Education, Training, and Information: The fifth principle emphasizes the concern of cooperativism with the intellectual progress of its members and collaborators. The focus on education reflects a commitment to individual, professional, and organizational development. This practice highlights that education, training, and information are fundamental for engagement, knowledge, and the effective performance of members, contributing to the success of cooperatives.	SDGs No. 1, 3, 4, 5, 7, 9, 13, and 14
6. Cooperation Among Cooperatives: The sixth principle emphasizes the importance of cooperation between cooperatives to strengthen the cooperative movement. This involves local, regional, national, and international partnerships, promoting intercooperation. This solidarity practice aims to ensure the continuity of the movement by encouraging integration and collaboration between cooperatives of the same or different sectors.	SDGs No. 2 and 3
7. Concern for the Community: The final principle highlights the social responsibility of cooperativism for local development. Cooperatives focus on their communities' impact, committing to collectivity and sustainability. By prioritizing people over capital, cooperatives strive for balanced community development, promoting well-being supported by economically, socially, and environmentally sustainable projects.	SDGs No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17

Source**:** Silva *et al.* (2022).

The chart above presents a study conducted by Silva *et al.* (2022), which investigated the Sicredi Cooperative and revealed that cooperativist principles align with the Sustainable Development Goals (SDGs). This alignment results in a tangible integration of these principles into the cooperative's activities. Additionally, the study indicated that adherence to the SDGs occurred naturally within the institution, providing it with a competitive market advantage to enhance its value and improve its positive impact indicators in the community where it operates.

SOCIAL EFFICIENCY AND THE IMPORTANCE OF ANALYSIS

Despite the importance of organizational and technological factors in the operations of credit cooperatives, financial and economic variables play a critical role. Key elements for stability include adequate volume and structure of funds, levels of revenue, expenses, and profits, configuration and

sources of funding, effective allocation, as well as liquidity and financial stability (ANTONOVA *et al.*, 2018). These elements, when managed integratively, require a holistic approach.

The efficiency of financial institutions has been extensively researched, with implications for improvements such as greater profitability, efficient resource allocation, competitive pricing, and quality services (BERGER *et al.*, 1993).

In the service industry, particularly in the banking sector, productivity assessments frequently focus on effectiveness and efficiency. Effectiveness relates to the achievement of planned goals, while efficiency pertains to the ability to produce results with minimal resources (SHERMAN; ZHU, 2006).

In this context, measuring efficiency is imperative for businesses, not only to maximize output and profit but also to enable effective analysis and management of operational costs (MOKHTAR *et al*., 2008). This approach views efficiency not as an isolated metric but as a strategic instrument for continuous operational improvement, guiding managerial decisions toward more robust, sustainable, and enduring economic outcomes.

Thus, efficiency evaluation is crucial, enabling managers to assess institutional performance and identify areas for improvement (MOSTAFA, 2007). It is important to note that inefficiency does not merely indicate mismanagement but can stem from managerial, technological, or socioeconomic factors (SHERMAN; ZHU, 2006).

Additionally, social efficiency expands the traditional analysis by incorporating not only economic outcomes but also the social impacts generated by institutions, particularly in contexts of vulnerability and financial inclusion. This perspective considers organizations' ability to promote social well-being, inclusion, and sustainable development while maintaining economic viability (SIMAR; WILSON, 2007).

Recent studies highlight that social efficiency has gained prominence in institutional performance analyses by integrating environmental, social, and governance (ESG) dimensions, reinforcing organizations' strategic role in achieving collective and sustainable outcomes (TONE; TSUTSUI, 2021; TOMA *et al*., 2020; LU *et al*., 2023).

Data Envelopment Analysis and *Malmquist Index*

The foundation presented earlier underscores the importance of efficiency evaluations in organizations, directly linked to the economic principles of efficiency proposed by Farrell (1957) and the Data Envelopment Analysis (DEA) methodology developed by Charnes *et al*. (1978). DEA is a non-

parametric approach used to analyze the efficiency of production units, comparing the efficiency of similar units by utilizing multiple inputs and outputs (LINS; MEZA, 2000).

The model can be described as a quantitative and empirical method for measuring the relative performance of independent and similar units, generating a single performance indicator for each evaluated unit based on the weighted relationship between inputs and outputs. In this context, DEA employs linear programming optimization to construct an empirical production frontier or enveloping surface of maximum performance, identifying reference units that serve as *benchmarks* for those considered inefficient (NIEDERAUER, 1998).

Regarding the Malmquist-DEA method, the model was developed by renowned researchers Färe *et al.* (1994) and has gained prominence in recent years as a robust tool for evaluating production efficiency. This method integrates with Data Envelopment Analysis (DEA), a powerful and widely employed approach to identify efficient frontiers. Two critical advantages arise from applying DEA: the elimination of price information requirements and the ability to decompose changes in Total Factor Productivity (TFP) into components such as 'technological changes' and 'technical efficiency changes.'

Determination of Efficiency in Two Stages

The DEA modeling stands out as one of the most widely used methodologies for determining the efficiency frontier in enterprises. This approach is often enhanced by integrating other models, referred to as the "second stage." A review of the literature reveals various models, such as Tobit Regression and the *Malmquist Index*, among others, used to validate the variables employed in the study. These additional calculations not only validate the dependent and explanatory variations but also enhance the precision of interpreting efficiency by considering its influence on technological changes or technical efficiency variations.

It is important to note that the literature on studies regarding social efficiency in credit cooperatives is limited, unlike the more common studies on private and/or public banks. The latter predominantly focus on demonstrating economic efficiency and, occasionally, social efficiency, as illustrated in Chart 2.

Chart 2 – Characteristics of Studies on Economic and/or Social Efficiency Based on DEA Modeling and Second-Stage *Tobit* or *Malmquist*

Authors/Year	Variables Used	Methods	Efficiency Type
Ureña and Úbeda (2008)	Input: Personnel expenses, Administrative expenses, Financial intermediation expenses; Output: Customer socialization.	1	Economic Efficiency
Ureña (2012)	Input: Personnel expenses, Administrative expenses, Financial intermediation expenses; Output: Financial inclusion.	1	Social Efficiency
Araújo and Carmona (2015)	Input: Operational expenses, Number of employees; Output: Number of active clients.	1 and 3	Financial and Social Efficiency
Baten and Kasim (2015)	Input: Fixed assets, Personnel expenses, Total loans, Number of employees; Output: Total cost, Profit, Advances, Other profitable assets, Off-balance sheet items.	1 and 3	Economic Efficiency
Martínez-Campillo and Fernández-Santos (2017)	Input: Amortization expenses, Personnel expenses, Interest expenses; Output: Customer socialization degree, Financial inclusion.	1	Social Efficiency
Widiarto and Anastasakis (2017)	Input: Total assets, Number of employees; Output: Interest income, Inverse of the average loan balance/GDP per capita, Number of borrowers.	1 and 2	Financial and Social Efficiency
San-Jose, Retolaza, and Lamarque (2018)	Input: Net equity, Deposits; Output: Loans, Personnel expenses, Social contribution/taxes, Risk.	1*	Social Efficiency
Martins *et al.* (2018)	Input: Operational liabilities, Funding sources, Long-term deposits, Third-party resources, Net equity, Operational assets, Financial reserves and funds, Return on capital; Output: Earnings and income, Results available to the General Assembly.	1 and 3	Economic Efficiency
Sierra-Fernández, Martínez-Campillo, and Fernández-Santos (2019)	Input: Number of employees, Number of branches, and Equity (member quotas and reserves); Output: Number of loans to clients/total members, Number of branches in municipalities with fewer than 25,000 inhabitants/total branches (%), % of net profit allocated to the social fund.	1 and 2	Social Efficiency
Bayiley (2022)	Input: Interest expenses, Operational expenses, Total deposits; Output: Interest income, Non-interest income, Total loans.	1 and 3	Economic Efficiency
Shah *et al.* (2022)	Input: Interest expenses, Non-financial expenses; Output: Net interest income, Non-financial income.	1	Economic Efficiency
Cavinato and Capitani (2023)	Input: Personnel expenses, Financial intermediation expenses, Total assets, Net equity; Output: Indicator of benefits to low-income individuals, Number of loan recipients, Number of loans.	1**	Social Efficiency

Source: Self elaboration.
Notes: In this study, the authors considered Factorial Variance Analysis as the second stage, comparing means of two or more factors (San-Jose, Retolaza, and Lamarque, 2018).

The Chart 2 highlights several studies that aimed to evaluate efficiency exclusively through DEA modeling (CRS or VRS). In addition, it reveals that many research works have emerged with the application of additional approaches, known as second-stage modeling.

MATERIALS AND METHODS

This study adopts a quantitative approach of an applied nature, with exploratory-explanatory objectives and a theoretical-deductive foundation. The methodology was structured to ensure rigor in data collection, processing, and analysis, in line with scientific standards recognized in recent literature (LEE *et al.*, 2023; BANSAL; ALONSO, 2022).

Scientific Method

The adopted logic is theoretical-deductive, where, based on theoretical assumptions and the conceptual framework on social efficiency, an analytical model is structured and applied to empirical data. This method allows hypotheses to be derived and tested based on observable evidence, and it is widely recommended in studies utilizing Data Envelopment Analysis (DEA) and the *Malmquist Index*, particularly in research on institutional performance (KUNC; TONE; KAZEMIKHOO, 2023).

Data Collection Procedures

The data collection process was documentary and census-based, relying on secondary sources provided by the Sicredi Centro-Sul MS cooperative for 24 service units located along the Brazil-Paraguay border. The collected data covered the years 2019 to 2021, focusing on financial, operational, and social information related to the performance of the units.

To ensure the confidentiality of data from the selected DMUs, agency identifiers were coded, as presented in Chart 3.

Chart 3 – Coding of Sicredi Centro-Sul MS Service Units

A402	A306	A311	A315	A319	A323
A403	A308	A412	A316	A220	A324
A304	A209	A313	A317	A321	A325*
A305	A410	A314	A418	A322	A328

Source: Self elaboration.
Note: *Example of coding for A325: ‘A’ stands for "agency"; ‘3’ relates to the size of the agency; and ‘25’ indicates the 25th agency among the 44 service units of Sicredi Centro-Sul MS.

Additionally, secondary data were extracted from public reports by the Central Bank of Brazil and IBGE to validate regional indicators. The strategy of collecting data from institutional sources reinforces the reliability of the information, as recommended by Zhang and Choi (2023) for studies in cooperative contexts.

Data Profile

Primary data consisted of variables directly provided by the studied institution (inputs and outputs), processed in standardized spreadsheets. Secondary data included demographic and socioeconomic statistics from the regions covered by the service units, obtained from national public databases.

The input and output variables used in this study are detailed in Chart 4.

Chart 4 – Description of Input and Output Variables

Variable	Abbreviation	Variable	Description
input 1	*EDP*	Personnel expenses	Sum of personnel expenses
input 2	*EDC*	Fundraising expenses	Cost that the financial institution has to raise resources that will be used for a specific purpose
input 3	*EPL*	Net worth	Accounting indicator resulting from the difference between the cooperative's assets and liabilities
Output 1	*P*	Benefit indicator for low-income individuals	It measures the extent of the benefits created for the neediest population through the actions of credit cooperatives. K = average loan balance per member / 100 municipal GDP per capita
Output 2	*ITE*	Loan taking indicator	Number of active members who take credit

Source: Self elaboration.

The selection of these variables aligns with literature on evaluating social efficiency in financial organizations, particularly in cooperatives (AIDOO; JANG, 2022; GIANNENI; BASTIAN; MÜLLER, 2021).

Regarding the benefit indicator for low-income individuals, the goal is to analyze the extent of benefits provided to vulnerable populations through credit cooperative initiatives. Gutiérrez-Nieto, Serrano-Cinca, and Mar-Molinero (2009) and Cavinato and Capitani (2023) emphasize that the same credit amount may yield different impacts depending on community needs. They recommend contextualizing the average loan balance per client relative to the GDP per capita of the city where the credit cooperative operates.

In this study, the abbreviation 'P' represents this indicator. It is important to note that certain calculations are essential to derive this indicator, requiring the following operations:

$$K = \frac{Average\ loan\ balance\ per\ customer}{municipal\ GDP\ per\ capita} \qquad (1)$$

Since the K index must be standardized to values between 0 and 1:

$$p_i = 1 - \frac{K_i - Min\ (K)}{Max\ (K) - Min\ (K)} \qquad (2)$$

Based on this indicator, the observation units with the greatest impact on the needy population have p_i values closer to 1.

Next, the p_i index must be multiplied by the number of member borrowers. Thus, the variable *P* is obtained, which, according to the authors, can be used as a social output (GUTIÉRREZ-NIETO; SERRANO-CINCA; MAR-MOLINERO, 2009).

$$P = p_i * borrowing\ members \qquad (3)$$

The configuration of 3 inputs and 2 outputs follows the standard established by Banker *et al.* (1989) for its implementation in data envelopment analysis (DEA) models, known as the 'Golden Rule'. This rule determines that the number of decision-making units must be at least three times greater than the total of variables used.

In this study, the social efficiency index is calculated through the application of the data envelopment analysis method, using the VRS model with product orientation. This model aims to maximize the proportional increase in production levels (*y*), while keeping the quantity of inputs (*x*) constant.

Two-Stage Data Analysis Procedures

- ***Relative Efficiency Analysis***

Relative efficiency was assessed using the DEA model under VRS (Variable Returns to Scale) orientation, focusing on outputs, as proposed by Banker *et al.* (1984). This model is suitable when considering that different units operate at varying scales and is widely applied in measuring cooperatives' social efficiency (JAHANSHAHI; GHORBANI; SEIFI, 2023).

Literature highlights DEA's ability to identify reference sets of units, which serve as *benchmarks* for improving the efficiency of those below the efficiency frontier (LINS; MEZA, 2000). Among DEA formulations, the two most common models are CRS (Constant Returns to Scale), introduced by Charnes *et al.* (1978), and VRS (Variable Returns to Scale), developed by Banker (BANKER *et al.* 1984).

The VRS model, which considers variable returns to scale, updates the prediction of proportionality between inputs and outputs based on the convexity premise. Thus, even with the production frontier being convex, the VRS model allows DMUs to operate with low input values and have increasing returns to scale, while those that operate with high values have decreasing returns to scale. In mathematical terms, these specificities are represented by an additional variable in the objective function and in the second constraint (u* or v*), with this variable being responsible for representing the scale factor, generating increasing, decreasing or zero returns to scale (COOK; ZHU, 2008).

Equation 4 presents the VRS model, with output orientation:

$$Max\ h_0 = \sum_{j=1}^{m} u_j\ y_{j0} + u^*$$

Subject to:

$$\sum_{i=1}^{n} v_i\ x_{io} = 1$$

$$\sum_{j=1}^{m} u_j\ y_{jk} - \sum_{i=1}^{n} v_i\ x_{ik} \leq 0\ , k = 1, \dots, s \qquad (4)$$

$$u_j\ , v_i \geq \quad \forall x, y$$

$$u^* \in \Re$$

Where:

h_0 = Efficiency of DMU_0 in analysis; η = Inverse of efficiency ($1/h_0$); λ_k = Participation of DMU_k in the target of the DMU under analysis; x_{ik} = Quantity of input *i* of DMU_k ; y_{ik} = Quantity of output *j* from DMU_k ; x_{i0} = Quantity of input *i* of the DMU under analysis; y_{j0} = Quantity of DMU output under analysis; *saw* = weight assigned to input *i* ; u_j = weight assigned to output *j*; *u** = scale factor; *j* =1 = convexity constraint; s = Number of outputs, e *;* r = Number of inputs (CHARNES *et al.*, 1978; BANKER *et al.*, 1984).

- ***Intertemporal Efficiency Variation Analysis***

This analysis was conducted using the *Malmquist Index*, following the methodology of Färe *et al*. (1994). It enables the decomposition of efficiency changes over time into two components: technical efficiency change (catch-up) and technological change (frontier shift). This index is particularly useful for identifying the impact of external shocks, such as the COVID-19 pandemic, on institutional performance (YU; LI; WANG, 2022).

The *Malmquist*-DEA method begins by utilizing the DEA linear programming algorithm to construct a specific production frontier for a given period. This model then calculates the ratio between the distances of two production points, both belonging to the same unit but in different periods, relative to the newly constructed frontier (FÄRE *et al.*, 1994).

A notable advantage of this method is the ability to avoid the complicated choice between the two production frontiers typical in other index calculation approaches. A *Malmquist Index* (M_o) greater than *1* indicates growth or evolution in Total Factor Productivity between periods '*t*' and '*t+1*', while a value less than *1* suggests a decline in this indicator. The mathematical formulation (equation 5) proposed by Färe *et al. (*1994) for the *Malmquist Index* uses the variables *'e*' and '*u'* to represent the volumes of inputs and outputs of the decision-making unit (DMU) at time '*t*', while the variable '*v'* denotes the distance to the border at time '*t*', measured in terms of relative efficiency according to the DEA calculation, oriented towards product maximization.

Furthermore, an essential component of the analysis is the comparison of the results obtained in this application when applying the proposal of Färe *et al.* (1994) with the approach of Bjurek (1996), in order to evaluate the impact of the assumptions of constant returns of DEA scale when calculating the *Malmquist Index*. This comparison provides a more comprehensive and in-depth view of changes in efficiency over time, enriching the understanding of the productive performance of the units under analysis.

Output-oriented distance function for more than one period is presented in equation 5:

$$D_o^t(x^{t+1}, y^{t+1}) = (max\{\phi: (x^{t+1}, \theta y^{t+1}) \in S^{t+1}\})^{-1} \qquad (5)$$

This ratio reflects the variation in efficiency over time, being obtained by determining the distance from the production point of period '*t'* to the frontier of that same period and the distance from the production point of period '*t+1'* to the frontier from period '*t+1'* to the border of the same period '*t'*. The result of this calculation provides the *Malmquist Index*, as proposed by Färe *et al. (*1994), represented in equations (6) and (7), respectively.

$$M^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \qquad (6)$$

$$M^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \qquad (7)$$

Output-oriented *Malmquist Index* occurs through the geometric mean of equations (6) and (7):

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (8)$$

Färe *et al.* (1994), show that equation (8) is equivalent to:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \quad (9)$$

The result of equation (9) can be greater than, equal to or less than one. The interpretations of the results can be as follows:

$M_o > 1$: Indicating that an increase in productivity occurs DMU_k in period *t+1* in relation to *t*;

$M_o = 1$: Productivity DMU_k remained constant in period *t+1* in relation to *t*;

$M_o < 1$: Indicating that productivity DMU_k decreased in period *t+1* in relation to *t*.

In this way, the index M_o can be decomposed, enabling the analysis of the dynamics of technical efficiency and the behavior of the efficient frontier.

By decomposing equation (9), it is possible to capture two effects: i) catch-up effect, which identifies whether the DMU's technical efficiency improved, remained constant or worsened in period *t+1* relative to *t*; and ii) the effect of shifting the efficient frontier (frontier-shift effect) in period *t+1* in relation to *t*. This occurs due to the incorporation of new technologies (or reduction), allowing us to analyze whether there has been technological progress (regress) (ARAÚJO-JÚNIOR *et al.*, 2017).

Equation (10) shows the catch -up effect:

$$EE_o = \left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right) \quad (10)$$

On what,

$EE_o > 1$: It indicates that there was an increase in technical efficiency DMU_k in period *t+1* in relation to *t*;

$EE_o = 1$: The technical efficiency of DMU_k remained constant in the period *t+1* in relation to *t*;

$EE_o < 1$: There was a reduction in technical efficiency DMU_k in period *t+1* in relation to *t*.

The shift of the efficient frontier (frontier-shift effect) is presented in equation (11):

$$ED_o = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}} \qquad (11)$$

On what,

$ED_o > 1$: It represents technological progress in DMU_k in the period *t+1* in relation to *t*;

$ED_o = 1$: There were no technological advances in DMU_k in the period *t+1* in relation to *t*;

$ED_o < 1$: There was a technological setback in DMU_k in the period *t+1* in relation to *t*.

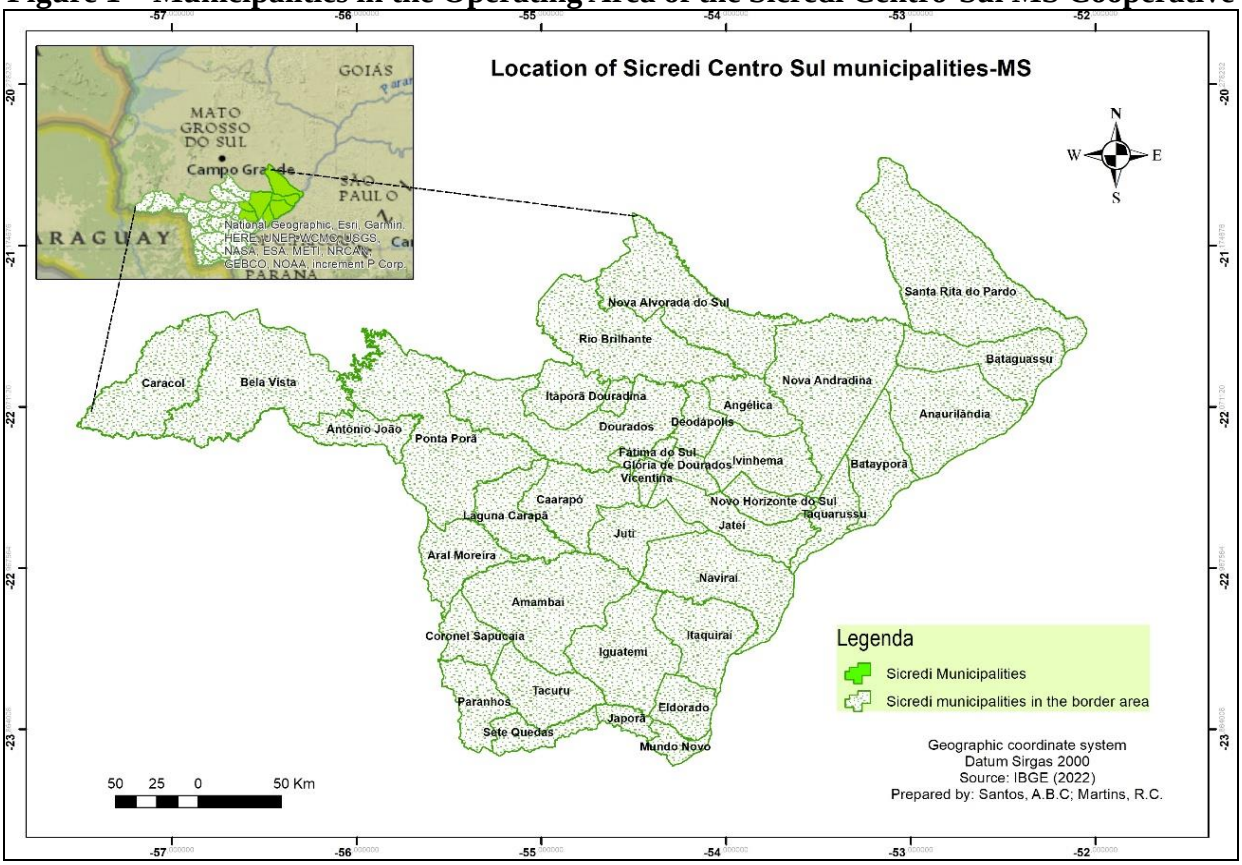
Methodological Justification

The adoption of Data Envelopment Analysis combined with the *Malmquist Index* is justified by their ability to measure efficiency without requiring a functional production specification. These methods are particularly suitable for contexts where social performance and the multiplicity of objectives are relevant, as is the case with credit cooperatives (TAVARES *et al.*, 2023).

Scope of the Sicredi Centro-Sul MS Credit Cooperative

The Sicredi Centro-Sul MS Credit Cooperative, located in the southern region of the state of Mato Grosso do Sul, operates across 38 municipalities under its jurisdiction. Its area of operation spans from the municipality of Caracol to Santa Rita do Pardo, covering both the westernmost and easternmost parts of the state. Most of these municipalities are characterized by extensive territorial areas and low population density, with 31 of them classified as border municipalities, as highlighted in Figure 1.

Figure 1 – Municipalities in the Operating Area of the Sicredi Centro-Sul MS Cooperative



Source**:** IBGE, 2022.

Characteristics such as population size, demographic density and year of foundation of the municipality are presented in Chart 5 and highlight particularities of the region where the cooperative operates.

Chart 5 – Description of Municipalities in the Operating Area of Sicredi Centro-Sul MS: Founding Year, Population, and Demographic Density

Municipality / Founding Year	Census Population	Demographic Density (inhabitant/km²)	Municipality / Founding Year	Census Population	Demographic Density (inhabitant/km²)
Jateí (1963)	3,586	1.85	Paranhos (1987)	12,921	9.89
Taquarussu (1980)	3,625	3.45	Deodápolis (1976)	13,663	16.49
Novo Horizonte do Sul (1993)	4,721	5.56	Iguatemi (1965)	13,808	4.67
Caracol (1985)	5,036	1.71	Coronel Sapucaia (1985)	14,289	13.96
Douradina (1980)	5,578	19.89	Mundo Novo (1976)	19,193	40.12
Vicentina (1989)	6,336	20.28	Itaquiraí (1980)	19,423	9.41
Juti (1989)	6,729	4.29	Fátima do Sul (1963)	20,609	65.36
Laguna Carapã (1993)	6,799	3.94	Bela Vista (1908)	21,613	4.41
Santa Rita do Pardo (1987)	7,027	1.14	Nova Alvorada do Sul (1991)	21,822	5.42
Anaurilândia (1963)	7,653	2.24	Bataguassu (1953)	23,031	9.63
Japorã (1992)	8,148	19.56	Itaporã (1953)	24,137	17.98
Antônio João (1964)	9,303	8.14	Ivinhema (1963)	27,821	13.89
Glória de Dourados (1956)	10,444	21.17	Caarapó (1963)	30,612	14.47
Batayporã (1963)	10,712	5.86	Rio Brilhante (1930)	37,601	9.44
Angélica (1976)	10,729	8.36	Amambai (1948)	39,325	9.38
Aral Moreira (1976)	10,748	6.50	Nova Andradina (1958)	48,563	10.18
Tacuru (1981)	10,808	6.06	Naviraí (1963)	50,457	15.82
Sete Quedas (1980)	10,994	13.10	Ponta Porã (1892)	92,017	17.17
Eldorado (1976)	11,386	11.24	Dourados (1935)	243,367	59.91

Source: IBGE (2022).

From Figure 1 and Chart 5, it is possible to observe details that highlight the peculiar characteristics of the region where Sicredi Centro-Sul MS operates, including: **a)** 55.26% of the municipalities (representing a total of 21) have a population density of less than 10 inhabitants/km2 – Santa Rita do Pardo has the lowest density (1.14 inhabitants/km2); **b)** 78.95% have a population of less than twenty-five thousand inhabitants. The municipality of Jateí has the smallest population among the municipalities listed in the area of operation, with 3,586 inhabitants; **c)** 52.63% of the municipalities listed were founded between 30 and 47 years ago; **d)** 81.57% of the municipalities are located in the border area with the Republic of Paraguay; **e)** 5 (five) municipalities – Bela Vista, Mundo Novo, Paranhos, Ponta Porã and Coronel Sapucaia – are considered twin cities.

Regarding these particularities, a study carried out by Assunção (2020) outlined some characteristics of the benefits of credit unions and their impacts on banking that help to understand the challenges (between threats and opportunities) that the cooperative under analysis may face. The study finds that:

- Cooperative branches seek to serve less populated areas, in areas with rural characteristics and more isolated than those served by traditional bank branches. The credit union model has been established in areas where vulnerable people have great difficulty accessing banking services and products;
- In this regard, the study indicates that traditional bank branches tend to be concentrated in more populated areas, being closer to the state capitals;
- Another point highlighted is that the study demonstrates a deepening of the Sicredi system, which has increased its penetration in the country. Previously, in 2007, the system's entry model was only capable of serving municipalities with a population greater than 6,000 inhabitants. However, today the model allows an entry threshold of around 2,300 inhabitants, with examples of application mainly in the southern region of the country;
- In addition, in simulated exercises, it is shown that Sicredi has the potential to extend its coverage offered by bank branches to almost 9.5 million people, reaching around 1,900 municipalities. This public mainly resides in more isolated areas and lives in places with more rural and poorer characteristics than those that can also be served by bank branches considered traditional.

From the perspective presented in the studies prepared by Assunção (2020, p.3) associated with the characteristics of the municipalities in the area of operation of Sicredi Centro-Sul MS, cooperativism, according to the author, presents itself as 'an important inclusion mechanism for individuals who live in poorer, more isolated and less urbanized areas of the country', ratifying the relevance of the expansion of the financial and credit systems as fundamental for the socioeconomic development of Brazil.

RESULTS AND DISCUSSIONS

Table 1 below presents the correlation between the selected variables, indicating potential dependencies or independencies among them (BARROGA; MATANGUIHAN, 2022).

Table 1 – Correlation between the input and output variables selected for the model

		Input			Output	
	Variables	**EDP**	**EDC**	**EPL**	**P**	**ITE**
Input	**EDP**	1				
	EDC	0.90	1			
	EPL	0.93	0.95	1		
Output	**P**	0.26	0.21	0.34	1	
	ITE	0.97	0.91	0.95	0.35	1

Source: Self elaboration.

In the context presented, the input and output variables selected for the study mostly present 'strong and positive' correlations (HOPKINS, 2006), validating their application to the proposed model.

The descriptive analysis of the data used in the study is presented in Table 2:

Table 2 – Descriptive statistics of the variables applied to the study (2019-2021)

Year	Description	EDP	EDC	EPL	P	ITE
2019	**Average**	R$ 1,910,916	R$ 2,486,872	R$ 218,663,386	R$ 255	1763
	DesP*	R$ 1,087,175	R$ 2,413,121	R$ 175,286,031	R$ 130	999
	Minimum	R$ 876,318	R$ 218,606	R$ 47,883,279	R$ 1	526
	Maximum	R$ 4,675,977	R$ 8,888,125	R$ 730,537,925	R$602	4171
2020	**Average**	R$ 2,015,309	R$ 1,945,376	R$257,892,408	R$ 232	1920
	DesP*	R$ 1,128,825	R$ 1,770,511	R$188,435,324	R$89	975
	Minimum	R$ 937,564	R$ 212,633	R$90,966,572	R$ 1	839
	Maximum	R$ 5,032,183	R$ 6,759,016	R$801,110,085	R$384	4311
2021	**Average**	R$ 2,254,484	R$ 3,129,542	R$ 289,480,962	R$ 362	3101
	DesP*	R$ 1,209,774	R$ 3,108,957	R$ 199,394,019	R$ 158	1640
	Minimum	R$ 1,060,713	R$ 334,075	R$ 121,365,719	R$ 1	1356
	Maximum	R$ 5,688,282	R$ 14,119,265	R$ 886,966,184	R$712	6819

Source: Self elaboration.
Note: * DevP = Standard deviation. Values expressed in reais (R$)

Table 2 shows retractions in the values of the variables for the period in 2020, which is probably due to the effects of COVID-19, due to all the prevention measures related to pandemic care (WILDER-SMITH; FREEDMAN, 2020; BACEN, 2021). Likewise, it is noted that in 2021 the numbers resumed growth, with a considerable increase in the cost of raising funds accompanied by a relative increase in the number of borrowers, as seen in the average described. The increases observed in these variables denote the growing demand for access to credit in an imminent attempt to resume economic stabilization after COVID-19.

The efficiency frontier, based on the application of the output-oriented DEA/VRS model, showed the following results:

Table 3 – Social efficiency frontier for the selected DMUs (2019-2021)

DMUS	2019	2020	2021		DMUS	2019	2020	2021
A402	1.0000	1.0000	1.0000		**A315**	0.7901	0.7411	1.0000
A403	0.8987	0.9211	0.9300		**A316**	0.9610	0.9020	0.8960
A304	0.8475	0.9823	1.0000		**A317**	0.8290	0.7765	0.8746
A305	0.8639	0.8289	0.9306		**A418**	1.0000	0.9432	1.0000
A306	0.7653	0.6440	0.7047		**A319**	0.5399	0.4844	0.5534
A308	0.6616	0.6320	0.8345		**A220**	1.0000	1.0000	1.0000
A209	0.9288	0.9327	1.0000		**A321**	0.8240	0.7501	0.8247
A410	0.9594	0.8719	1.0000		**A322**	0.9375	0.8451	0.8744
A311	0.9974	0.8157	0.8900		**A323**	0.8658	0.8334	1.0000
A412	1.0000	1.0000	1.0000		**A324**	1.0000	1.0000	1.0000
A313	0.9743	0.9068	1.0000		**A325**	1.0000	0.8249	0.7938
A314	0.9453	0.8091	0.9203		**A328**	1.0000	0.6452	1.0000

Source: Self elaboration.

Among the 24 service units analyzed, only four DMUs (A402; A412; A418 and A324) reached and remained within the efficiency frontier for the three periods analyzed.

The descriptive analysis of the results obtained in the previous table can be better observed in Table 4, as shown:

Table 4 – Descriptive analysis of the efficiency scores of the 24 DMUs analyzed (2019-2021)

DESCRIPTION	2019	2020	2021
Average	0.8996	0.8371	0.9178
Minimum	0.5399	0.4844	0.5534
Maximum	1.0000	1.0000	1.0000
Dev.P	0.1171	0.1335	0.1110
%eff	29.17%	16.67%	50.00%
Qty. Eff	7	4	12

Source: Self elaboration.

Although the agencies under analysis presented an average efficiency greater than 0.80 in all periods analyzed, the period of 2020 was the one that presented the smallest number of DMUs operating under the efficiency frontier in addition to presenting DMUs operating with less than 50% of its capacity (DMU A319 – Table 3). In this aspect, similar results were observed in a study carried out by Tanjung and Purnamadewi (2021) who analyzed the impacts of the COVID-19 pandemic on microenterprises and cooperative institutions.

The efficiency scores for the respective years of analysis are presented in Table 5 and indicate that the maintenance of the social efficiency frontier was only achieved and maintained over the three years of analysis (2019 to 2021) by four agencies: A402; A412; A220 and A324, demonstrating a *benchmark performance* for the others.

Table 5 – Ranking of efficiency scores obtained in the DEA/VRS model – output-oriented (019 to 2021) and respective benchmarks

	SCORE			*BENCHMARKS*		
DMUs	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
A402	1.0000	1.0000	1.0000	A412	A324	-
A403	0.8987	0.9211	0.9300	A412; A324	A412; A324	A304; A313
A304	0.8475	0.9823	1.0000	A412; A324	A412; A324	-
A305	0.8639	0.8289	0.9306	A412; A324	A412; A324	A304; A412; A315; A324
A306	0.7653	0.6440	0.7047	A412; A324	A412; A324	A304; A412; A324
A308	0.6616	0.6320	0.8345	A412; A324	A412; A324	A412; A324
A209	0.9288	0.9327	1.0000	A412; A220; A325	A220; A324	A324
A410	0.9594	0.8719	1.0000	A412; A324	A412; A324	A304; A412; A324
A311	0.9974	0.8157	0.8900	A412; A324	A412; A324	A220; A324
A412	1.0000	1.0000	1.0000	-	-	-
A313	0.9743	0.9068	1.0000	A412; A324	A324	-
A314	0.9453	0.8091	0.9203	A412; A220	A412; A324	A304; A410; A324
A315	0.7901	0.7411	1.0000	A412; A220	A412; A324	A324
A316	0.9610	0.9020	0.8960	A412; A324	A412; A324	A412; A315; A324
A317	0.8290	0.7765	0.8746	A412; A324	A412; A324	A412; A315; A324
A418	1.0000	0.9432	1.0000	-	A402	A412
A319	0.5399	0.4844	0.5534	A412; A324	A412; A324	A315; A324
A220	1.0000	1.0000	1.0000	-	-	-
A321	0.8240	0.7501	0.8247	A412; A220	A412; A324	A315; A324
A322	0.9375	0.8451	0.8744	A412; A220	A412; A324	A412; A324
A323	0.8658	0.8334	1.0000	A220; A324; A325; A328	A220; A324	-
A324	1.0000	1.0000	1.0000	-	-	-
A325	1.0000	0.8249	0.7938	-	A220; A324	A313; A315; A324
A328	1.0000	0.6452	1.0000	-	A220; A324	-

Source: Self elaboration.

In analysis, it is possible to identify that 70.83% or 17 service units showed reductions in efficiency in the period of 2020, signaling likely consequences caused by the COVID-19 pandemic and the introduction of public health measures discouraging personal contacts (BACEN, 2021). However, in the following year (2021), 83.33% of service units resumed improving their performance, increasing the result from 8 DMUs (A304; A209; A410; A313; A315; A418; A323 and A328) to 100% of efficiency.

The *benchmarks* that can guide the other agencies are presented in Chart 6, organized with the aforementioned DMUs and respective pair frequencies.

Chart 6 – Benchmark pairs for the years 2019 to 2021

2019		**2020**		**2021**	
DMUs	**Frequencies**	**DMUs**	**Frequencies**	**DMUs**	**Frequencies**
A412	18	A324	20	A324	15
A324	17	A412	15	A304	6
A220	7			A412	9
A325	3	A220	5	A315	7
				A313	3
A328	2	A402	2	A220	2
				A410	2

Source: Self elaboration.

The A324 DMUs; A412 and A220 (size III, IV and II respectively) are the main *benchmarks* for the other service units, highlighting a heterogeneity in management models, considering the size of the agencies. It is also observed that, in 2020, where only 4 UAs achieved 100% efficiency, the *benchmark*

was mainly restricted to DMUs A324 and A412, indicating the possibility of studies on the factors that contributed to them achieving such performance.

Malmquist Index for the Service Units under analysis are presented in Table 6.

Table 6 – Malmquist indices for the 24 service units – M_0 : 2019 ~ 2020; M_0 : 2020 ~2021

	MPTF			MPTF Variation		MT			Variation MT		MEE			Variation MEE	
DMUs	2019	2020	2021	2019 ~ 2020	2020 ~ 2021	2019	2020	2021	2019 ~ 2020	2020 ~ 2021	2019	2020	2021	2019 ~ 2020	2020 ~ 2021
A402	0.74	1.02	1.52	37.51	49.01	0.66	1.14	1.20	71.79	4.78	1.12	0.89	1.27	-19.95	42.21
A403	0.31	0.98	1.57	216.29	59.87	0.44	1.14	1.20	157.48	4.78	0.70	0.86	1.31	22.84	52.58
A304	0.41	1.02	1.67	147.24	64.02	0.55	1.14	1.20	108.01	4.78	0.75	0.89	1.39	18.86	56.54
A305	0.33	1.06	1.39	224.61	31.25	0.45	1.14	1.20	154.10	4.78	0.73	0.93	1.16	27.75	25.26
A306	0.34	0.95	1.41	183.06	47.95	0.44	1.14	1.20	160.66	4.78	0.77	0.83	1.17	8.60	41.20
A308	0.28	1.06	1.60	274.39	50.65	0.46	1.14	1.19	149.95	3.82	0.62	0.93	1.35	49.79	45.11
A209	0.30	1.21	1.27	301.50	5.09	0.36	1.13	1.15	216.31	1.62	0.84	1.07	1.11	26.93	3.41
A410	0.55	1.01	1.57	82.84	56.14	0.69	1.14	1.20	66.47	4.78	0.80	0.88	1.31	9.83	49.02
A311	0.34	1.06	1.18	212.87	11.41	0.41	1.17	1.07	189.64	-9.05	0.84	0.90	1.10	8.02	22.49
A412	0.41	1.08	1.45	167.14	33.88	0.47	1.14	1.20	143.60	4.78	0.87	0.95	1.21	9.67	27.77
A313	0.30	0.99	1.31	235.77	32.48	0.38	1.11	0.95	190.06	-14.10	0.77	0.90	1.38	15.76	54.22
A314	0.53	0.98	1.47	85.18	50.86	0.70	1.14	1.20	63.98	4.78	0.76	0.85	1.23	12.93	43.98
A315	0.31	0.96	1.64	211.96	71.36	0.44	1.14	1.12	161.72	-2.20	0.70	0.84	1.47	19.20	75.21
A316	0.38	0.96	1.22	149.97	28.26	0.36	1.02	1.07	184.64	4.37	1.06	0.93	1.15	-12.18	22.89
A317	0.30	1.04	1.20	246.62	15.82	0.31	1.04	1.09	232.31	4.66	0.96	1.00	1.11	4.31	10.66
A418	0.65	0.90	1.44	37.19	61.17	0.77	1.14	1.20	48.38	4.78	0.85	0.78	1.21	-7.54	53.82
A319	0.45	1.06	1.32	134.21	24.76	0.56	1.14	1.19	104.89	4.41	0.81	0.93	1.11	14.31	19.50
A220	0.37	1.23	0.98	232.31	-20.43	0.37	1.23	0.98	232.31	-20.43	1.00	1.00	1.00	0.00	0.00
A321	0.48	1.01	1.22	111.77	20.88	0.50	1.13	0.98	128.63	-13.14	0.96	0.89	1.24	-7.37	39.17
A322	0.45	1.00	1.15	119.68	15.56	0.45	1.19	1.07	163.15	-10.37	1.00	0.84	1.08	-16.52	28.92
A323	0.34	1.22	1.01	256.19	-16.94	0.33	1.15	1.10	253.09	-4.80	1.05	1.06	0.92	0.88	-12.76
A324	0.34	1.10	0.98	225.86	-10.28	0.34	1.10	0.98	225.86	-10.28	1.00	1.00	1.00	0.00	0.00
A325	0.35	0.95	0.91	172.59	-4.67	0.33	1.19	0.94	265.02	-21.40	1.07	0.80	0.97	-25.32	21.27
A328	0.31	0.91	1.07	198.38	16.58	0.34	1.09	1.12	220.06	3.10	0.90	0.84	0.95	-6.78	13.08

Source: Self elaboration.
Note: *MPTF refers to the change in total factor productivity; **MT refers to technological change; ***MEE refers to change in scale efficiency;

The MPTF, MT and MEE variation columns show the progress or return of the respective indices for the periods: M_0 2019 ~ 2020 and M_0 2020 ~ 2021.

The results indicate that the UAs under analysis show evolution in the change in scale efficiency (MEE) over the three years. Similar behavior was also observed in studies carried out by Zaman and Khan (2023) who analyzed cooperative banks in Jammu and Kashmir/India in the period between 2015 and 2019.

In the present study, in 2020 only 7 UAs showed a decline in the index and of these 2 were below 1 (A325 and A328) for the following year (2021). The timid escalation of the scale change for 2020 may be a consequence of the effects of the COVID-19 pandemic, being overcome in the following year (2020), as seen in the indices presented in Table 6.

Regarding technological change (MT) in 2019, all agencies under analysis presented M_0 below 1. Comparatively, other studies highlighted the positive contribution of technological change in the

construct of better performances (MPTF), whether in Indian banks, according to research carried out by Dar, Mathur and Mishra (2021) or in commercial banks in Ethiopia (ABDULAHI *et al.,* 2023).

However, it is noteworthy that the adversities of 2020 required cooperatives to be more adaptable to available technologies in a homogeneous manner, meaning greater investments in new technologies, such as the expansion of mobile use banking (FEBRABAN, 2021).

The results predominantly point to an evolution in the change of scale (MEE) with the result of M_0 greater than 1, indicating that the analyzed UAs overcame the challenges associated with the pandemic period (COVID-19) that impacted economic activities in Brazil and in the world in 2020.

Technological change (MT) shows predominant results of M_0 greater than 1 in the two years of analysis, remaining below 1 only for A313 DMUs; A220; A321, A324, and; A325, but with results very close to 1. The improvement in total factor productivity is adjusted based on the scale efficiency (MEE) for DMUs A313 and A321, which does not occur for DMUs A220; A3024, and A325, which showed technological change (MT) from 2020 to 2021, in addition to stagnation in scale efficiency indexes (MEE), affecting the agencies results. Change that predominantly continued in 2021.

As for the total factor productivity change (MPTF), the A220 DMUs were discarded; A323; A324 and A325 all others or 83.33% showed a growing and constant evolution in the index that considers the influence of technological change (MT) or change in scale efficiency (MEE). In this regard, it is worth highlighting that the indices indicated in MPTF are the result of two moments: i) MPTF for M_0: 2019 ~ 2020 positive influence of technological change (MT); ii) MPTF for M_0: 2020 ~ 2021 positive influence of scale change (MEE), (see Table 6).

Malmquist Index allows a better analysis of the results obtained (Table 7).

Table 7 – Descriptive statistics – *Malmquist Index* for the period (2019-2021)

	MPTF			MT			MEE		
DMUs	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Average	0.40	1.03	1.32	0.46	1.14	1.11	0.87	0.91	1.18
Maximum	0.74	1.23	1.67	0.77	1.23	1.20	1.12	1.07	1.47
Minimum	0.28	0.90	0.91	0.31	1.02	0.94	0.62	0.78	0.92
Standard deviatio	0.12	0.09	0.22	0.13	0.04	0.09	0.13	0.07	0.15
Coef. Variation	29.27%	8.48%	16.82%	27.61%	3.82%	7.98%	15.43%	8.18%	12.43%

Source: Self elaboration.

The index averages confirm the perception that the cooperatives (UAs) under study expanded their efforts in technology to achieve productivity in 2020. Reading validated based on the reduction in the coefficient of variation in the period of 3.82% demonstrating that the technological action was homogeneous in the sampling. It can also be seen that the DMU with the lowest MT migrated from 0.31 to 0.94, an increase of 203.26% if we consider the three years of analysis.

The readings of mean scale efficiency change (MEE) are more evident in 2021, with means consistently growing across the three periods. The maximum MEE index of 1.47 in 2021 highlights the importance of scale efficiency combined with technological efficiency (MT) in improving total productivity (MPTF), as achieved by DMU A315 (MPTF of 1.64 – see Table 6) during the period.

Regarding the applied method, it is worth emphasizing that the *Malmquist* Productivity Index offers the opportunity to compare productivity changes in the banking sector as well as productivity changes among the agencies composing the cooperative system in question (PATHAK, 2017). In this regard, the averages presented for the 24 service units indicate that the cooperative has achieved productivity improvements despite the sanitary and consequent economic adversities experienced during the analysis period.

Furthermore, the decomposition of the *Malmquist Index* into its components—technical efficiency and technological change—revealed that most of the observed variation stemmed from the technological frontier component (technological shift), suggesting that best management practices and innovation were not equally disseminated among units. This conclusion aligns with the findings of Oliveira and Tabosa (2019), who, when analyzing the performance of cooperatives within the Sicoob system, also identified that technological diffusion and innovation capacity are critical factors for enhancing intertemporal efficiency.

Finally, the results indicate the need for internal policies that promote *benchmarking* between efficient and inefficient units, as recommended by Mendes and Souza (2018), who argue that systematic sharing of high-performance management practices can reduce result variability and broaden the cooperative's social reach.

FINAL REMARKS

The initial analysis revealed results within the DEA/VRS model, highlighting the performance of selected DMUs, with a decline in values in 2020, very likely due to the effects of the COVID-19 pandemic. In 2021, there was a recovery in values, indicating a possible resumption of members seeking credit access and the reestablishment of economic development.

The efficiency frontier analysis showed that only four units remained efficient across the three periods analyzed, with 2020 recording the lowest number of units operating efficiently. Over the three years, only four agencies served as *benchmarks*, suggesting a reference performance for the others.

The *Malmquist Index* results revealed an evolution in scale efficiency over the three years, with a modest increase in 2020 due to the pandemic. Regarding technological change, most units adapted

homogeneously in 2020, overcoming the COVID-19 challenges. The adversities caused by the pandemic and the economic consequences demanded technological improvement processes from the cooperative and behavioral changes from users (members). The study indicates that Sicredi Centro-Sul MS achieved an upgrade in this aspect when considering the base year (2019).

Although the cooperative presented a mean VRS/2021 efficiency frontier of 0.9178 (Table 3), the analysis of technological change and scale change factors reveals improvement margins that could increase the number of DMUs operating under the social efficiency frontier, especially considering that nine agencies (A311; A313; A315; A220; A321; A322; A324; and A325) experienced declining MT results (Table 5).

The study highlights the novelty of this analysis, considering particular regional characteristics such as: i) operating in border municipalities; ii) presence in twin cities with the Republic of Paraguay; iii) operation in more than 50% of municipalities less than 47 years old; iv) among which 78.95% have populations below 25,000 inhabitants.

These characteristics underscore the importance of credit cooperativism as an alternative for economic development and social inclusion for individuals, especially in poorer, isolated, less urbanized locations often overlooked by traditional financial institutions due to lack of financial return guarantees.

The study stresses the importance of social cooperatives in advancing the Sustainable Development Goals (SDGs) and emphasizes that policymakers should pay greater attention to these types of enterprises, continuing to support their efforts.

It is suggested that further studies be conducted in agencies with negative variation in technological change (MT) to determine whether these difficulties relate to members or staff. Additionally, the cooperative under analysis is encouraged to develop or promote courses/seminars for members on using new technologies (e.g., mobile banking via smartphones), treating this as a digital inclusion initiative and consequently socioeconomic inclusion of its members.

In conclusion, the results obtained in this research indicate that Sicredi Centro-Sul MS, despite the challenges imposed by the pandemic and structural limitations of its operational region, managed to maintain high social efficiency standards in a significant portion of its units. However, opportunities for improvement persist, especially regarding the dissemination of technological innovations and overcoming operational asymmetries among agencies. Thus, the analysis confirms the relevance of credit cooperativism as a driver of development and inclusion in border regions, while also pointing to concrete paths for its continuous qualification.

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