



*Research article*

## **Financial resilience of electricity sector companies in emerging and developed economies: a comparative analysis during times of distress**

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**Abstract:** This study delved into the determinants of the financial performance of energy firms in both developed and prominent emerging markets, employing a comparative lens. By examining companies within the electric power generation, transmission, and distribution sectors in BRICS and G7 markets throughout the years 2018–2022, including the disruptive COVID-19 period, we leveraged the dual multiple factor analysis (DMFA) technique. Our analysis uncovered four key dimensions—asset-to-debt ratios, operational profitability, liquidity, and the interplay between growth and financial stability—providing clarity on over 65% of the sector’s financial dynamics. Our primary findings underscore discernible heterogeneity and emphasize the heightened resilience demonstrated by G7 firms, particularly during the pandemic era. The implications of these disparities carry significant economic and financial ramifications for both groups, influencing their response and recovery mechanisms in the face of disruptive shocks.

**Keywords:** BRICS; Covid-19; electric power sector; factor analysis; financial dynamics; G7

**JEL Codes:** G32, L94, C38, Q43, F65

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**Abbreviations:** DMFA: dual multiple factor analysis; PCA: principal component analysis

## 1. Introduction

Energy is the most important industrial sector in the world, owing to its impact on the economic and social development of countries (Zhang, 2017). Analyzing the financial resilience of such a sector in times of generalized uncertainty and market distress is of utmost importance for both policymakers and market participants. Monitoring the financial dynamics of companies in a globalized environment is relevant for managers of electricity, generation, and distribution companies interested in risk assessment. It also allows governments to implement more effective policies aiming for the financial stability of companies during energy transition.

Within the electric power sector, the market encompassing power generation, transmission, and distribution does not solely play a crucial role in the day-to-day operations of modern economies; it also finds itself at the epicenter of broader transformations within the global energy landscape. In pursuit of a more sustainable and environmentally conscious energy matrix, the electric power sector is undergoing a transition toward cleaner and renewable energy sources (Spiru, 2023; Deželak, 2023). The entities operating within these segments not only serve as custodians of critical infrastructure that fuels economic activity and daily life but also emerge as pivotal agents in shaping a more sustainable energy future.

Nonetheless, despite the strides toward renewable energy adoption, the operations and performance of these enterprises are not immune to substantial challenges. The transition to clean energies introduces new complexities, such as the inherent intermittency of sources like solar and wind, necessitating innovative approaches to energy storage and management (Zhang et al. 2023; Ibáñez-Rioja et al., 2023; Seddighi et al., 2023). Additionally, fluctuations in energy demand, variability in energy resource prices, and shifts in the regulatory landscape can deeply impact the financial sustainability of these entities (Joaqui-Barandica and Manotas-Duque, 2023).

The substantial investment in the renewable energy sector in recent times has not only propelled the growth of these operators but has also heightened the pressure on their ability to effectively manage the diversity of energy sources and meet the expectations of consumers and regulators in terms of reliability and sustainability. In this context, the capability of these companies to uphold their financial resilience and adapt to these emergent challenges becomes a critical indicator of their capacity to spearhead the transition toward a cleaner and more sustainable energy future.

The COVID-19 pandemic serves as a poignant illustration of an unforeseen shock that reverberated across the energy sector and the broader economy (Raj et al., 2023; Dai et al., 2023). The abrupt drop in electricity demand, resulting from widespread lockdown measures and trade restrictions, posed unparalleled challenges for companies within the sector. This underscored the critical interplay between a resilient energy infrastructure and sustained economic stability. Notably, the pandemic-induced disruptions spotlighted the intrinsic vulnerability of traditional energy models and underscored the urgency of transitioning toward adaptable, sustainable energy systems (IEA, 2022). The inclusion of the COVID-19 period is not incidental to our analysis but central to understanding firms' financial resilience. The pandemic constitutes an exogenous, system-wide shock that affected all electricity companies simultaneously, regardless of country-specific conditions. This makes COVID-19 a unique natural experiment, offering an opportunity to compare how firms in emerging and developed economies absorb and adjust to unexpected disruptions. Studying this period provides insight into the structural robustness of the sector and generates lessons for future crisis preparedness, particularly as energy markets continue to face volatility, geopolitical tensions, and climate-related uncertainties.

Amid these tumultuous events, the examination of financial resilience takes on renewed significance. The pandemic's reverberations across the energy sector were not confined to operational hurdles but extended to substantial financial repercussions, affecting revenues, investments, and overall financial health. As governments and policymakers maneuvered to mitigate the socio-economic fallout, energy companies encountered a dual imperative: navigating the immediate operational disruptions while ensuring the viability of long-term financial sustainability (IEA, 2022). Hence, the analysis of financial resilience in times of crisis has assumed an even more pivotal role, offering insights into the strategies and capacities that enable energy entities to endure unforeseen upheavals.

Against this backdrop, our study delves into the financial dynamics of electric power generation, transmission, and distribution companies in both emerging and developed economies. By examining the resilience of these companies during a tumultuous period, which encompassed the COVID-19 pandemic and its ensuing consequences, we aim to shed light on the diverse trajectories that different economies have adopted to withstand such shocks. In particular, we focus our investigation on two distinct groups: emerging economies (BRICS) and developed economies (G7), which are the main authors in the global climate change scenario, and also relevant economic groups; according to Zheng et al. (2019), they represent more than 60% of world emissions. This duality allows us to discern nuances in financial responses and outcomes, offering valuable insights into the interplay between economic maturity, regulatory frameworks, and energy market dynamics during periods of unprecedented challenges.

Within this context, our primary objective is to conduct a comprehensive analysis of the financial performance of electric power generation, transmission, and distribution companies. This analysis will focus on comparing the financial resilience of these firms in emerging and developed economies, with a particular emphasis on identifying factors that influence their capacity to endure financial stress. Our sample comprises 406 companies from both BRICS and G7, spanning the period from 2018 to 2022. This duality allows us to discern nuances in financial responses and outcomes, offering valuable insights into the interplay between economic maturity, regulatory frameworks, and energy market dynamics during periods of unprecedented challenges. By scrutinizing the financial dynamics of these entities amidst a turbulent landscape that includes the unprecedented challenges posed by the COVID-19 pandemic, our study seeks to provide insights into the varying strategies and mechanisms that enable companies to navigate and mitigate financial crises effectively.

Employing a dual multiple factor analysis (DMFA) methodology, we discern four dimensions that expound on approximately 65.5% of the total financial variability within the sector. These dimensions encompass asset and debt management, operational profitability, liquidity and inventory handling, and the interplay between growth and financial robustness. The outcomes unearth distinctive dynamics between emerging and developed economies, unequivocally highlighting the heightened resilience observed among G7 nations' corporations. Furthermore, they underscore the uneven influence of geopolitical events on specific enterprises, exemplified by the sensitivities witnessed in companies hailing from Germany, France, and Russia, inextricably linked to the energy crisis stemming from the Russia–Ukraine conflict.

This study takes on fundamental relevance in exploring the financial dynamics of electricity companies in the distinctive G7 and BRICS groups. The importance lies in understanding the economic disparities and resilience between the developed powers of the G7 and the emerging economies of the BRICS. By delving deeper into these dynamics, the analysis not only sheds light on the economic and energy interconnections between these groups but also reveals how critical

events, such as the Russia-Ukraine conflict in 2022, can trigger financial shocks that reverberate through markets and directly affect economic stability and investment strategies. This not only concerns G7 and BRICS groups but also resonates on a global scale, as the financial dynamics examined influence the decision-making of international investors, policymakers, and businesses, thus forging a collective impact on global economic stability.

The inclusion of the Russia-Ukraine conflict in our discussion adds a critical dimension to our analysis of the financial dynamics of electric utilities in the BRICS countries. This geopolitical event, which occurred in 2022, had a direct impact on the economic and financial stability of Russia, a key member of the BRICS. The war and resulting sanctions could have significantly influenced the financial strategies and performance of Russian electricity companies, in turn affecting the overall financial dynamics of the BRICS. The situation in Russia could have generated greater volatility in the energy markets and, therefore, influenced the financial dynamics of electricity companies in other BRICS countries, since they are interconnected in economic and energy terms. The uncertainty generated by the conflict could have affected investments and financial decision-making in the electricity sector, and it is essential to examine how these specific dynamics may have transmitted financial shocks between the BRICS countries.

Despite extensive research on the financial implications of systemic shocks, existing studies generally analyze resilience through isolated indicators, market-based connectedness, or regression-based sensitivities. What remains underexplored is how multiple financial dimensions jointly evolve and reconfigure during crises, particularly when comparing firms across heterogeneous macroeconomic environments. This gap is especially relevant for the electricity sector, where financial robustness depends not on a single indicator but on the interaction between leverage, liquidity, profitability, and overall financial strength. Furthermore, comparative evidence on BRICS and G7 electricity firms during COVID-19 remains limited, despite growing recognition that emerging and developed economies differ significantly in their exposure to and capacity to absorb systemic shocks. Our study addresses this gap by applying a structured, multidimensional approach to examine how these financial dimensions shift before, during, and after a global exogenous crisis.

The present work unfolds in a meticulously structured manner. The second section entails an exhaustive exploration of pertinent literature, unveiling the unique contributions of this study. Subsequently, the third section intricately elucidates the analysis methodology, encompassing the selection and processing of employed data. The ensuing fourth section serves as the platform for the presentation and discussion of the results. Ultimately, the fifth and final section provides grounded conclusions and proposes avenues for future research in this domain.

## 2. Related literature

In terms of global financial integration, the link between economies in the G7 and BRICS has been strengthened in recent times. In the last decade, energy markets have been of interest to international investors, highlighting ways of diversification (Billah et al., 2022). Rehman (2020) highlighted that developed economies, such as the G7, and emerging economies, such as the BRICS, show greater diversification in this type of market; in addition, there is no evidence of contagion traces during periods of financial and economic turbulence. In contrast, Agyei et al. (2022) showed that there is transmission from the G7 to BRICS in the short term. In particular, France, Germany, and the UK have a greater impact on the BRICS. Zhang et al. (2021) found that the G7 are risk exporters, while

the BRICS are risk takers. Other scenarios that have influenced this global integration are the war between Russia and Ukraine (Alam et al., 2022) and the COVID-19 pandemic (Wu et al., 2022).

Despite the clear globalization that exists between different economies, the study of the financial performance of companies in the energy sector from the perspective of developed and emerging economies is still limited. In contrast, the energy economics literature has advanced substantially in understanding the structure and dynamics of energy markets (Maghyreh et al., 2016; Mensi et al., 2021; Sadorsky, 2012; Zhang et al., 2021). It has also documented the effects of different factors on energy commodity prices (Le et al., 2021; Mosquera-López et al., 2018; Oviedo-Gómez et al., 2021; Uribe et al., 2022).

The specific sector of electric power generation, transmission, and distribution is scarcely represented in the literature in terms of integrated analysis from the globalization perspective of markets. For example, Tiwari et al. (2022) studied the connectivity of energy sectors by comparing different regions, showing that regions such as the G20 and G7 contribute more to volatility in the energy markets; Southeast Asia is the largest recipient of this volatility, while America stands out as a net recipient of energy shocks. Aspects such as pandemics, financial crises, and political uncertainty influence the magnitude of market volatility. The strong globalization and transmission of risks between economies have direct implications for companies in the energy sector. Loch et al. (2018) evaluated the degree of influence of a government on the financial performance of electricity service providers and found that company returns decreased with increased government equity participation.

Delen et al. (2013) documented that the financial ratios of profitability, indebtedness, and debt have the greatest impact on a company's performance in the sector. These ratios indicate a company's potential ability to control costs and expenses, directly impacting its return on equity (ROE) and return on assets (ROA); they also reflect whether a company is making an adequate investment of debt funds in profitable operations. Rosso and Rodriguez (2021) studied ROE, ROA, and EBITDA margin through a panel data model and regression analysis to identify and quantify factors that determine profitability for electric utilities in Colombia and other Latin American countries. The authors found that investment in fixed assets plays a relevant role for large and medium-sized companies, while the debt ratio represents a key factor for small and medium-sized companies. On the other hand, according to Schabek (2020), it is observed that the size of the company positively impacts financial indicators such as ROE and ROA, while the share of electricity from renewable sources has a negative impact on financial performance. In addition, one of the factors impacting both ROA and ROE is the producers' electricity prices (Dopierała et al., 2022).

Recent literature on the electricity sector has converged in the exploration of crucial dimensions, merging research that addresses financial performance and resilience in different contexts. A notable study by Liu and Zhu (2023) delved into China's "maximum carbon and carbon neutrality" initiative, exploring the relationship between carbon information disclosure and the financial performance of electric utilities. Their findings highlight the need to integrate information disclosure to achieve sustainable goals. This approach finds resonance in the present research as it considers how electric utilities approach the transition to cleaner sources. On the other hand, Zhang et al. (2023) explored supply chain resilience during the pandemic, highlighting the importance of crisis management. This perspective is relevant as this work focuses on the critical period of the pandemic and the resilience of businesses in emerging and developed markets. Sun et al. (2023) contributed to the analysis by correlating climate risks with the financial performance of Chinese electricity companies, identifying important mediators. It is crucial to consider the impact of climate change on financial stability, and

these results inform the relevance of integrating climate risk management into business strategies. Furthermore, Zimon et al. (2022) examined the management of financial security in renewable energy SMEs during the pandemic, revealing conservative strategies adopted to maintain stability. These conservative tactics can shed light on how power companies have coped with financial uncertainty during the crisis, an aspect that the present research seeks to understand on a global level. Finally, Zhou and Sun (2022) compared the financial performance between fossil energy generation and new energy in China, highlighting the evolution of profitability over time. This temporal analysis provides important context for understanding how electric utilities have responded to changes in profitability. Integrating this research into this literature review enriches the understanding of the global context of financial performance and resilience in the electricity sector, providing a comprehensive framework for comparison between emerging and developed markets in times of crisis.

The financial effects of the COVID-19 shock remain an active and relevant topic in corporate finance and sector-specific resilience analysis. Makki and Alqahtani (2023) examined the financial performance of listed energy companies in Saudi Arabia before, during, and after the pandemic using a hybrid multi-criteria decision-making approach, documenting how profitability, efficiency, leverage, and liquidity dimensions shifted in response to the health and economic crisis. Their findings confirm that the pandemic altered the multidimensional financial structure of energy firms, reinforcing the need for methods capable of capturing integrated financial dynamics. Tóth et al. (2024) analyzed the resilience of successful non-financial firms in Hungary and showed that liquidity buffers, indebtedness levels, and access to funding were central determinants of post-shock recovery, a result that aligns with our focus on the interplay between asset structure, profitability, and liquidity as channels of resilience in the electricity sector. In addition, a recent bibliometric study by Obrenovic et al. (2024) highlighted that economic resilience, financial fragility, and sectoral heterogeneity remain dominant themes in the post-COVID research agenda, underscoring the ongoing relevance of investigating how firms adapt and reorganize their financial structures after systemic disruptions. Integrating these recent contributions strengthens the positioning of our analysis within the contemporary debate on corporate resilience under unprecedented global shocks.

A growing body of research highlights that the financial resilience of non-financial firms under systemic shocks depends on the interaction between sector-specific vulnerabilities, macroeconomic transmission mechanisms, and firm-level financial structures. In the electricity sector, resilience is shaped not only by market conditions and policy environments associated with the energy transition but also by internal financial dimensions such as liquidity buffers, capital structure, profitability stability, and balance-sheet strength. Following macroprudential perspectives such as the framework proposed by the National Bank of Poland for COVID-19 stress-testing (Nehrebecka, 2021), financial fragility emerges when shocks propagate asymmetrically across firms and financial attributes. This suggests that resilience must be analyzed as a multidimensional construct rather than through isolated indicators or purely market-based measures. This conceptual view motivates our use of a block-structured approach to capture how the main financial dimensions jointly evolve before, during, and after a systemic shock.

This study stands as a distinctive contribution to existing literature by offering a comprehensive and comparative perspective on the financial resilience of electric utilities during periods of crisis, particularly in the context of the COVID-19 pandemic. Unlike previous research, which has explored individual elements such as carbon disclosure, climate risk management, or supply chain resilience, our approach encompasses these dimensions in an integrated and comprehensive manner. By synthesizing these factors, we provide a more holistic understanding of the strategies adopted by

electric utilities to ensure their financial resilience. Furthermore, by focusing on the comparison between emerging (BRICS) and developed (G7) markets, we highlight key disparities and convergences, thereby identifying unique patterns that inform both theory and practice. The DMFA methodology amplifies the quality of our findings by revealing four essential dimensions that capture more than 65% of the financial variability in the electricity sector. This study not only fills a gap in the literature by providing a more comprehensive view but also presents a novel and highly relevant approach to understanding financial resilience in a crucial sector in an ever-changing global context.

This study makes two main contributions to the literature on financial resilience in the electricity sector. First, our theoretical contribution lies in applying DMFA to examine financial resilience in a cross-country, crisis-driven setting. While prior research has studied firm performance using isolated financial indicators, regression-based sensitivity analyses, or market connectedness models, there is limited understanding of how multiple financial dimensions evolve jointly in response to systemic shocks. By uncovering latent structures, such as the interaction between leverage, profitability, liquidity, and financial strength, DMFA offers a multidimensional framework for analyzing resilience at the firm level. This approach fills a methodological and conceptual gap in corporate finance and energy economics, where resilience is often treated as a unidimensional characteristic. Our framework therefore complements and extends existing crisis-related studies by providing a structural view of how firms adjust across multiple financial fronts when facing global disruptions.

Second, the study provides practical and empirical contributions for managers, investors, and policymakers. The comparative results reveal asymmetric patterns of financial robustness between BRICS and G7 firms, showing that developed-economy companies displayed greater stability in key financial dimensions during COVID-19. These findings have direct implications for capital structure design, liquidity policies, and risk management practices within electricity companies. For investors, the results highlight differences in vulnerability and recovery speed across markets, which are important for portfolio allocation and sectoral risk assessment. For policymakers, especially in emerging economies, the evidence identifies which financial dimensions require strengthening to enhance crisis preparedness and support the long-term stability of the electricity sector. Overall, the study offers insights that can inform decision-making under conditions of heightened uncertainty and market volatility.

### **3. Empirical modeling and data**

In this section, we use dual multiple factor analysis (DMFA) to find the common correlation between emerging and developed countries on financial performance from 2018 to 2022. The choice of DMFA was motivated by the structure of our research problem. First, the financial condition of electricity firms is inherently multidimensional, involving correlated blocks of indicators—leverage, profitability, liquidity, and financial strength—that evolve together during crisis periods. DMFA is specifically designed to integrate such blocks into a common latent space while preserving the internal coherence of each dimension. Second, the method is well-suited for data with natural groupings, such as BRICS and G7 firms observed over multiple years, enabling meaningful comparisons across country groups within a unified framework. Unlike PCA or standard MFA, DMFA allows each block to contribute proportionally to the global solution, preventing dominance by variables measured on larger scales or by groups with more observations. Finally, because our aim is exploratory—identifying structural patterns of financial resilience rather than estimating causal effects—DMFA offers an

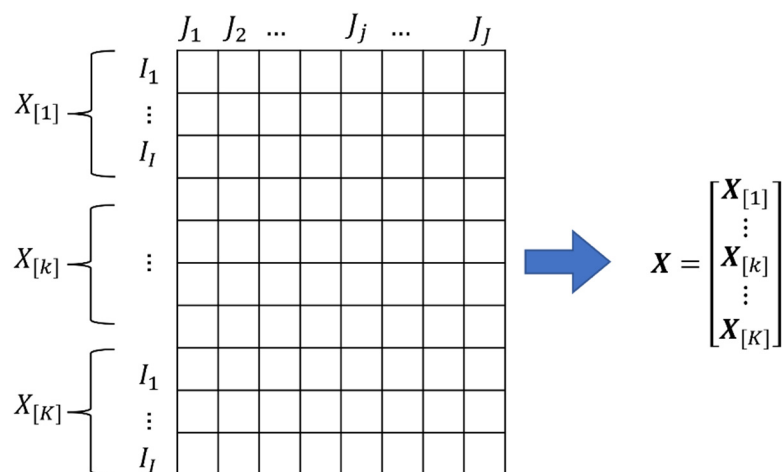
appropriate, assumption-light approach that can reveal how firms move across latent financial dimensions before, during, and after a systemic shock. This makes DMFA particularly suitable for understanding resilience dynamics in a cross-country, crisis-driven context.

### 3.1. DMFA

DMFA is an extension of multiple factor analysis (MFA) developed by Escofier and Pagès (1988). The main difference between these techniques is that, in DMFA, the individuals are partitioned into groups, while in MFA, the variables are partitioned into groups. The context of DMFA allows us to adapt the structure of our data, where the companies are grouped by year into BRICS or G7 categories.

It is important to note that DMFA is an exploratory, descriptive technique and does not provide formal statistical inference or causal interpretation. Our goal is therefore not to test hypotheses about the determinants of resilience but to uncover the structural configuration of financial dimensions and how these configurations differ between BRICS and G7 firms. DMFA is well-suited for this purpose because it integrates multiple correlated financial subdimensions into a common latent space without imposing parametric assumptions. The method allows us to examine broad group-level patterns and trajectories during the COVID-19 shock, while acknowledging that the results reflect structural tendencies rather than inferential effects.

According to Abdi et al. (2013), in DMFA, the data consist of  $K$  sets of observations, which have a measure on the same number of variables.  $K$  cross-product covariance matrices between the variables are then used to subsequently treat the data as MFA. Thus, different partial charges are obtained for each set  $K$  of observations. In our structure,  $K = 2018, 2019, 2020, 2021, 2022$ , and variables such as country or economic status are supplementary.



**Figure 1.** Data matrix structure for DMFA. **Note:** In DMFA, the data consist of  $K$  sets of observations, each of which has a measure on the same number of variables. In this case,  $K$  corresponds to the years 2018–2022.

$\mathbf{X}_{[k]}$  is a matrix of dimension  $(I \times J)$  being  $I = I_1, \dots, I_i$  individuals and  $J = J_1, \dots, J_j$  variables (see Figure 1). The singular value decomposition of a given  $I \times J$  matrix is  $\mathbf{X} = \mathbf{U}\mathbf{\Gamma}\mathbf{V}^T$ , where  $\mathbf{U}$  ( $I \times L$ ) and  $\mathbf{V}$  ( $J \times S$ ) are orthogonal matrices with orthonormal eigenvectors,  $S$  is the rank of  $\mathbf{X}$ ,

and  $\mathbf{\Gamma}$  is the diagonal matrix of the  $S$  singular values. A classical principal component analysis (PCA) is followed over the entire  $\mathbf{X}$  data table, decomposing the total variability into variability between and within groups. In such a way, Equation 1 shows the PCA of each data table.

$$\mathbf{X}_{[k]} = \mathbf{U}_{[k]} \mathbf{\Gamma}_{[k]} \mathbf{V}_{[k]}^T \quad (1)$$

In PCA, principal components are linear combinations of the original variables  $j \in J$ , that can be written as  $F_s = \sum_j u_s(j)j$ , where  $u_s(j)$  denotes the vector of the coordinates of the variables  $j$  on the principal component of rank  $s$ . Due to the restriction that exists for each data table or subpopulation, it is denoted by  $F_s^k$ , being the vector of the coordinates of group  $k$ , so  $F_s^k = \sum_k u_s(j)j^k$ . Variables are assumed to be standardized and centered by group; in this way, the contributions to the components do not change between groups, and the interpretation is guaranteed as in a classic PCA.

To calculate the coordinate  $G_s^k(j)$  of a variable  $j$  restricted to individuals  $I^k$  (see Equation 2), it is necessary to calculate the correlation coefficient  $r(\cdot)$  between  $j$  and  $z$  (a variable that is correlated with the axis of rank  $s$ ), which leads to estimating the coefficient  $\lambda$  of the linear combination associated with variable  $j$  in the construction of fs within group  $k$ .

$$G_s^k(j) = \frac{1}{\sqrt{\lambda_s}} \frac{1}{\sqrt{\text{var}(F_s^k)}} \sum_{z \in J} r(z^k, j^k) G_s(z) \quad (2)$$

This allows us to interpret the different proximity between the financial performance variables across all years as a measure of the similarity of the companies. In addition, the inclusion of complementary variables such as the status of the economy as emerging (BRICS) or developed (G7), or even the identification of the country, allows us to identify a broader picture of the dynamics of companies over the years (Lê and Pagés, 2010).

The choice of the DMFA method over other empirical approaches is based on careful consideration of its advantages and disadvantages. First, DMFA provides insights by simultaneously addressing multiple dimensions, which is critical to capturing the complexity of factors affecting financial performance in the electricity sector. Furthermore, this method allows us to identify latent dimensions that explain a significant proportion of financial variability, facilitating the identification of key factors that drive financial resilience. Additionally, DMFA offers the advantage of reducing data dimensionality, condensing information into a few meaningful dimensions. This improves the interpretability of the results and avoids problems associated with the high dimensionality of the data sets. This methodological choice is based on the technique's ability to offer a comprehensive and structured vision of financial resilience in the electricity sector. We are aware of the challenges associated with assumptions and interpretation, and we strive to rigorously address them in our analysis. In this context, DMFA provides an appropriate framework because it allows the integration of several financial subdimensions into a common latent space while preserving the internal coherence of each block. Unlike unidimensional analyses or parametric models that assume stable relationships across firms and time, DMFA is designed for comparing structured groups—in our case, BRICS and G7 firms—across multiple periods. This makes it particularly suitable for exploring how financial resilience is expressed in multidimensional trajectories during a systemic shock such as COVID-19.

### 3.2. The (regularized) iterative PCA algorithm

To balance the data panel, we use the regularized iterative PCA algorithm to complete the data. This algorithm uses regularized reconstruction formulas, where first it starts replacing the missing values with the mean of each variable. Subsequently, through cross-validation, it estimates the number of components to replace the imputed information. It repeats the process until convergence is achieved (Josse and Husson, 2012). The central objective of this method is to ascertain a subspace that effectively reduces the distances between individuals and their corresponding projections within this subspace. The algorithm unfolds through the following stages:

1. Commencement with initial values, replacing missing values with the mean of each variable.
2. The iterative (regularized) algorithm advances to executing PCA using the complete dataset. Subsequently, missing values are imputed through reconstruction formulas (regularized) of order  $ncp$  (number of components), leveraging the  $ncp$ -component fitted matrix for scores and loads (regularized). The number of components employed for imputing missing data is determined via cross-validation to minimize the mean square error of prediction.
3. Cross-validation is employed to estimate the optimal number of  $ncp$  components. Complete dataset PCA is carried out to derive the parameters  $\hat{M}^\ell, \hat{F}^\ell, \hat{U}^\ell$ , where  $F_{T \times S}$  and  $U_{N \times S}$  are matrices of rank  $S$ , with  $S < T$ , with  $T$ : Time.  $M$  is a matrix of size  $T \times K$  with each row equal to  $(m_1, \dots, m_N)$ , i.e., the vector with the mean of each variable.
4. The imputation process replaces missing values with adjusted values  $\hat{X}^\ell = \hat{M}^\ell + \hat{F}^\ell \hat{U}^\ell$ .
5. Steps 2 and 3 are iteratively undertaken until convergence is attained.

Before conducting DMFA, we assessed missing-data patterns and found that missingness was concentrated on specific profitability and liquidity indicators. Because the objective of the analysis is descriptive and multidimensional rather than inferential, we applied simple mean imputation within each indicator to preserve the relative structure across financial blocks while avoiding model-driven assumptions. More advanced imputation methods would require distributional assumptions that are inconsistent with the exploratory nature of the study. Nevertheless, we recognize that imputation may reduce variability and therefore interpret all results at the group level rather than at the level of individual countries or firms.

### 3.3. Data

Regarding the data, a sample of 406 electric power generation, transmission, and distribution companies from emerging and developed economies was used. We use the classification of G/ economies (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States of America) and BRICS (Brazil, Russia, India, and China). The sample does not include companies from South Africa due to the limited availability of information on electricity companies in this country in the data source used, the financial data platform Refinitiv. We use gross profit margin, working capital (USD), current ratio, quick ratio, inventory turnover, return on equity, total assets (USD), total debt (USD), total liabilities (USD), and return on assets as financial indicators. These indicators were extracted from Refinitiv. Table 1 shows the number of firms for each country: 218 firms in the BRICS economy and 188 firms in the G7. The USA and Russia are the countries with the highest participation in the sample. The period of analysis is between 2018 and 2022.

The number of firms varies across countries, which limits the validity of country-level comparisons. For this reason, we frame all interpretations at the BRICS-G7 group level and avoid drawing conclusions about individual countries. DMFA is robust to unequal group sizes because it weighs each block proportionally, but we nonetheless acknowledge that structural imbalances in the data may influence the representation of certain financial trajectories.

**Table 1.** Distribution of the samples among the different countries of emerging and developed economies.

Economy	Country	n	Total
BRICS	Brazil	41	218
	China	62	
	India	40	
	Russia	75	
G7	Canada	25	188
	France	11	
	Germany	15	
	Italy	9	
	Japan	20	
	United Kingdom	13	
	United States of America	95	

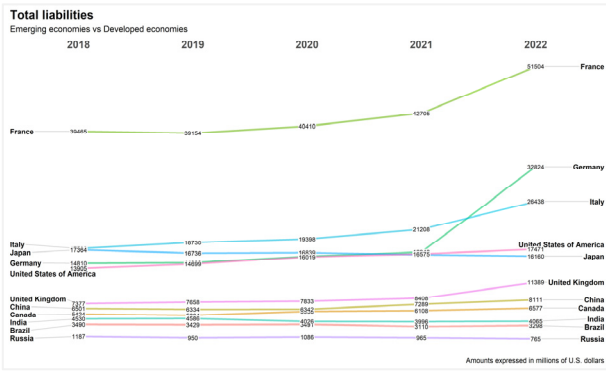
**Note:** BRICS: Group of emerging economies comprising Brazil, Russia, India, and China. G7: Group of developed economies comprising Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States of America.

## 4. Empirical results

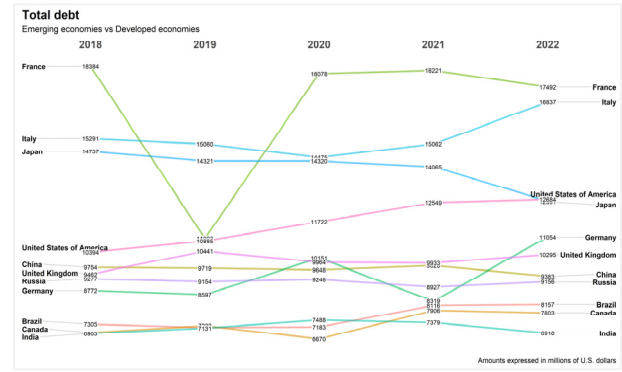
### 4.1. Evolution of financial indicators: BRICS vs. G7

In this section, we present the exploratory analysis of financial indicators on the BRICS and G7 economic groups. In this analysis, we explore the evolution throughout the pre- and post-pandemic period.

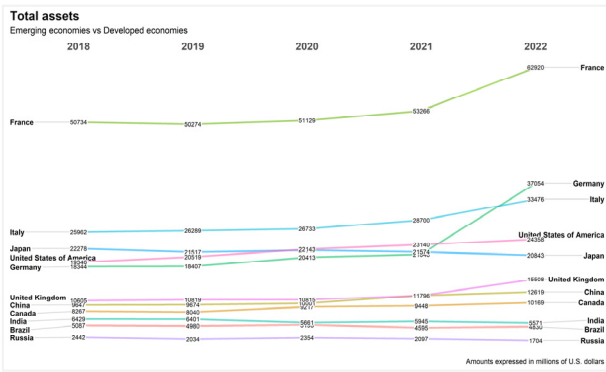
Figures 2, 3, and 4 show the changes in the different financial indicators at the time of study. Regarding total liabilities (see Figure 2A), the electric power generation, transmission, and distribution companies from France have the highest liabilities from 2018 to 2022; in this last year, the obligation increased above \$51.504 million USD. Similarly, Germany increased its obligation above \$32.824 million USD during the year 2022. In general, developed countries such as Italy, the US, and the United Kingdom presented notable increases in liabilities in 2022. Meanwhile, the BRICS countries stand out for having smaller and relatively constant obligations throughout the period.



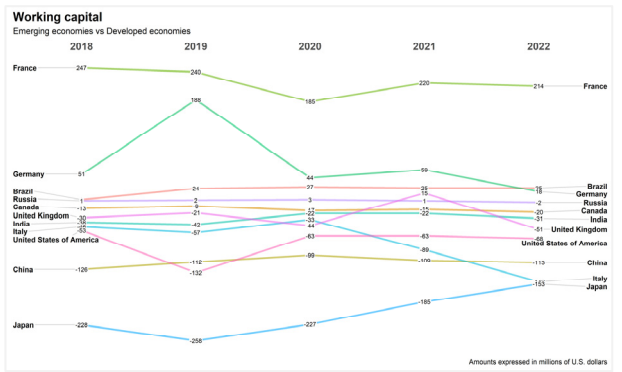
A)



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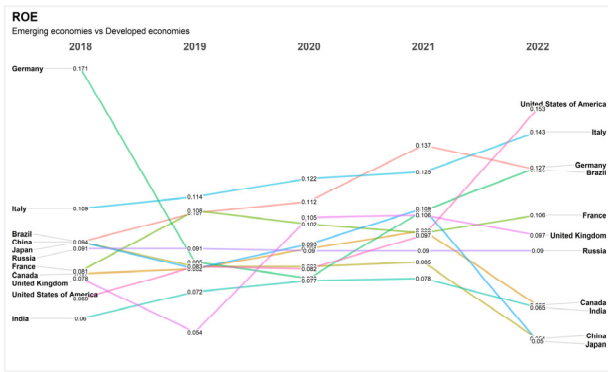


C)

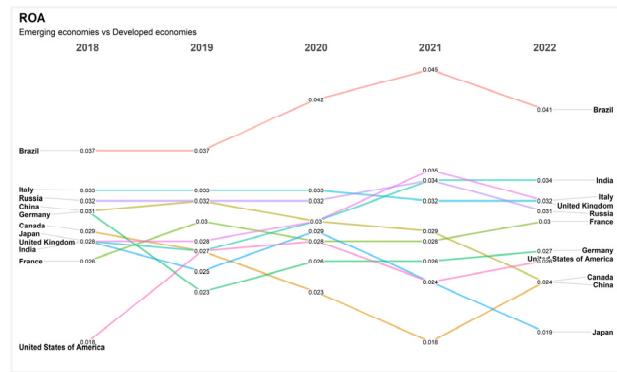


D)

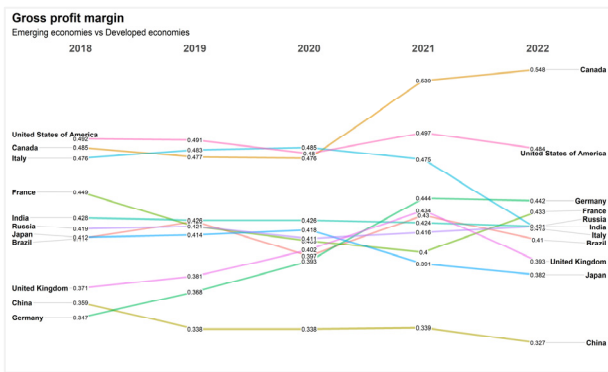
**Figure 2.** Changes in financial indicators between the pre-pandemic and post-pandemic periods. A: total liabilities. B: total debt. C: total assets. D: working capital.



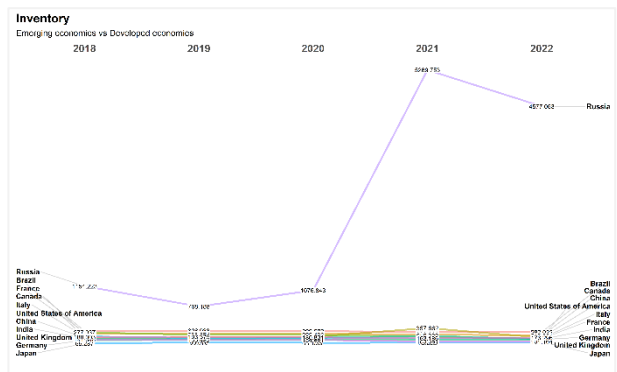
A)



B)

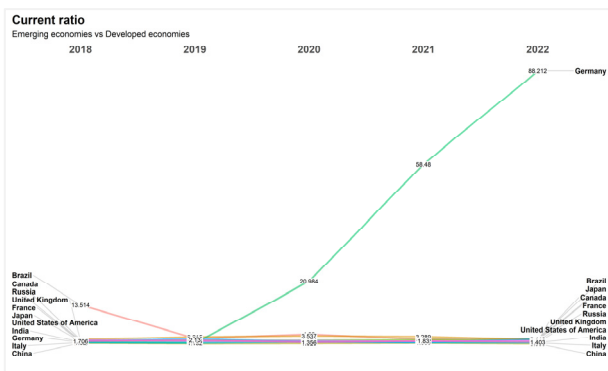


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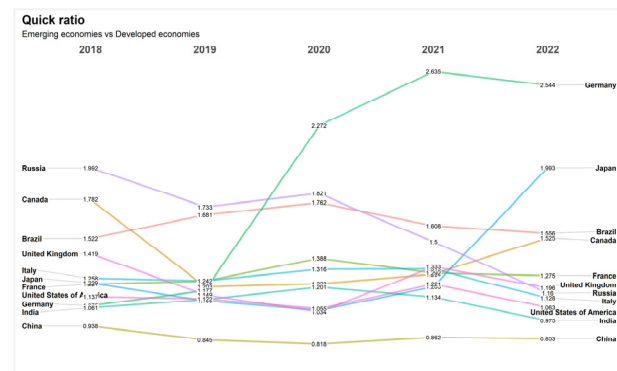


D)

**Figure 3.** Changes in financial indicators between the pre-pandemic and post-pandemic periods. A: ROE. B: ROA. C: gross profit margin. D: inventory.



A)



B)

**Figure 4.** Changes in financial indicators between the pre-pandemic and post-pandemic periods. A: current ratio. B: quick ratio.

The total debt in Figure 2B shows a smaller gap between France and the rest of the countries. We point out that the debt of companies in Japan has been decreasing from 2018 to 2022, while the USA has presented an upward trend in total debt. Italy and Germany have presented the largest increase in debt for the year 2022 compared to 2021.

Total assets are presented in Figure 2C; this shows a similar behavior to the one presented by total liabilities. Figure 2D shows the working capital, where France stands out as the country in which electric power generation, transmission, and distribution companies present a higher working capital. This indicates that French electricity generation companies can finance their current operations and invest in future activities and growth. In other words, they enjoy operational efficiency and financial health in the short term. Germany and Brazil also present positive values of working capital: while Brazil has been constant, Germany has been falling in its working capital. Russia is at the boundary between positive and negative values, while the rest of the countries present negative values of working capital. Japan presents the lowest values, and Italy presents the strongest drop in its working capital for the year 2022.

Regarding profitability, Figure 3A shows the profitability behavior measured from the ROE. In 2022, US companies presented the highest ROE levels, followed by Italy, Germany, and Brazil. A general pattern is that companies within each country have been increasing their profitability over the years, generating value for their potential shareholders. The companies with the lowest returns are located in Canada, India, China, and Japan. Regarding ROA (Figure 3B), Brazil stands out by a large margin as the country with the highest profit produced from company assets. India has a rebound over the year 2022, while Italy presents a relatively constant ROA, being one of the most profitable countries within the group of developed countries. Gross profit margin is presented in Figure 3C, where Canada shows growth during the years 2021 and 2022, while the USA stands out with a constant index, being one of the countries with the highest gross profit margin. On the other hand, China shows the lowest gross profit margin. Regarding the level of inventory, Figure 3D shows that Russian companies have a greater inventory compared to the other countries, which present a homogeneous behavior.

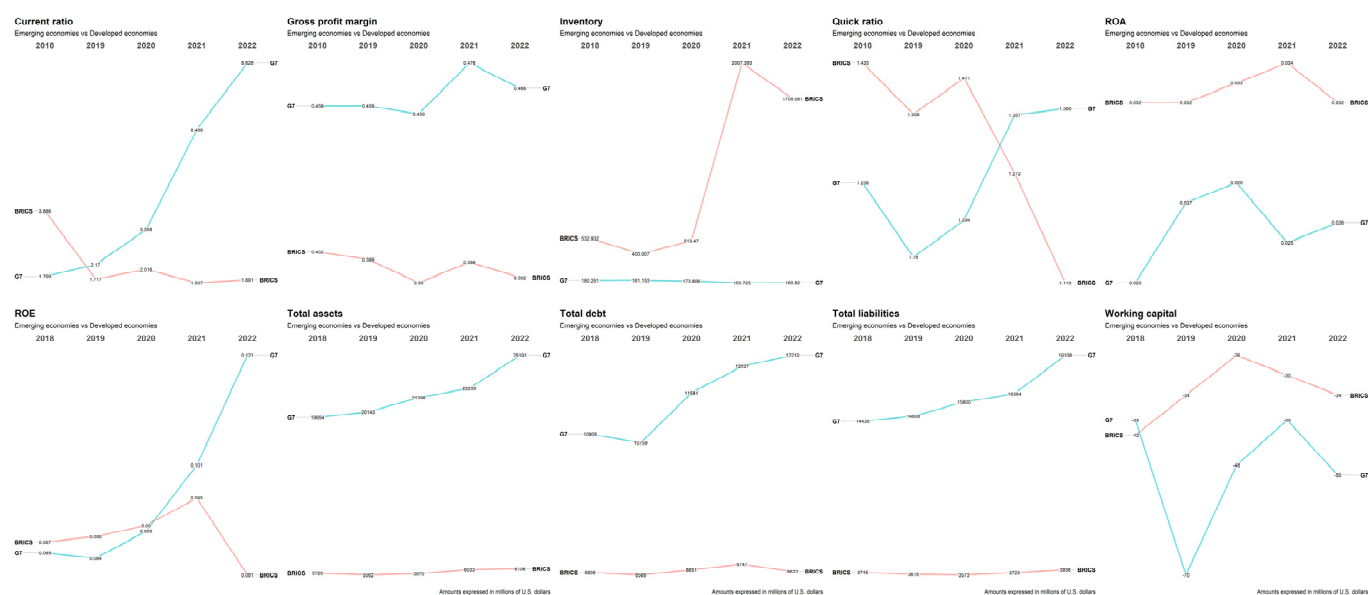
Regarding liquidity (see Figure 4A and B), the current ratio shows that Germany presents the best capacity to pay short-term obligations. This gap starts to be significant from 2020. The remaining countries have homogeneous behavior. Regarding the quick ratio, Germany shows strength in the most liquid assets, allowing it the capacity to meet its obligations.

The effect of the pandemic, between 2020 and 2021, was not equally marked for all financial indicators. Mainly, the different countries show an upward trend for the year 2022 in each indicator. In contrast, the quick ratio is the most sensitive indicator with downward trends since 2020 for most BRICS countries. Figure 5 summarizes the trends of all the indicators. It highlights that both the profitability indicators and the liquidity indicators compared between BRICS and G7 present an inverse behavior: while profitability decreases in the BRICS, it increases for the G7. From the year 2022 onward, more variations are perceived. Although this analysis is exploratory, the results seem to indicate that there is a lag in the effect of the pandemic on the indicators, which may show that we are on the verge of a financial crisis in the sector, especially for the BRICS.

#### 4.2. Financial relationship of electric power generation, transmission, and distribution companies: BRICS and G7 evolution of financial indicators

The DMFA factorial model allows us to assess the joint movements of the financial indicators of companies within the different economies and countries. This model shows the dynamics on the factorial plane, made up of the different components or dimensions that correlate the financial variables. Four dimensions were estimated that manage to explain a total of 65.5% of the financial variability of the financial relationship of electric power generation, transmission, and distribution companies. The COVID-19 shock also offers a forward-looking perspective. Understanding how electricity companies adjusted during this crisis helps identify structural features that enhance or weaken resilience. These lessons remain relevant for future episodes of market distress, given that energy systems are increasingly exposed to disruptions arising from geopolitical conflicts, climate risks, and demand fluctuations.

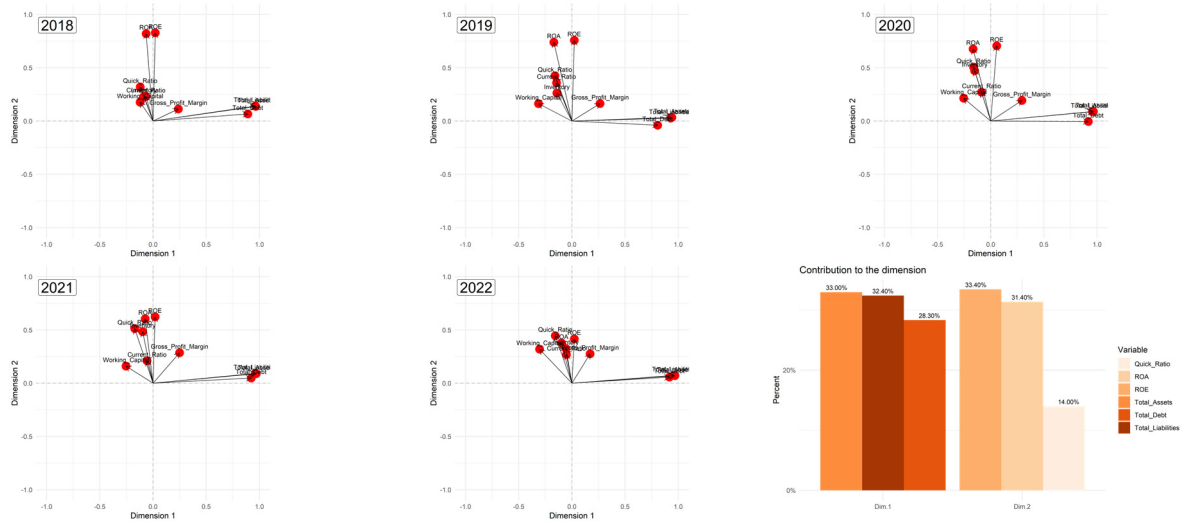
Figures 6 and 7 show the estimation of each dimension on the different factorial planes and the contribution of the variables. Dimension 1 presents an explanatory power of 28.1% and is mainly composed of total assets, total debt, and total liabilities. Dimension 2 presents an explanatory power of 13.7% and is mainly composed of ROE, ROA, and quick ratio. Dimension 3 has an explanatory power of 13.5% and is mainly composed of quick ratio and inventory. Dimension 4 has an explanatory power of 10.3% and is mainly composed of working capital and gross profit margin. Each dimension has been related to the following constructs: Dim 1, Assets and debt; Dim 2, Profitability; Dim 3, Liquidity and inventory; and Dim 4, Growth and financial strength.



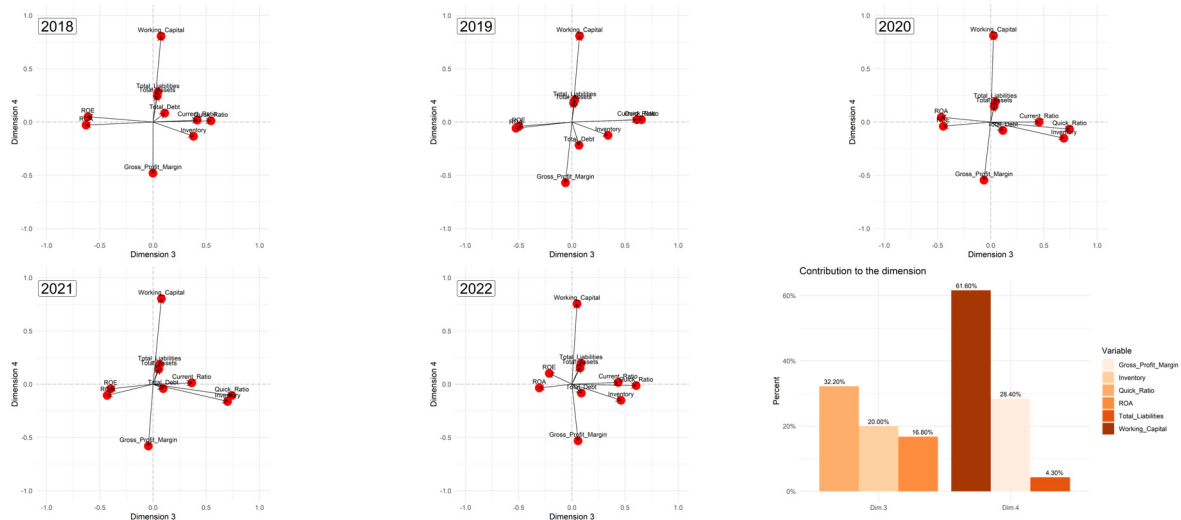
**Figure 5.** Changes in financial indicators between the pre-pandemic and post-pandemic periods of the BRICS vs. the G7. Note: The indicator for each group is calculated as the average of the countries.

Throughout the study years, these dimensions do not change; however, changes in the strength of their representation can be observed. For example, in Figure 6, dimension 2—clearly defined by ROE and ROA— shows a decline in representational quality from 2018 to 2022. This is evidenced by the

shortening of the variable vectors, indicating that company profitability in the post-pandemic period is less relevant compared to dimension 1, which achieves a higher quality of representation. Our factorial model manages to capture and identify the most statistically relevant variables to model the financial behavior of the companies.



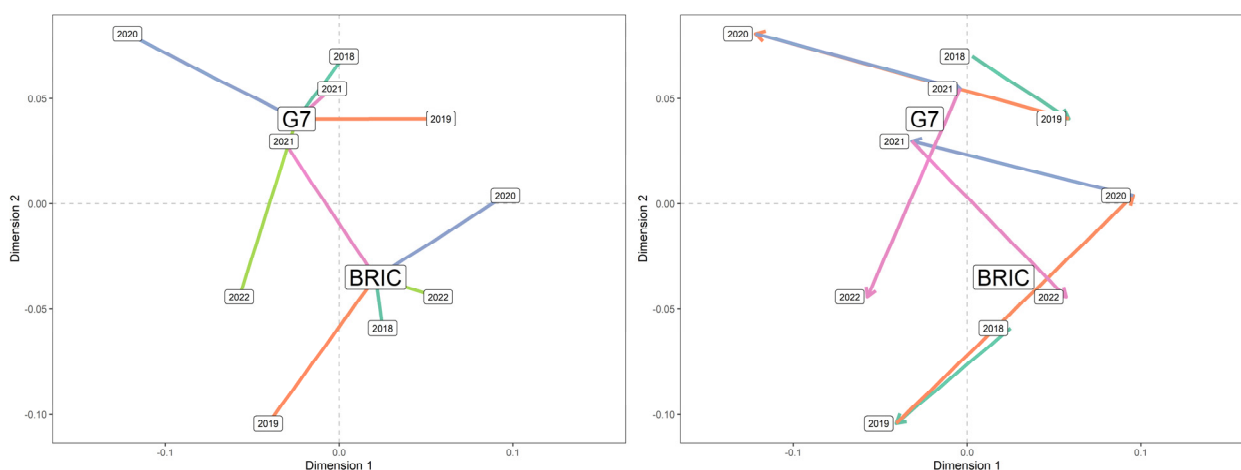
**Figure 6.** Factorial plane between dimension 1 and dimension 2 for the pre-pandemic and post-pandemic periods. **Note:** Dimension 1 is interpreted as assets and debt, and dimension 2 is interpreted as profitability; these names are given due to the contribution of the variables to each dimension.



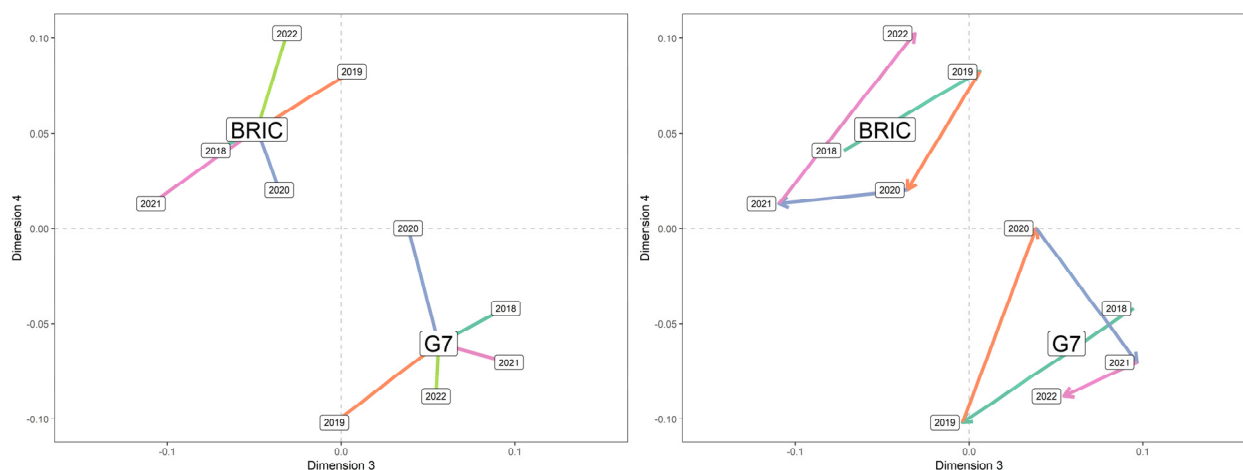
**Figure 7.** Factorial plane between dimension 3 and dimension 4 for the pre-pandemic and post-pandemic periods. **Note:** Dimension 3 is interpreted as liquidity and inventory, and dimension 4 is interpreted as growth and financial strength; these names are given due to the contribution of the variables to each dimension.

Figures 8 and 9 detail the dynamics of the BRICS and G7 economies on the estimated dimensions. Figure 8 shows the dynamics for the dimensions of assets and debts vs. profitability. The centroid of the BRICS is located in the lower right quadrant closest to the vertical axis, i.e., profitability dimension 2. In contrast, the centroid of the G7 is located in the opposite upper left quadrant, closer to the vertical axis, i.e., the dimension of profitability, asset, and debt. This clearly shows an opposite dynamic in terms of profitability for the financial relationship of electric power generation, transmission, and distribution companies. Moreover, when the dynamics of the economies are detailed over the years, they clearly show that the estimated vectors tend to be generally in opposite directions. For example, while the 2020–2021 vector for the BRICS moves to the upper left quadrant, the 2020–2021 vector for the G7 already comes from that direction. Figure 9 shows the dynamics for the dimensions of liquidity and inventory and growth and financial stability; similarly, we identify opposite scenarios in the financial performance of companies for each year.

The results allow us to observe the dynamics of the estimated dimensions over the years. Analyzing together Table 2 and Figures 8 and 9, where the square cosine indicates the contribution of a dimension to each year, we can state the following:



**Figure 8.** Dynamics of BRICS and G7 economies through dimension 1 and dimension 2 for the pre-pandemic and post-pandemic periods. **Note:** Dimension 1 is interpreted as assets and debt, and dimension 2 as profitability. The left panel shows the centroids for each economy over time, while the right panel shows the path of each economy over time. The figure shows that the dynamics between BRICS and G7 are opposite.



**Figure 9.** Dynamics of BRICS and G7 economies through dimension 3 and dimension 4 for the pre-pandemic and post-pandemic periods. **Note:** Dimension 3 is interpreted as liquidity and inventory, and dimension 4 is interpreted as growth and financial strength. The left panel shows the centroids for each economy over time, while the right panel shows the path of each economy over time. The figure shows that the dynamics between BRICS and G7 are opposite.

**Table 2.** Contribution of the dimensions to each year. **Note:** This table shows the association between each dimension and each year, i.e., the characterization of each year with respect to financial dynamics.

Year	Dim 1. Assets and liabilities	Dim 2. Profitability	Dim 3. Liquidity and inventory	Dim 4. Financial growth
2018	46.5	15.3	10.8	6.3
2019	44.8	14.8	12.4	7.7
2020	50.1	14.9	15.8	6.3
2021	50.6	11.6	13.5	7.0
2022	52.2	4.1	5.0	5.8

#### 4.2.1. Assets and debt

A stable trend of assets and debt among BRICS and G7 companies is perceived during the pre-pandemic years, specifically in 2018. In contrast, in 2019, this relationship is different due to the sharp decrease in debt for French companies. In the first year of the pandemic (2020), the relationship between BRICS and G7 remained opposite, but this time with greater force due to the increase in debt for French, USA, and German companies. Even though this relationship remained relatively constant during 2021, we were able to identify that it turned opposite again for the post-pandemic year (2022). While companies from countries such as France, Germany, Italy, and the USA increase their assets and liabilities, emerging countries tend to be stable or decrease in liabilities and debt, driven by Russia and India. Even though what is happening to G7 companies in 2022 can be attributed to post-pandemic effects, it is necessary to highlight that the Russia-Ukraine war and the various energy constraints in the region may also have an influence. As such, our results show that companies in France, Germany, and Italy have decided to increase their total assets and liabilities to boost efficiency in electricity service.

#### 4.2.2. Profitability

During the pre-pandemic years, in 2018 and 2019, there was a great contrast in the levels of company profitability, where emerging economies, driven by Brazil, showed higher profitability indicators, while companies in developed economies such as Germany and the United Kingdom experienced a decline. In the years 2020 and 2021, during the pandemic, companies in developed economies such as Italy, the United Kingdom, Germany, and the USA began to experience profitability, which closed off the gap between emerging and developed economies. During the post-pandemic year 2022, the gap widened again, in favor of companies in developed economies, specifically driven by the USA and Italy, coupled with the decline in profitability of companies in Brazil. In terms of sensitivity, we can identify the resilience of developed countries in dealing with the pandemic crisis, while emerging economies demonstrate business fragility in the face of external circumstances.

#### 4.2.3. Liquidity and inventory

During the pre-pandemic years, specifically in 2018, G7 countries were more related to liquidity and inventory, as opposed to emerging countries, which showed downward trends for indicators such as current ratio, quick ratio, and inventory. During the pandemic, this dimension became more relevant; during 2020 and 2021, companies in developed countries presented a greater growth in their liquidity, driven by Germany, while companies in the BRICS countries decreased their liquidity levels and increased their inventory, mainly driven by companies in Russia that have a large gap in inventory. In this relationship, the war between Russia and Ukraine may also have an effect. In the post-pandemic period, this dimension showed decreased relevance for companies, as other dimensions stand out more. There is a tendency to maintain pandemic levels, with the exception of Russia, which has shown a downward trend in its inventory.

#### 4.2.4. Growth and financial strength

Regarding financial growth, during the pre-pandemic years, specifically in 2019, emerging and developed economies presented opposing behaviors. While the BRICS showed an increase in working capital, driven by Brazil, the G7 group showed a high gross profit margin, driven by Germany and the United Kingdom. During the pandemic period, there was no clear relationship on these dimensions in the economies; during the post-pandemic period, similar behaviors to those that existed before the pandemic are observed, but this time, the G7 is driven by Canada and France.

In general, companies from emerging economies do not follow those from developed economies in terms of financial performance. In each year, the relationship between the G7 and BRICS seems to be going in opposite directions. For example, in 2020, while the BRICS were characterized by increases in assets and debt, the G7 group was characterized by increases in profitability. This characterization opens the door to different internal and external determinants that may influence variations in financial indicators and ultimately define the sensitivity and pattern of companies' financial strategies in the face of various shocks and their resilience in times of crisis.

Figures 10 and 11 (see Appendix) show the movement of countries in the estimated dimensions. In terms of dimension 1 (assets and debt), the countries with the greatest dynamics were Italy, France, and Germany. For dimension 2 (profitability), the United Kingdom experienced the greatest dynamics

over the years 2020 and 2021. In dimension 3 (liquidity and inventory), France, Germany, and the United Kingdom experienced the greatest dynamics, while in dimension 4 (growth and financial solidity), those were Japan, Canada, and Italy. The fact that a country experiences greater dynamics with respect to a dimension means that, for a particular year, the financial movements of the companies of electric power generation, transmission, and distribution presented variations different from the usual behavior observed in other years.

Our research reveals a number of fundamental economic and financial implications arising from the financial dynamics of power generation, transmission, and distribution companies in the BRICS and G7 country groups. First, we observed a strategic divergence in asset and debt management, where the BRICS opted for conservative stability, while G7 countries, such as France, Germany, and Italy, adopted proactive strategies to strengthen efficiency in electricity service. This divergence could have repercussions on resource allocation and investment decisions, influencing economic and financial relations between the two groups.

Furthermore, we have identified a reconfiguration in profitability, where the BRICS, led by Brazil, initially showed higher profitability, but the G7 countries closed the gap during the pandemic, demonstrating the resilience of developed economies in the face of global crises. This reconfiguration could have implications for investment and collaboration strategies, affecting the transfer of technology and knowledge between groups. In terms of liquidity and inventory management, we observed decreases in liquidity and increases in inventory for the BRICS, led by Russia, while G7 companies experienced growth in liquidity, especially in Germany and France. These differences could influence international trade strategies and partnerships, affecting global economic and financial dynamics. When it comes to growth and financial strength, the BRICS experienced more moderate growth after the pandemic, while G7 countries such as Canada and Italy experienced more notable growth. This divergence could influence the perception of risk and return for investors and global market players.

Our observations suggest that the differential resilience of the BRICS and the G7 during the pandemic highlights how economic events can have different effects on different groups of countries. Variation in financial strategies among these groups can influence how they respond to and recover from economic shocks, thereby impacting the global economy. The divergence in financial strategies between the two groups of countries, BRICS and G7, emerges as a crucial aspect that shapes their response and recovery from economic shocks, thus exerting a significant impact on the global economy. The differences in asset management, debt, and other financial variables between these groups not only reflect their distinctive approaches to addressing economic challenges but also point to the interdependence between their financial decisions and the global economic landscape. For example, if the BRICS adopt more cautious financial strategies, focusing on long-term stability, this could translate into greater resilience to certain shocks, but could also mean slower adaptation to sudden changes. On the other hand, if the G7 opts for more dynamic and proactive financial policies, faster recovery could be experienced, but, in turn, additional risks and volatilities could occur.

Although the COVID-19 pandemic represents a unique non-financial and exogenous shock, certain patterns observed in our analysis resonate with findings from previous bear-market episodes, including the 2008 global financial crisis. In both crises, firms with stronger liquidity positions, more balanced leverage profiles, and more stable profitability metrics tended to exhibit greater resilience and faster recovery. These recurring patterns suggest that some financial dimensions—particularly liquidity management and capital structure flexibility—are crisis-invariant determinants of robustness, regardless of the origin of the shock. At the same time, COVID-19 also introduced sector-specific

disruptions, particularly through demand contractions and supply-chain constraints, which differentiate it from financially driven downturns. Acknowledging these similarities and differences helps generalize our findings while recognizing that resilience in the electricity sector is shaped by both structural financial characteristics and the nature of the crisis itself.

The use of DMFA also aligns with the exploratory nature of our objective, as it allows us to examine how multiple financial dimensions shift simultaneously in response to global shocks without imposing restrictive modeling assumptions. This complements, rather than replaces, traditional econometric approaches, offering a structural view of financial resilience that is difficult to obtain through unidimensional or regression-based methods.

This analysis highlights the complexity of international financial relations and underlines how economic decisions made by these groups of countries reverberate globally. These observations show the need to thoroughly understand how the financial strategies of the BRICS and G7 not only determine their individual economic destinies but also directly influence the collective response to critical global economic events. This approach is presented as a significant contribution to addressing interconnection and cross-border economic ramifications in an increasingly interdependent world.

Because DMFA is a descriptive technique, all interpretations presented in this study should be understood as structural patterns rather than causal explanations. The observed movements in the latent financial space reflect co-movements among financial indicators, not behavioral or strategic decisions by firms. We therefore avoid attributing intentional responses to companies and focus exclusively on the multidimensional configurations revealed by the data.

## 5. Conclusions

Our study employed a comparative approach to delve into the financial performance of electric power generation, transmission, and distribution companies across both developed and developing economies. This investigation was enriched by analyzing the pre-pandemic, pandemic, and post-pandemic periods, enabling us to discern vulnerabilities and resilience during times of market distress.

In the quest to explore the dynamics of financial resilience, our research identified four pivotal dimensions: assets and debt, profitability, liquidity and inventory, and growth and financial performance, that collectively account for the majority of the financial dynamics within the sector. These dimensions provided information on the interplay of variables that shape the financial stability of these entities.

Beyond its methodological contribution, our findings offer actionable insights into financial decision-making in the electricity sector. The stronger resilience observed in G7 firms suggests that certain structural features, such as more balanced leverage profiles, stronger liquidity buffers, and more stable profitability, may play a critical role in absorbing systemic shocks. Policymakers in emerging economies may consider reinforcing these dimensions through regulatory incentives or financial support mechanisms. For managers, the results highlight the importance of maintaining flexibility in capital structure and liquidity management during periods of uncertainty. Investors may also find value in recognizing the heterogeneous financial responses of firms across markets when assessing country-level or sector-specific risk exposure. These implications provide practical relevance that extends beyond the COVID-19 shock and remains pertinent for future episodes of market distress.

Exploring the realm of profitability, a crucial aspect of financial resilience, our research underscores the differing abilities of companies in developed countries to withstand shocks in contrast to their counterparts in emerging economies. This divergence highlights the significance of established

financial infrastructures and strategic frameworks in buffering against adversities. Notably, the liquidity and inventory capacity of Germany and Russia came under the spotlight due to the aftermath of the Russia–Ukraine conflict, which disrupted the gas distribution landscape between the two nations. On the other hand, the dimension of growth and financial solidity surfaced as a focal point of divergence between emerging and developed markets. This exemplifies how geopolitical events can reverberate within financial dimensions within the energy sector.

This study provides exploratory evidence on how the financial structures of electricity firms in BRICS and G7 economies evolved before and during the COVID-19 shock. Because the analysis is based on a descriptive, multidimensional technique (DMFA), the results should be interpreted as patterns in the underlying financial configuration rather than as causal relationships or behavioral responses. The findings illustrate broad structural tendencies—such as the relative stability of G7 financial profiles and the higher dispersion observed among BRICS firms—but cannot be generalized beyond the scope of the data or the methodological framework used. Accordingly, all interpretations remain tentative and are intended to contribute to a better understanding of financial resilience rather than to provide definitive or policy-prescriptive conclusions.

Several limitations must be acknowledged. First, the dataset is unbalanced across countries, and missing values require simple imputation, which may attenuate variance in some indicators. Second, DMFA does not allow formal hypothesis testing, meaning that differences between BRICS and G7 groups cannot be interpreted as statistically significant. Third, the exploratory nature of the method implies that the patterns identified here may reflect the specific composition of the sample rather than general structural mechanisms. Future studies may incorporate inferential approaches, causal identification strategies, or firm-level stress-testing frameworks to extend and validate the patterns observed in this exploratory analysis.

It is important to acknowledge the limitations of our study. The constraints imposed by available data and the complexity of financial dynamics within the sector may have influenced the scope of our analysis. Additionally, while our study offers valuable insights into financial patterns, external factors, and local nuances that could affect specific companies may not have been fully captured.

### **Author contributions**

Orlando Joaqui-Barandica: Conceptualization, Methodology, Formal analysis, Writing – Original Draft, Visualization, Supervision. Diego F. Manotas-Duque: Supervision, Validation, Writing – Review & Editing, Project administration. Oscar W. Orozco-Cerón: Data curation, Software, Investigation, Writing – Review & Editing.

### **Use of AI tools declaration**

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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## Conflict of interest

All authors declare no conflicts of interest in this paper.

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