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A Delphi–Fuzzy Delphi Study on SDGs 9 and 12 after COVID-19: Case Study in Brazil

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Abstract: The COVID-19 pandemic has affected all Sustainable Development Goals (SDGs), leading to setbacks in various Latin American countries. In Brazil, progress in technological development and the adoption of sustainable practices by organizations has been significantly hindered. Yet, there remains a limited understanding of the long-term impacts on the country's development, and a structured national plan for recovery and resuming progress toward the SDGs is lacking. This paper aims to investigate the repercussions of COVID-19 on SDGs 9 (industry, innovation, and infrastructure) and 12 (sustainable consumption and production) in the context of a latecomer country such as Brazil. This study adopted the Delphi-based scenario and Fuzzy Delphi approach and involved the participation of 15 sustainability experts with extensive experience in the Brazilian industrial sector. The findings elucidate the long-term impacts of the pandemic on these SDGs, focusing on Brazil's socioeconomic landscape and developmental challenges. The pandemic worsened pre-existing issues, hindering infrastructure modernization, technological investment, and sustainable practices. Insufficient research funding, industry modernization, and small business integration further impede progress. Additionally, the paper identifies implications for research, companies, and public policies, aiming to provide actionable insights for fostering sustainable development in the post-pandemic era.

Keywords: future; sustainability; Sustainable Development Goals; innovation; COVID-19; pandemics; Delphi; fuzzy set theory; Brazil

Citation: Sousa, I.C.d.; Sigahi, T.F.A.C.; Rampasso, I.S.; Moraes, G.H.S.M.d.; Leal Filho, W.; Eustachio, J.H.P.P.; Anholon, R. A Delphi–Fuzzy Delphi Study on SDGs 9 and 12 after COVID-19: Case Study in Brazil. *Forecasting* **2024**, *6*, 550–567. https://doi.org/10.3390/forecast6030030

Academic Editor: Bożena Gajdzik

Received: 5 June 2024
Revised: 12 July 2024
Accepted: 14 July 2024
Published: 17 July 2024

1. Introduction

The restrictions put in place to prevent COVID-19 proliferation have led to a decline in industrial activity, triggering a cycle of business closures and widespread unemployment globally [1,2]. In Latin American nations, the pandemic has exacerbated income inequality and the prevalence of informal employment [3–5]. Notably, in this region, informal employment comprises nearly half of all job opportunities, underscoring the importance of recognizing that individuals without formal employment face heightened vulnerabilities, including diminished labor rights and social protections [6].

The academic literature has consistently demonstrated that income inequality significantly contributes to poverty rates, particularly in developing nations [7,8]. Consequently,

poverty exacerbates disparities in opportunities among social classes, hindering overall national development [9,10]. Moreover, income inequality fosters disparities in human capital, as families with lower incomes often lack access to resources for better educational opportunities [11,12]. In this context, implementing public policies aimed at reducing income inequality can stimulate economic growth and improve living standards [13,14].

Poverty and socioeconomic inequality have remained longstanding structural issues in Latin America for decades [15]. The COVID-19 pandemic has further exacerbated these challenges, particularly in latecomer contexts such as Brazil [5]. The small advances made in these areas over the years were quickly eroded within a matter of months [15–17]. In Brazil, poverty and inequality have deep historical roots. Scholars such as Marquetti et al. [18] argue that the country's political structure has played a significant role in perpetuating inequality over time. This claim is supported by Tavares and Betti [6,19]. According to UNECLAC [6], the COVID-19 pandemic has led to a contraction of the Brazilian economy, resulting in increased unemployment, informality of labor, and poverty. With ineffective government measures and the rise of antiscience movements, Brazil has lagged behind in its response to COVID-19, exacerbating social and public health challenges [5].

Anholon et al. [20] highlighted the concerning nature of Brazil's public debt, especially considering the repercussions of the COVID-19 pandemic. Looking ahead, further challenges are anticipated regarding the development of decent work and sustainable, equitable, and inclusive growth [21]. The widening technological gap resulting from reduced investment is poised to affect productivity and emerge as a critical factor in Brazilian competitiveness [22,23]. This underscores the need for more efficient public policies to drive innovation and technological development while also supporting businesses [20].

It is worth noting that poverty can hinder economic development through its impact on education [24]. According to Nakabashi [9], children from low-income families are more vulnerable to malnutrition, which can impede their development and learning, ultimately resulting in lower human capital. Souza and Carvalhaes [25] emphasized the pivotal role of education in reducing income inequality in Brazil. They argued that changes in the educational landscape through public policies can foster a more educated workforce, mitigate income disparities, and consequently alleviate societal inequality [25]. These assertions are well supported by the literature, which underscores the critical importance of education in achieving comprehensive and sustainable societal development [26–28].

According to UNECLAC [15], the closure of educational institutions during the pandemic has adversely affected the academic performance of many students, particularly those from vulnerable socioeconomic backgrounds. This is expected to impede their academic advancement, leading to an increase in school dropout rates. This scenario suggests a decline in future educational indicators in Brazil, along with associated professional and economic repercussions. Furthermore, Medeiros et al. [29] observed a significant increase in household poverty issues in Brazil in recent years, resulting in serious sanitation and precariousness challenges. Tavares and Betti [19] argue that these issues expose a considerable portion of the Brazilian population to severe social and economic vulnerability, necessitating immediate attention through targeted public policies.

Given the evidence of the adverse impacts of COVID-19 on achieving sustainable development, it is crucial that all sectors of society contribute to recovering losses and returning to a path of prosperity [30]. The business sector, in particular, plays a pivotal role in facilitating this recovery [31,32]. SDGs 9 (industry, innovation, and infrastructure) and 12 (responsible consumption and production) are of particular relevance in this context as they feature targets directly pertinent to the business sector [33,34]. Therefore, there is an urgent need to enhance our understanding of the role of companies in achieving the SDGs [35], especially in light of COVID-19 and its impact on Latin America [15]. Furthermore, it is imperative to explore how researchers and policymakers can contribute to this endeavor.

In light of this context, the following research question guided this study: What will the repercussions of COVID-19 on SDGs 9 and 12 be in the coming years in a latecomer context like Brazil, and what are the implications for research, companies, and public

policies? Delphi studies have been recognized as a powerful tool for examining future scenarios in various contexts, including the impacts of the COVID-19 pandemic [34,36]. This paper adopts a Delphi-based scenario and a Fuzzy Delphi approach to investigate the effects of COVID-19 on Brazil's future trajectory toward achieving SDGs 9 and 12 and to discuss how researchers, companies, and policymakers can contribute to this progress.

2. Background of Analysis

SDGs 9 and 12 are strongly linked to business and industrial aspects. The focus of SDG 9 is to build "resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", whereas SDG 12 calls for ensuring "sustainable consumption and production patterns" [37]. These SDGs are critical components of sustainable development [38], affecting all other SDGs directly or indirectly [39].

According to Zimmerling and Chen [40], the COVID-19 pandemic disrupted the continuity of several production chains around the world, stressing the importance of adaptation to societal demands. Margherita and Heikkilä [41] and Dohmen et al. [42] emphasize the need to incorporate business continuity principles into supply chain management practices to ensure that future disruptions do not significantly compromise value chains. In fact, the pandemic revealed a significant lack of preparation on the part of many businesses in the face of disruption [43].

In late-pandemic and post-pandemic scenarios, Chen et al. [32] advocate for the implementation of public policies aimed at commercial operations in order to reduce the impact of business and consumption activities on sustainable development. Wang and Huang [44] and Mattera et al. [35] highlight that it is up to governments to develop long-term plans for economic reconstruction by encouraging sustainable business models, which, when combined with corporate social responsibility strategies, allow for the overcoming of the challenges imposed by periods of crisis.

According to Ranjbari et al. [39], achieving the SDGs has never been more urgent in light of the challenges posed by COVID-19, and in this regard, organizational resilience, the circular economy, digital sustainability, and innovation tools are among the most important topics for achieving SDGs 9 and 12. Severo et al. [30] observe that the COVID-19 pandemic has generated behavioral changes in society, influencing individuals to rethink their concepts of environmental awareness and social responsibility and favoring changes toward more sustainable consumption.

The COVID-19 pandemic has set the stage for rethinking actions and planning transitions to a more sustainable future [45,46], which represents an opportunity for innovation development, the promotion of sustainable consumption, and the adaptation of production standards [39]. According to Zimmerling and Chen [40], it is critical to maintain the innovative approaches that have emerged to provide organizations with greater flexibility in production and adaptation in the post-pandemic period. Kumar et al. [47] emphasize that the pandemic provided a chance to develop flexible and resilient manufacturing systems capable of enhancing the economic and social sustainability of production processes, whereas Su and Urban [48] and Klemeš et al. [49] highlight the opportunity to carry out an energy transition by increasing the use of renewable energy.

In general, the literature has concluded that the pandemic has had a negative impact on achieving the goals of all SDGs; however, it has also created several opportunities to strengthen actions between organizations, businesses, and communities in order to build new paths for sustainable development [44].

3. Materials and Methods

This research was conducted based on five main stages, as shown in Figure 1.

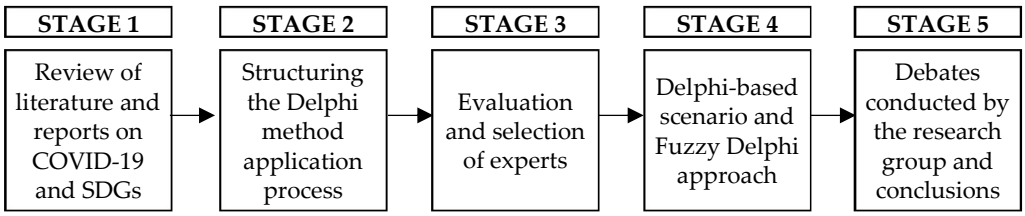

Figure 1. Research stages. Source: Authors' own creation.

3.1. Stage 1: Establishing the Conceptual Foundation Based on Literature and Reports

In Stage 1, bibliographic research was conducted to establish the theoretical background. International scientific databases were considered to identify relevant research that addressed social and economic problems in Brazil, relating them to the context of the COVID-19 pandemic and sustainable development. In addition, reports from international institutions were considered, with a greater emphasis on the most comprehensive and up-to-date reports published by the United Nations at the time of the study, the "Social Panorama of Latin America" [15]. Other relevant reports can be mentioned, such as "SDG Progress Report 2022" [37] and "SDG Report 2023" [50]. The literature review, combined with the analysis of these reports, enabled the identification of the research gap and served as the foundation for the development of Sections 1 and 2 of this paper.

3.2. Stage 2: Structuring the Delphi Study

Stage 2 consisted of structuring the Delphi method application process. The Delphi method [51], introduced at the RAND Corporation in the 1950s, has become a widely used tool for measuring and assisting forecasting and decision making in a variety of disciplines [52]. Landeta and Barrutia [53] state that Delphi-based scenario studies seek a reliable group opinion from a group of individual experts, each of whom can contribute significantly to the resolution of a complex problem. In this regard, the Delphi method is appropriate for the purpose of this study, which is to investigate the effects of COVID-19 on Brazil's future path toward SDGs 9 and 12 based on experts' opinions.

The Delphi method is based on a multi-round survey [54] in which experienced and knowledgeable professionals debate their points of view in successive rounds until some level of consensus on the topic under discussion is reached [55]. Throughout the rounds, participants can defend their positions, complement their ideas, or even change their opinions [52]. Ahmad and Wong [56] emphasize that consensus does not necessarily imply unanimity and that Delphi studies can be conducted using different levels of agreement. Donohoe and Needham [57] state that the commonly used measure for expert agreement is 60% but that this is a subjective decision. Thus, studies that use, for example, 50% [58], 75% [56], and 80% [59] can be found in the literature.

The Delphi method is particularly suitable in forecasting complex issues [36,60]. Its iterative rounds of questioning and feedback help refine expert opinions, reducing the likelihood of extreme views and fostering a more accurate consensus [53]. This method's anonymity feature prevents dominance by a single expert, promoting diverse perspectives [52]. On the other hand, the Delphi method can be considered time-consuming and requires significant coordination, which can delay decision-making processes [61]. The quality of the outcomes heavily depends on the selection of experts, and biases in expert judgment can affect results [56]. Specifically for forecasting COVID-19's impact on SDGs, while the Delphi method can provide valuable insights into uncertain and rapidly changing scenarios, its reliance on expert opinion may struggle to capture real-time data and emergent trends, making it challenging to offer timely and actionable forecasts amidst the dynamic nature of the pandemic. However, the Delphi method has been applied in similar research, i.e., forecasting the effects of COVID-19 related to the SDGs [36,60].

Initially, the research instrument used to guide respondents in the first round of Delphi was developed. Points for expert discussion in the Brazilian context were prepared based

on the targets of SDGs 9 and 12. Targets with similar themes were aggregated, resulting in ten topics (see Table 1). It is worth noting the inclusion of targets 9.c and 12.4, even though the original UN proposal was to achieve them by 2020, because Brazil is clearly still far from that reality.

Table 1. Research instrument used to guide expert discussions in the first round of the Delphi study.

Code	Description	Targets
P1	Expand access to information and communication technologies by making internet access universal and affordable.	9.c
P2	Enhance technological development, research, and innovation; foster an enabling policy environment for industrial diversification; promote more sustainable production technologies; strengthen scientific research and industrial technological capabilities; increase the number of scientists and investments in science.	9.b, 9.5, 12.a
P3	Modernize industries through greater adoption of sustainable technologies and practices; promote inclusive industrialization and significantly increase industry's participation in employment and Gross Domestic Product; encourage greater transparency and informative content in corporate sustainability reports.	9.2, 9.4, 12.6
P4	Increase the access of small-scale industrial and other enterprises to financial services, including affordable credit, and their integration into value chains and markets.	9.3
P5	Develop quality, reliable, sustainable, and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.	9.1
P6	Increase public awareness of sustainable development and encourage more balanced consumption.	12.a, 12.8
P7	Increase the promotion of sustainable public procurement practices in accordance with national policies and priorities.	12.c, 12.7
P8	Stimulate sustainable tourism in order to create jobs and promote local culture and products.	12.b
P9	Promote efficient use of natural resources in all economic sectors; reduce waste generation through prevention, reduction, recycling, and reuse; develop actions to discourage excessive use of fossil fuels; develop environmentally sound management of chemicals and waste.	12.c, 12.2, 12.4, 12.5
P10	Reduce food waste throughout the production and supply chain.	12.3

Source: Authors' own creation.

Experts were asked to express their thoughts on the impacts of the pandemic on each of the ten points. One of the researchers served as a moderator and was in charge of summarizing the responses. New rounds were performed until a consensus was reached. In the planning phase, 80% was defined as the level of agreement, following the guidelines proposed by Labuschagne and Brent [59]. The responses were managed using the Google Forms platform. It is important to highlight that this research was approved by the Research Ethics Committee of the State University of Campinas (Certificate of Presentation of Ethical Approval—CAEE 50627921.4.0000.5404) and that informed consent was provided by the research subjects.

3.3. Stage 3: Search, Assessment and Selection of Experts

Stage 3 began with the pre-selection of participants using the Lattes Platform, the main Brazilian system for registering the curriculum of researchers, managed by the National Council for Scientific and Technological Development. In this pre-selection, 79 candidates were chosen from various knowledge domains, all with a PhD and Brazilian nationality, mostly professors of postgraduate programs at federal or state universities in the country with expertise in the field of sustainability. Of the candidates chosen, 15 agreed to take

part in the study. It is important to note that some authors recommend a sample size of 10–15 participants [52], while others recommend a sample size of between 5 and 20 [61]. Throughout the research process, the participants' identities were protected.

3.4. Stage 4: Application of the Delphi and Fuzzy Delphi Methods

Stage 4 consisted of the actual application of the Delphi method process. The Fuzzy Delphi method, which combines the traditional Delphi technique with fuzzy logic [62], offers several advantages and disadvantages when selecting or rejecting alternatives. One key advantage is its ability to handle uncertainty and vagueness in expert opinion, making it well suited to complex and ambiguous issues such as the COVID-19 pandemic [63]. The fuzzy logic component allows for a more nuanced aggregation of expert judgments, providing a clearer picture of consensus and enabling better decision making in uncertain scenarios [64]. Additionally, the iterative nature of the Delphi method facilitates the refinement of expert views, enhancing the accuracy of predictions [65]. However, the Fuzzy Delphi method also has its drawbacks. It can be more computationally intensive and complex to implement compared to the traditional Delphi method, requiring expertise in fuzzy logic. When these methods are integrated, as in the case of this study, an additional stage is needed, which may not be ideal in rapidly evolving situations such as a pandemic. Moreover, the quality of the outcomes is highly dependent on the selection of knowledgeable experts, and any bias in their opinions can influence the results. Despite that, the combination of Delphi and Fuzzy Delphi offers a robust methodological approach to study situations involving emerging topics with uncertainty [63].

E-mails were sent to the candidates with clarifications about the topic and the relevance of the research, explanations about how the Delphi process works, an invitation to participate in the study as a volunteer, a consent form, and a link to the questionnaire to be answered. Three rounds were completed, as recommended by Belton et al. [61], with the Fuzzy Delphi method used in the final round. Participants in each round had four weeks to submit their responses.

In the first round of the Delphi study, participants expressed their opinions on the ten proposed items (see Table 1). Following the deadline for delivering the completed questionnaire, the collected data were organized and critically analyzed to ensure that the answers obtained were in line with the scope of the research and to eliminate duplications, as recommend by Fritschy and Spinler [66].

In the second round of the Delphi study, participants were sent a new questionnaire containing a summary of the first round's responses, allowing them to complement or adjust the information. Flostrand et al. [52] emphasize the importance of this step, since it allows participants to analyze and modify their initial responses. After the conclusion of this round, the collected responses were reorganized and analyzed in order to complement the synthesis of the responses obtained initially.

In the third round of the Delphi study, 11 experts participated, providing their opinions on the synthesis of the results obtained in the two previous rounds. This method was first proposed by Ishikawa et al. [67]. The use of fuzzy numbers to analyze linguistic terms allows the incorporation of uncertainties associated with the data collected [68]. In this study, triangular fuzzy numbers (TFN) are used. A TFN is a form of a fuzzy number represented by a triplet (l, m, u), where l is the lower limit, m is the peak (or most probable value), and u is the upper limit [69]. This structure forms a triangular-shaped membership function, with the value increasing linearly from a to b and then decreasing linearly from b to c. TFNs are used to model uncertain or imprecise data by providing a flexible way to describe values that are not exact but rather range within certain limits [70]. They are particularly useful in decision-making processes, such as in the Fuzzy Delphi method, where expert opinions are aggregated to handle uncertainty and vagueness in predictions or evaluations. For example, in forecasting the effects of COVID-19 on sustainable development goals, TFNs can help quantify expert uncertainty and facilitate more nuanced and reliable consensus-building. Within fuzzy expert systems, TFNs are used

to model and quantify vague or ambiguous data, allowing for more flexible and realistic decision-making processes [71,72]. When assessing expert opinions on the potential impacts of COVID-19 on sustainable development goals, TFNs can capture the inherent uncertainty in expert judgments, enabling the system to process and integrate diverse expert insights more effectively and ultimately provide more robust recommendations.

Table 2 shows the linguistic terms and the corresponding TFNs.

Table 2. Transformation of linguistic terms into fuzzy numbers.

Code	Triangular Fuzzy Numbers		
	a	***b***	***c***
Very low agreement	0	0	0.25
Low agreement	0	0.25	0.5
Medium agreement	0.25	0.5	0.75
High agreement	0.5	0.75	1
Very high agreement	0.75	1	1

Source: Authors' own creation.

Following the recommendation of Singh and Sarkar [62], the TFNs shown in Table 2 were obtained after data collection and were determined based on the theory of fuzzy sets using the type-2 fuzzy set (Equation (1)).

$$\mu_A = \begin{Bmatrix} \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0 & \end{Bmatrix} \quad (1)$$

where, $\mu_A \to [0,1], \forall x \in U$.

The consensus analysis for the obtained responses was developed based on the fuzzy weights criterion used by Bui et al. [73], Singh and Sarkar [62], and Rampasso et al. [63]. To calculate the fuzzy weights, Equations (2)–(4) were used.

$$\widetilde{a}_i = \min(a_{ij}) \quad (2)$$

$$\widetilde{b}_i = \left(\prod_1^n b_{ij} \right)^{\frac{1}{n}} \quad (3)$$

$$\widetilde{c}_i = \max(c_{ij}) \quad (4)$$

where $i = 1, 2, 3, \ldots, n$ and $j = 1, 2, 3, \ldots, m$.

In Equations (2)–(4), n represents the number of questions (from P1 to P10), and m represents the number of respondents.

After calculating the fuzzy weights, the mean method was used to obtain the defuzzification value S_i using Equation (5):

$$S_i = \left(\widetilde{a}_i + \widetilde{b}_i + \widetilde{c}_i \right) / 3 \quad (5)$$

where $i = 1, 2, 3, \ldots, m$.

In the Fuzzy Delphi method, the opinions of individuals (experts) are consolidated into a single aggregated opinion using a fuzzy technique. The triangular fuzzy number contains $\widetilde{a}_{ij}$ (the lowest point within the responses of the group of experts, given by Equation (2)), $\widetilde{b}_{ij}$ (the geometric mean of all points, given by Equation (3)), and $\widetilde{c}_{ij}$ (the highest point within the responses of the group of experts, given by Equation (4)). In the sequence, following Si et al. [74], the Equation (5) is used to defuzzify the fuzzy numbers through the center

of area method, obtaining the crisp number (Sj) that represents the aggregated opinion of the experts.

The Sj represents the final value calculated for each alternative j and indicates its level of acceptance. Thus, these values were then compared with a threshold value in order to select or reject the item [62], allowing the determination of whether there was consensus among the participants on each of the proposed items (see Table 1). The threshold value adopted was 0.5 (average value between 0 and 1), as recommended by Bodjanova [75] and Rampasso et al. [63]. As demonstrated by these authors, this value is largely used for being the middle point of the interval [0, 1]. This means that the interest is in agreement from the average level upwards. It should be noted that in this study, this level of agreement is applied after the Delphi process itself (two rounds), with the Fuzzy Delphi being the third round of evaluation by experts who participated in the first two rounds, therefore already having a prior evaluation for consensus. In addition, it is also important to highlight that this research has an exploratory nature, and the threshold established aims to select those proposed points according to experts' agreement for each point. This is important so as not to discard important points at an exploratory level, and the threshold used is suitable for this. Thus, for consensus to be considered reached, the S_i corresponding to each item needed to be equal to or greater than 0.5.

All the calculations were implemented using MS Excel 2019.

3.5. Stage 5: Debate of the Findings and Establishment of Conclusions

Finally, the information gathered from the literature, reports, Delphi rounds, and Fuzzy Delphi were integrated. The results were discussed by the research group, connecting with the literature and generating findings that can be useful for researchers, companies, and policymakers. The outcomes are reported in the following sections.

4. Results

After the completion of the first two Delphi rounds, the experts' opinions on each of the ten proposed points related to SDGS 9 and 12 (as described in Table 1) were organized and synthesized. The results obtained for each of the ten points at the end of round 2 are presented sequentially.

4.1. Consolidating the Findings from the Delphi Study

4.1.1. P1: Access to Information and Communication

Respondents recognized that the pandemic was disruptive to people's way of life and that the effects of that disruption will be visible in the different ways of working, studying, and living.

According to their perceptions, access to information and communication technologies (ICT) will continue to be unequally distributed in Brazil. Even before COVID-19, dedicated efforts to achieve service quality, free internet access, and availability in remote regions were insufficient, and such projects were abandoned after the pandemic. Although there have been some specific evolutions, such as in some municipalities where computers were distributed and internet access was provided for students in the basic education network, digital inclusion in Brazil is still in its early stages. Even with the arrival of 5G technology, infrastructure issues remain strong limiting factors. The budgetary difficulties projected for the coming years in Brazil will have a significant impact on projects associated with technology and, as a consequence, will have an impact on the universalization of internet services at affordable prices, an essential factor for population development, including content consumption of quality, access to employment opportunities, and digital education.

4.1.2. P2: Research and Sustainable Production Technologies

The experts expressed that the COVID-19 pandemic exposed the shortcomings of Brazilian scientific and technological policy. Despite the fact that the majority of Brazilian society values science, a lack of investment and the structural dismantling of scientific

bodies will cause irreversible damage in the coming years. It is not only a budget issue (which, as previously stated, has become even more critical in light of the pandemic) but also a matter of choices that will inhibit scientific research and technological development. The government (most notably at the federal level, but also at all other levels) has not improved working conditions and the environment for teaching and research and has systematically reduced financial resources for this purpose. A problem whose impact will be felt considerably in the coming years is the brain drain, i.e., the exodus of highly skilled professionals who are vital human capital for organizations, communities, and nations. The experts noted that this problem was already being faced by Brazilian universities, but it was exacerbated by the pandemic. Some of the respondents highlighted that those topics of extreme relevance to the country's development, such as Industry 4.0 and the circular economy, rely heavily on investment in research and that the lack of investment in science and technology will impact national development.

4.1.3. P3: Modernization of Industries and Corporate Sustainability

When addressing topics concerning the modernization of Brazilian industries, experts expressed that the major problem is that the federal government is not engaged in the sustainable development agenda, which has become even more critical with the COVID-19 pandemic, jeopardizing actions and programs that encourage Brazilian companies to adopt sustainable technologies and practices in the coming years. In the absence of policies, investments, and national-level actions, the evolution of the industrial sector, both in terms of technology and sustainability, will be compromised, and the full potential of Brazilian organizations will not be used for the country's development. Although there are some companies in Brazil that stand out and can be considered reference models in sustainable practices, in general, their actions are isolated and not integrated into the value chain, which is insufficient for the real transformations required in Brazilian industry. Some experts emphasized the importance of deepening ESG (environmental, social, and corporate governance) concepts for real organizational culture transformation and making sustainability reports more transparent and factual, with the potential to be used as a governance mechanism by society. For most respondents, the pandemic will affect Brazil's progress on these issues in a way that will make it extremely difficult to achieve the targets in the coming years.

4.1.4. P4: Small Businesses Development and Integration into Value Chains

The pandemic has caused significant changes in many companies' management, primarily affecting small businesses that lack organizational resilience capabilities to withstand major disruptions. Numerous small businesses in Brazil had their finances severely harmed, and many went bankrupt. Despite recent improvements in access to credit for small businesses, it can still be argued that there is no broad and well-structured economic policy in Brazil that provides access to low-cost financial resources for long-term investments; neither is there a program aimed at their integration into value chains to improve collaboration with large corporations. As a result, the development and entrepreneurial activity of such small-scale industries will continue to face many obstacles in the post-pandemic period. Given the costs of the COVID-19 pandemic and Brazil's projected public debt in the near future, experts believe that meeting these targets will be difficult. Unfortunately, they believe that this will jeopardize the growth of the Brazilian economy in the coming years, as small businesses play a vital role in national development.

4.1.5. P5: Infrastructure Improvement and Development Strategy

Experts observed that the majority of Brazilian infrastructure requires modernization and urgent investment, which is critical for the country's economic development, particularly in regions far from large urban centers. Several existing problems were raised in order to meet the target in question. One of the major issues is the lack of a long-term policy for infrastructure development. Although infrastructure projects in Brazil have been

completed, the development strategy has historically changed as the federal government's command changes, causing all of the effort made by one political group to be wasted by the next. In practice, governments have prioritized short-term benefits over long-term strategic goals. Moreover, experts linked this issue to the worsening of public debt as a result of COVID-19 pandemic expenses, which will make the Brazilian scenario less attractive for investments, compromising the future economy's overall development.

4.1.6. P6: Sustainable Consumption and Awareness

The experts highlighted the high inequality of access to information in Brazil as an important obstacle to achieving the related target. For a part of the population, the pandemic has raised awareness of the need to respect environmental and economic limits, leading to reflections on more sustainable consumption patterns that can be reflected in people's future lifestyles. Although there are some policies associated with education for sustainability (for example, the National Environmental Education Policy), it should be noted that in Brazil, a large portion of the population struggles to achieve the bare minimum for survival, making sustainable consumption an elitist issue. Most experts believe that there is a lack of public policies capable of disseminating the concepts of sustainability at all educational levels and throughout society. In short, issues concerning sustainable consumption will be of interest to a small portion of the Brazilian population, but not to the most vulnerable, who constitute the majority.

4.1.7. P7: Sustainable Public Procurement Practices and Policies

The purchasing power of the State is an excellent tool for inducing cultural transformations, and it can contribute decisively to more sustainable production and consumption patterns if it encompasses all economic sectors. When compared to other countries, Brazilian laws concerning sustainable public procurement practices are well structured; however, there is a need for the more rigorous regulation of municipal actions to ensure that these laws are followed. Most experts do not believe that the effects of the pandemic will result in significant changes in national policies and priorities. They envision future opportunities for improvement, particularly in the application of more sustainable procurement practices, emphasizing that this is closely related to how Brazil will engage in the sustainable development agenda.

4.1.8. P8: Promotion of Sustainable Tourism Economic Activities

Tourism has enormous potential in Brazil in terms of job creation and promoting local culture, which has been severely impacted by the COVID-19 pandemic. In attempting to regain full operational capacity, tourism organizations should incorporate sustainability principles. The evolution of Brazilian tourism activities is dependent on multiple actors, including the government, municipalities, and businesses, and therefore should be viewed in terms of integrated actions. Another point raised is that in recent years, tourism has become more accessible to people of different socioeconomic classes. Most experts believe that the pandemic has influenced a segment of the population to reassess the importance of sustainable development, which will have a positive impact on the appreciation of local culture and products, boosting Brazilian tourism in the coming years. However, experts contend that the budgetary challenges mentioned in previous items (P1 and P2) will hinder government efforts to promote Brazilian tourism. According to some experts, communication between federal, state, and municipal governments is very poor and clearly insufficient to achieve such a goal. In summary, there are positive and negative predictions about how the pandemic will impact the achievement of this target.

4.1.9. P9: Development of Environmentally Friendly Practices by All Actors in Society

The pandemic stressed the urgency of all actors in society and all economic sectors to behave in a more sustainable manner. Most experts believe that this will increase societal pressure on companies to engage in more sustainable practices. However, in order for

this to happen, it will be necessary to develop public policies and actions associated with long-term governance mechanisms; and this, according to experts, is the main concern. Current political decisions, which do not value aspects of sustainability, will have an impact in the coming years. This fact, associated with Brazil's financial difficulties, does not result in a good prognosis for this target.

4.1.10. P10: Reduction of Food Waste at All Stages of Production

The COVID-19 outbreak exposed a humanitarian disaster that affected the most vulnerable sections of society, for whom minimum standards of living are not guaranteed. Food waste is an extremely critical issue in this situation. The pandemic altered some people's dietary habits, but similar to P6, this issue only makes sense for the minority portion of the Brazilian population that have better socioeconomic conditions. Most experts point to the worsening fiscal scenario and increased political uncertainty in the country as the main barriers to such actions being implemented in the coming years. There have been isolated actions in some municipalities and economic sectors, but there has been no systemic impact. Thus, there is still a long way to go to achieve this goal. The experts observed that individual actions, while insufficient, can help in this regard because a large amount of food is wasted in homes, and that this reality must be changed in the coming years as many people continue to struggle for survival on a daily basis.

4.2. Decision-Making through Fuzzy Delphi Approach

In the third round, the results of the previous rounds were presented to the participants, and they were asked to indicate their level of agreement with them. The data collected in this round were analyzed using the Fuzzy Delphi method. Based on the answers given by the 11 experts that participated in third round, the Equations (2)–(4) were used to aggregate the experts' opinions, and Equation (5) allowed the defuzzification. The results are shown in Table 3. The detailed procedures are explained in Section 3.4. As an illustration, P1 ($j = 1$) is used as a numerical example:

$$\widetilde{a}_1 = \min\,(0.75,\ 0.75,\ 0.5,\ 0.5,\ 0.5,\ 0.75,\ 0.75,\ 0.5,\ 0.75,\ 0.75,\ 0.5) \ = \ 0.5$$

$$\widetilde{b}_1 = (1,\ 1,\ 0.75,\ 0.75,\ 0.75,\ 1,\ 1,\ 0.75,\ 1,\ 1,\ 0.75)^{1/11} \ = \ 0.8774$$

$$\widetilde{c}_1 = \max\,(1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1) \ = \ 1$$

$$S_1 = (0.5 + 0.8774 + 1)/3 = 0.792$$

Thus, these procedures are replicated for all propositions (P2 to P10), generating the results that allowed decisions (select or reject) to be made.

Table 3. Fuzzy weights calculated for each point of discussion.

Code	$\widetilde{a}_i$	$\widetilde{b}_i$	$\widetilde{c}_i$	S_i	Decision (Select/Reject)
P1	0.5	0.8774	1	0.792	Selected
P2	0.5	0.9007	1	0.800	Selected
P3	0.25	0.8911	1	0.714	Selected
P4	0.5	0.9245	1	0.808	Selected
P5	0.5	0.8774	1	0.792	Selected
P6	0.5	0.9007	1	0.800	Selected
P7	0.25	0.8681	1	0.706	Selected
P8	0.5	0.8774	1	0.792	Selected
P9	0.25	0.8457	1	0.699	Selected
P10	0.5	0.9007	1	0.800	Selected

Source: Authors' own creation.

As the threshold value adopted was 0.5 [63,75], it can be verified that all ten points were selected.

5. Discussion

The analysis of these results allows for some predictions about the impacts on SDGs 9 and 12 due to the economic and social distress resulting from the COVID-19 pandemic in Brazil. In general, current financial problems and recent political decisions will have a significant impact on Brazilian development [5,18,76]. Budgetary constraints will have an impact on technology-related projects, threatening the universalization of affordable internet services. Furthermore, the lack of public policies, investments, and actions in the area of innovation will jeopardize the modernization and competitiveness of industry.

The effects of the COVID-19 pandemic, combined with the Brazilian government's lack of engagement with the sustainability agenda, result in low expectations for actions and programs capable of fueling organizations' adoption of more sustainable technologies and practices. The absence of public policies that provide financial assistance to small businesses will have a negative impact on the country's future economic development. Aside from the humanitarian crisis, the COVID-19 pandemic also brought to light the problems of Brazilian scientific and technological policy, marked by a lack of investment and the structural dismantling of scientific bodies, which will cause irreparable damage in the coming years, such as brain drain [5].

The findings of this study shed light on the profound and multifaceted impacts of the COVID-19 pandemic on SDGs 9 and 12, particularly within the context of Brazil, a country still grappling with developmental challenges. The COVID-19 pandemic has not only exposed the vulnerabilities of Brazil's existing infrastructure and production systems but has also underscored the urgent need for innovative solutions to bridge the digital divide and promote sustainable consumption patterns. As a latecomer country, Brazil faces a daunting challenge in navigating the interplay between economic recovery, technological innovation, and environmental sustainability. The pandemic-induced disruptions have disrupted supply chains [43], stifled investment in research and development (R&D), and widened socioeconomic disparities [9,10], further exacerbating the country's developmental challenges.

Moving forward, a critical examination of the long-term effects of the pandemic on SDGs 9 and 12 is essential for guiding policy interventions and fostering resilience in the face of future crises. Thus, it is crucial to adopt a critical view regarding the potential dynamic changes that might influence the results presented, which are largely based on experts' opinions. The evolving nature of the pandemic, coupled with unpredictable socioeconomic shifts, underscores the need for the cautious interpretation of these findings. Factors such as evolving government policies, technological advancements, and global economic dynamics could significantly alter the trajectory of the sustainable development initiatives outlined in this study.

While the research offers valuable insights into the overall impact of the COVID-19 pandemic on SDGs 9 and 12 in Brazil, it is essential to acknowledge the importance of considering regional variations within the country. Brazil is characterized by significant diversity in terms of economic development, infrastructure, and access to resources across its various regions. Therefore, the challenges and opportunities related to sustainable development may vary significantly from one region to another. For instance, urban areas might face distinct issues related to the modernization of infrastructure and digital connectivity compared to rural or remote regions. Similarly, coastal regions might have different concerns regarding sustainable tourism and environmental conservation compared to inland areas. By incorporating a more nuanced understanding of regional disparities, future research efforts can better identify targeted interventions and policy measures to address specific challenges and promote more inclusive and equitable sustainable development outcomes across Brazil.

5.1. Implications for Research

The research findings have significant implications for future research on SDGs 9 and 12. By leveraging interdisciplinary approaches and engaging stakeholders from academia, industry, and government, researchers can facilitate knowledge exchange and co-create sustainable development strategies tailored to countries' unique contexts. In addition, longitudinal studies tracking the evolution of sustainable practices and technological adoption are essential for assessing the effectiveness of policy interventions and guiding future research priorities.

Researchers have a pivotal role in deepening our understanding of sector-specific barriers to sustainable development and identifying innovative solutions to mitigate these challenges. The research findings highlight a complex interplay of challenges across various sectors in Brazil. Unequal access to ICT infrastructure not only affects digital-dependent sectors such as IT [77] and manufacturing [40] but also exacerbates disparities in access to essential services and economic opportunities. Inadequate investment in R&D further impedes innovation-driven industries such as pharmaceuticals and high-tech manufacturing, limiting their competitiveness and potential for growth.

Moreover, the manufacturing and production sectors face hurdles in transitioning to sustainable practices due to a lack of supportive policies [78]. This issue particularly affects industries such as automotive and energy, where sustainable production methods are crucial for environmental conservation and long-term viability [79]. Small businesses encounter barriers to growth stemming from limited financial support and integration opportunities, hindering their ability to innovate and compete effectively in the market [23,80].

The infrastructure and construction sectors suffer from insufficient funding, delaying critical upgrades necessary for economic growth and industrial expansion [81]. Similarly, the tourism and hospitality industries struggle with a lack of support for sustainable tourism initiatives, limiting their economic potential and exacerbating environmental pressures [82]. Challenges in reducing food waste in agriculture [83] and the absence of policies for renewable energy sources [79] further underscore the need for comprehensive and integrated approaches to address sustainability issues across sectors.

5.2. Implications for Practice

The research findings offer valuable insights for companies seeking to contribute to SDGs 9 and 12 in Brazil, particularly in the context of post-pandemic recovery. The research underscores the urgent need for investment in technology and infrastructure to bridge the digital divide and foster inclusive economic growth. Companies can leverage these findings to prioritize initiatives aimed at improving access to information and communication technologies (ICT) across diverse regions and socioeconomic segments. By investing in the deployment of advanced ICT infrastructure, such as 5G technology [84], and partnering with local communities and government agencies [85], companies can play a pivotal role in expanding digital inclusion and unlocking new opportunities for innovation and entrepreneurship [86].

Moreover, the research highlights the importance of R&D in driving technological innovation and sustainable industrial practices. Companies can align their R&D strategies with national development priorities, focusing on areas such as Industry 4.0 and circular economy principles [87]. By fostering a culture of innovation and collaboration, companies can contribute to the advancement of sustainable production technologies and strengthen Brazil's competitiveness in the global market [88].

As Brazil navigates the challenges of post-pandemic recovery, companies must remain agile and adaptive in their approach to sustainable development. This includes leveraging emerging opportunities in sectors such as renewable energy, green infrastructure, and sustainable tourism while also addressing systemic barriers to progress, such as limited access to finance and inadequate policy support [19,89,90]. By collaborating with government agencies, civil society organizations, and other stakeholders, companies can drive collective

action towards achieving SDGs 9 and 12 while also contributing to broader socioeconomic development objectives.

5.3. Implications for Public Policies

In light of these research findings, policymakers must adopt a multi-dimensional approach to address the systemic challenges hindering progress towards SDGs 9 and 12 in Brazil.

Locally, targeted investments in infrastructure development, digital literacy programs, and renewable energy projects are essential for narrowing the digital divide and promoting inclusive economic growth. At the regional and national levels, policymakers should prioritize the formulation of robust regulatory frameworks, tax incentives, and financial mechanisms to incentivize private sector investments in sustainable innovation and production. Strengthening institutional capacities, promoting stakeholder engagement, and fostering knowledge exchange platforms are critical for enhancing policy coherence and effectiveness [91].

Internationally, Brazil can leverage its position as a global player to advocate for sustainable development financing, technology transfer, and capacity-building initiatives, fostering South–South cooperation and advancing the global sustainability agenda. By adopting a systemic and collaborative approach, policymakers can catalyze transformative change and lay the groundwork for a more sustainable and resilient future for Brazil and beyond [5].

6. Conclusions

This research aimed to investigate the impacts of COVID-19 on SDGs 9 and SDG 12 considering the Brazilian scenario in the coming years through a Delphi-based scenario and Fuzzy Delphi approach. In general, the COVID-19 pandemic has exacerbated pre-existing problems in Brazil, some of which have historical roots. The worsening of public debt and existing social problems will make it even more difficult to modernize national infrastructure, increase investment in innovative technologies and projects, and encourage sustainable consumption and production, jeopardizing the chances of meeting the SDG 9 and 12 targets. The lack of investment in R&D, the modernization of industries, and the integration of small businesses into value chains has further hampered the country's progress towards sustainable development.

In discussing these findings, it becomes evident that Brazil faces a complex array of challenges in navigating the post-pandemic recovery phase. The analysis underscores the urgent need for targeted interventions to address systemic barriers and promote inclusive economic growth, technological innovation, and sustainable consumption patterns. Moreover, the findings highlight the importance of collaborative efforts among government agencies, businesses, and civil society organizations in driving collective action towards achieving the SDGs.

The research makes several key contributions to the literature and the practice of sustainable development in Brazil. By adopting a Delphi-based scenario and Fuzzy Delphi approach, the study provides a nuanced understanding of the multifaceted impacts of the pandemic on SDGs 9 and 12, shedding light on key challenges and opportunities. Furthermore, the research offers actionable insights for policymakers, businesses, and other stakeholders seeking to advance sustainable development agendas in Brazil, emphasizing the importance of targeted investments, policy coherence, and stakeholder engagement.

It is essential to acknowledge the limitations of this study. Despite the comprehensive analysis conducted in this research, there are notable limitations that warrant consideration. Firstly, the homogeneity of the sample in terms of qualifications and expertise may have restricted the diversity of perspectives, potentially introducing biases into the analysis. The reliance on expert opinions, while valuable, may not fully capture the breadth of experiences and viewpoints relevant to SDGs 9 and 12 in Brazil. Additionally, the study's exclusive use of Delphi and Fuzzy Delphi methods may have limited the depth of analysis. While

these methods are well suited to exploring complex and uncertain issues, incorporating alternative research methodologies could have provided a more nuanced understanding of the multifaceted challenges and opportunities associated with sustainable development in Brazil. Additionally, the study's scope is limited to SDGs 9 and 12, leaving out other critical dimensions of sustainable development that warrant further investigation.

Looking ahead, future research endeavors should aim to address these limitations and explore additional facets of sustainable development in Brazil. Future research endeavors should consider diversifying the sample and integrating complementary research approaches to enrich the analysis and enhance the robustness of the findings. In addition, longitudinal studies tracking the implementation of policy interventions and their impact on developmental outcomes would provide valuable insights into the effectiveness of different strategies. Moreover, interdisciplinary research initiatives integrating perspectives from economics, sociology, and environmental science can deepen our understanding of the complex interactions shaping sustainable development trajectories in Brazil and inform evidence-based decision-making processes. By building on the foundations laid by this study, future research endeavors can contribute to the advancement of sustainable development agendas in Brazil and beyond.

Author Contributions: Conceptualization, I.C.d.S. and R.A.; methodology, I.C.d.S. and R.A.; software, I.C.d.S., T.F.A.C.S., I.S.R. and R.A.; validation, I.C.d.S., T.F.A.C.S., I.S.R. and R.A.; formal analysis, I.C.d.S., T.F.A.C.S., I.S.R. and R.A.; investigation, I.C.d.S.; resources, T.F.A.C.S., G.H.S.M.d.M., W.L.F. and R.A.; data curation, I.C.d.S., T.F.A.C.S., I.S.R. and R.A.; writing—original draft preparation, I.C.d.S., T.F.A.C.S., I.S.R., G.H.S.M.d.M., W.L.F. and R.A.; writing—review and editing, I.C.d.S., T.F.A.C.S., I.S.R., G.H.S.M.d.M., W.L.F., J.H.P.P.E. and R.A.; visualization, I.C.d.S., T.F.A.C.S., I.S.R., G.H.S.M.d.M., W.L.F., J.H.P.P.E. and R.A.; supervision, R.A.; project administration, R.A.; funding acquisition, T.F.A.C.S., G.H.S.M.d.M., W.L.F. and R.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Council for Scientific and Technological Development (CNPq/Brazil), grant numbers 304145/2021-1, 303924/2021-7 and 150662/2022-0.

Data Availability Statement: Data will be made available on request.

Acknowledgments: The authors are grateful for the support of the National Council for Scientific and Technological Development (CNPq/Brazil).

Conflicts of Interest: The authors declare no conflicts of interest.

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