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ABSTRACT

This article aims to identify the strategies for Amazonian development, through the benchmarking analysis between the innovation ecosystems focused on the bioeconomy of the state of Pará and the bioeconomy generated in Portugal. The methodology adopted included a qualitative approach, combining literature reviews, statistical data collection, and comparative case studies between the two regions. Data from government institutions and international organizations were used to identify regional policies, actors, and ecosystems. The results demonstrate that, while Portugal has a consolidated innovation ecosystem with a structured infrastructure and well-established incentive policies, the State of Pará faces significant challenges related to infrastructure and the lack of integration between local actors. The comparison revealed that collaboration between institutions and the presence of consistent public policies are crucial for the success of activities focused on the bioeconomy.

Keywords: Bioeconomy. Regional Development. Innovation. Amazon.

RESUMO

Este artigo tem como objetivo identificar as estratégias para o desenvolvimento amazônico, por meio da análise de benchmarking entre os ecossistemas de inovação focados na bioeconomia do estado do Pará e a bioeconomia gerada em Portugal. A metodologia adotada incluiu uma abordagem qualitativa, combinando revisões de literatura, coleta de dados estatísticos e estudos de caso comparativos entre as duas regiões. Como tal, foram utilizados dados de instituições governamentais e organizações internacionais para identificar políticas, atores e ecossistema regional. Os resultados demonstram que, enquanto Portugal possui um ecossistema de inovação consolidado com uma infraestrutura estruturada e políticas de incentivo bem estabelecidas, o Estado do Pará enfrenta desafios significativos relacionados à infraestrutura e à falta de integração entre os atores locais. A comparação revelou que a colaboração entre instituições e a presença de políticas públicas consistentes são cruciais para o sucesso de atividades com foco na bioeconomia.

Palavras-chave: Bioeconomia. Desenvolvimento Regional. Inovação. Amazônia.

1. INTRODUTION

Accelerated regional development impacts industrial and commercial structures globally and is explained by various theories: neoclassical ones focus on market mechanisms and factor mobility (Krugman, 1991); other theories explore the role of location and how the concentration of activities influences development (Dawkins, 2003); the cumulative causation and growth pole theories argue that development concentrates in areas that attract investment and talent, generating spillovers that drive regional growth (Perroux, 1983; Marshall, 1980); and institutional theories emphasize the importance of economic and social structures, advocating for interventions to reduce inequalities (Furtado, 1961). Together, these theories elucidate the complex dynamics of regional development, highlighting the interaction between economic, social, geographic, and institutional factors.

After decades of isolated and limited policies, a new set of economic development theories has emerged to guide public policies for regional development based on innovation ecosystems (Glaeser, 2008; Fujita; Krugman; Venables, 1999). From this perspective, Regional Innovation Systems (RIS) offer an analytical approach to understanding the processes and outcomes of regional development, emphasizing collaborative and interactive activities between different actors, such as businesses, universities, and research institutes (Kauffeld-Monz; Fritsch, 2013).

The new economic geography, aligned with contemporary theories of regional development (Fujita; Krugman; Venables, 1999), suggests a more detailed approach to understanding how economic and geographic forces shape the distribution of economic activities. Given the increasing importance of openness to foreign markets, regardless of future sectoral or global restrictions, innovation ecosystems emerge as crucial elements in forming economic clusters. These ecosystems enable the concentration of companies in strategic areas, reducing production costs, increasing efficiency, and facilitating the exchange of information and innovations, thus fostering environments conducive to economic growth and investment attraction.

From the perspective of new institutional economics, regional development must be accompanied by adaptation and changes in institutions (North, 1991). These theories encourage the development of innovation ecosystems as effective strategies for territorial development. Considering the G20 decarbonization initiatives and the upcoming COP 30, it becomes even more urgent to address regional demands by incorporating environmental concerns, security policies, and multilateral regulations.

Initiatives such as the State Bioeconomy Plan of Pará (Pará, 2022) and partnerships with European research institutions, such as the Lisbon School of Economics and Management (ISEG) and Nova University Lisbon, exemplify efforts to strengthen innovation networks and develop new bioeconomic products and processes. The creation of an Amazon Bioeconomy Hub, connected to Digital Innovation Hubs, aims to accelerate technology transfer and expand access to global markets.

To understand these changes and their implications, this study aims to identify strategies for Amazonian development through a benchmarking analysis between the innovation ecosystems focused on the bioeconomy in the state of Pará and those developed in Portugal.

Within the context of defining bioeconomy as a regional development strategy, this article addresses the following research questions: i) What are the bioeconomy strategies and action plans in the Brazilian Amazon, specifically in the state of Pará, and in Portugal? ii) Who are the key actors in a regional innovation ecosystem focused on the bioeconomy in Pará and in Portugal? iii) What bioeconomy practices in different regions and sectors of Portugal can offer

insights and benchmarking on challenges and opportunities for the state of Pará in the Brazilian Amazon? Given the points raised, the selection of this theme follows a series of criteria that include strategic relevance, sectoral significance, timeliness, academic importance, and the originality of the study.

This article is structured as follows. Section 2 presents the conceptual framework and analytical structure. Section 3 describes the methodology, which is based on data sources used to understand regional development conditions through bioeconomy policies. Section 4 includes comparative analysis with results and discussion, focusing on the policies adopted by the state of Pará and Portugal. The final section summarizes the main findings and presents concluding remarks.

2. LITERATURE REVIEW

2.1. BIOECONOMY

Bioeconomy is a broad concept based on the sustainable use of biological resources for the production of food, energy, materials, and renewable chemicals. It integrates economic development, environmental conservation, and improved quality of life. This flexibility allows different actors - governments, industry, academia, and civil society - to adapt their strategies, though it can also complicate the formulation of coherent public policies.

In Brazil, the bioeconomy adapts to regional characteristics, as illustrated by the State Bioeconomy Plan of Pará, which promotes the sustainable use of local biodiversity by valuing sociobiodiversity products and local communities (Pará, 2022). However, it faces challenges such as a lack of technological business models and the absence of a national bioeconomy strategy (Vargas; Pinto; Lima, 2023). In contrast, European countries like Portugal invest in a bioeconomy focused on replacing fossil-based products with biological alternatives and promoting a circular economy.

Despite these challenges, Brazil has the potential not only to adopt but also to adapt international models, leveraging its biological and cultural wealth to foster an inclusive and sustainable bioeconomy. Brazil's new industrial policy highlights the importance of the bioeconomy as a pillar of sustainable development, with a focus on decarbonization, digitalization, and the transition to a low-carbon

economy (Brasil, 2024). This approach allows Brazil to enhance the value of its natural resources, strengthening its value chains - especially in the Amazon.

Initiatives such as the State Bioeconomy Plan of Pará and partnerships with European research institutions (ISEG and NOVA University Lisbon) are examples of efforts to strengthen innovation networks and develop new bioeconomic products and processes. One such initiative is the Amazon Bioeconomy Hub, created by the Federal University of Western Pará (UFOPA) and connected to Digital Innovation Hubs (DIHs), aiming to accelerate technology transfer and increase access to global markets for Amazon bioeconomy products.

2.2. THE CONTEXT OF THE AMAZONIAN BIOECONOMY

Bioeconomy emerges as a new global economic paradigm that promotes the sustainable use of biological and natural resources, aiming for both economic development and environmental conservation. Despite its rich biodiversity, Brazil has yet to establish itself as a global leader in this emerging scenario. While countries like China, the United States, and EU members lead green transition efforts, Brazil struggles to define a clear and effective national strategy for bioeconomy (FGV; Nature Finance, 2024; Vargas; Pinto; Lima, 2023).

These international initiatives aim to resolve environmental challenges and promote sustainable economic growth through regulations, incentives, and technological innovation. Although Brazil is rich in biodiversity, it lacks sustainable, tech-based business models that could boost its participation in the global forest-compatible products market, valued at approximately USD 176.6 billion annually (COSLOVSKY, 2021). Products like açaí, Brazil nuts, and cupuaçu have great potential, but the market share of local companies remains small, revealing a major gap in capturing end-product value. The lack of modern economic models and adequate infrastructure hinders timely responses to global changes, repeating historical mistakes where the Amazon was treated merely as a commodity source - with minimal regional economic impact and high environmental costs.

The complexity of the Amazon biome, along with the diversity of other Brazilian biomes, makes defining a unified bioeconomy model difficult (Amazônia 2030, 2022). The lack of consensus and clarity on the concept of bioeconomy and which sociobiodiversity chains it includes creates confusion in public policy formulation and investment decision-making (Ferreira et al., 2024). Definitions vary depending on the actor - industry, academia, government, funding agencies, or civil society. While this flexibility enables different objectives to align, it also causes ambiguity regarding which chains truly belong to a specific biome's bioeconomy.

In this context, Brazil is advancing toward a National Bioeconomy Strategy, as outlined in Decree No. 12.044/2024. The decree defines bioeconomy as a "productive and economic development model based on values of justice, ethics, and inclusion, capable of generating products, processes, and services efficiently, with the sustainable use, regeneration, and conservation of biodiversity, guided by scientific and traditional knowledge, innovations, and technologies" (Brasil, 2024). This strategy seeks to improve Brazil's ability to capture value from its productive chains and foster sustainable regional development.

The Amazon, with its socio-economic diversity, presents specific challenges for applying a unified bioeconomy concept. The region includes areas with different types of land use and value chains operating under various models, each with distinct socio-environmental impacts (Ferreira et al., 2024). In response to this complexity, the State of Pará, through Decree No. 1.943/2021, established its State Bioeconomy Strategy. Although it does not define bioeconomy explicitly, it is structured around three thematic pillars: i) research, development, and innovation; ii) genetic heritage and associated traditional knowledge; iii) sustainable production chains and businesses (Pará, 2022).

The State Bioeconomy Plan of Pará defines bioeconomy as a "socioeconomic development opportunity that supports low-carbon production, promoting the transition to a diversified, fair, and inclusive economy aligned with science, technology, and innovation" (Pará, 2022). Reaching a consensus on the definition of bioeconomy is essential for effective public policy design and investment in promising chains and businesses. This is one of the goals of the project Technology Transfer Models for Development Routes Linked to Bioeconomy Productive Chains, supported by CNPq. The project aims to strengthen regional innovation ecosystems in the Amazon and Northeast Brazil through partnerships with internationally recognized groups.

The project's definition of bioeconomy incorporates three main conceptual perspectives: bioecological, biotechnological, and bioresource-based. It proposes tailoring the use of each perspective to align with local principles and characteristics (Vargas; Pinto; Lima, 2023; Bugge; Hansen; Klitkou, 2016).

2.3. O CONTEXTO DA BIOECONOMIA PORTUGUESA

The bioeconomy in Portugal is shaped by European policies promoting a sustainable and circular economy based on renewable biological resources. Portugal's biodiversity, geographic location, geomorphology, and land use patterns make it favorable for bioeconomic development, even though its context differs significantly from the Amazon.

According to the Bio-based Industries Consortium (BBI, 2021), Portugal's emerging bioeconomy sector already contributes nearly €20 billion to the national economy, with new opportunities for accelerating green economic growth. The country includes 22% of its territory in the Natura 2000 Network, a European Union initiative to protect biodiversity governed by the Birds Directive (2009/147/EC) and the Habitats Directive (92/43/EEC). Portugal is home to around 35,000 species of animals and plants—representing 22% of all described European species and 2% of the world's, according to the International Union for Conservation of Nature (Bioeconomy Plan, 2021).

The report Circular and Digital Bioeconomy by COTEC Portugal (Pintado; Rebelo; Ribeiro, 2019) states that bioeconomy accounts for 7% of Portugal's gross value added - about €12 billion - above the European average of 4.9%. The sector employs around 600,000 people, 13.3% of the country's total employment. The market share of biobased products in textiles, plastics, and construction is expected to reach 5% by 2030, potentially generating up to €579 million in annual revenue.

Portugal stands out in its primary sectors - forestry, agrifood, fishing, and aquaculture - as well as industries like cork and leather. These sectors have strong local components and contribute significantly to the national economy. With the extension of its continental shelf, Portugal could expand its maritime area to 3.9 million km² - 40 times its land area - boosting its marine bioresource potential.

The report Strategic Guidelines for Primary Production Sectors in the Context of the National Strategy for a Sustainable Bioeconomy 2030 (GPP, 2021) identifies key areas for advancing bioeconomy

in Portugal. The country also has a significant forest area, supporting various industries such as wood, paper, and cork. Forest biomass valorization is a bioeconomy pillar, alongside agriculture, fishing, and the food industry. Portugal also explores algae and microalgae, which can yield high-value innovative bioproducts. Biorefineries play a vital role in converting biomass into products like energy, biofuels, bioplastics, and chemicals.

Thus, Portugal has significant potential to develop its bioeconomy by leveraging agricultural and forestry residues. Biotechnology is also a key catalyst in Portugal's bioeconomy, driving innovation in sustainable processes, products, and services.

2.4. INNOVATION ECOSYSTEMS IN REGIONAL DEVELOPMENT

Innovation ecosystems have evolved from the concept of National Innovation Systems (NIS), widely disseminated by the studies of Freeman (1987) and Lundvall (1992). An NIS consists of a set of public and private institutions whose interactions facilitate the production, dissemination, and utilization of new knowledge, being fundamental to a country's innovative and competitive capacity (Lundvall, 1992).

Innovation ecosystems expand on this idea by creating an environment in which various entities - such as businesses, universities, research centers, governments, and civil society - collaborate to promote innovation.

These ecosystems are characterized by advanced technological infrastructure, incentive policies, a qualified workforce, and a culture of cooperation (Carayannis; Campbell, 2012; Etzkowitz; Zhou, 2006).

Kanter (1994) defines innovation ecosystems as clusters of companies from different industries that, despite their distinct competencies, collaborate in complementary ways to create value for end users, transcending firms, sectors, and national borders. This interaction can be catalyzed by favorable sustainability contexts, which also support transitions toward a bioeconomy (Hansen & Coenen, 2015; Hellsmark et al., 2016).

While they share characteristics with value chains, innovation ecosystems go further by integrating inter-industry networks in which a broader range of actors co-create value. Examples include industrial symbiosis and circular economy solutions, where different sectors benefit from their mutual interactions.

3. METHODOLOGY

This study employed a qualitative approach that combined empirical analyses and theoretical reviews. The focus was on a comparative case study, aiming to examine specific examples of regional development policies oriented toward the bioeconomy in Portugal and the state of Pará, Brazil. The choice of comparative case studies, with a qualitative nature, was considered essential for gaining a more in-depth understanding of innovation ecosystems as general phenomena.

The research began with a literature review to identify and understand the key concepts and theories related to regional development, both from a neoclassical perspective and within the context of innovation ecosystems and the bioeconomy. This phase involved bibliographic and documentary research, including journal articles, books, legislation, policy documents, and government reports, in order to compile relevant information on the bioeconomy.

Subsequent data collection included the use of statistical sources from governmental institutions and international organizations. For Portugal, data were obtained from the World Bank, the Organisation for Economic Co-operation and Development (OECD), the Agency for Competitiveness and Innovation (IAPMEI), Eurostat, and the European Commission. For Brazil and the Western region of Pará, data were collected from the Institute for Applied Economic Research (IPEA), the Ministry of Science, Technology, Innovations and Communications (MCTIC), the Ministry of Development, Industry, Trade and Services (MDIC), the World Bank, and the Brazilian Institute of Geography and Statistics (IBGE).

The data set included both regional economic indicators and environmental and social indicators related to the bioeconomy. Specific variables analyzed included investment in research and development (R&D), bioproduct production, and environmental impact.

4. RESULTS AND DISCUSSION

4.1. BIOECONOMY STRATEGIES AND ACTION PLANS OF THE STATE OF PARÁ AND PORTUGAL

In the State of Pará, the State Bioeconomy Plan—known as PlanBio (PARÁ, 2022)—outlines several actions aimed at strengthening the bioeconomy. The main guidelines include: i) promoting research and technological development, encouraging innovation in production processes that use Amazonian biodiversity; ii) fostering sustainable value chains, valuing sociobiodiversity products and promoting the social and economic inclusion of local communities; iii) implementing practices that maximize natural resource use and minimize waste, promoting a more sustainable and integrated economy; and iv) strengthening governance structures and implementing public policies that support bioeconomy development, including tax incentives and training programs.

In contrast, Portugal's bioeconomy plan is part of a broader strategy to promote sustainable development and technological innovation across the country. This plan aligns with the European Union's guidelines for transitioning to a bio-based economy that reduces dependence on fossil resources and minimizes environmental impacts. According to Dolge et al. (2023), the goals of Portugal's Bioeconomy Plan include promoting sustainability through the responsible use of renewable biological resources, while ensuring the future availability of these resources and implementing sustainable agricultural and forestry practices to preserve biodiversity and natural ecosystems. Below are the strategic lines and key elements from the bioeconomy plans of Portugal and the state of Pará:

Table 1 | Strategic Bioeconomy Lines: Portugal and State of Pará

Strategic Lines	Portugal	State of Pará
Sustainable Agriculture	Promote sustainable farming practices	Implement agroforestry systems
Forests and Land Use	Manage forests sustainably	Restore degraded areas
Fishing and Aquaculture	Develop sustainable aquaculture	Expand sustainable fish farming
Bioindustries	Foster innovative industries	Create bioindustry hubs
Bioenergy	Invest in bioenergy sources	—
Bioproducts	Produce high-value-added bioproducts	Encourage bioproduct production
Biodiversity and Ecosystem Services	Protect biodiversity	Preserve Amazonian biodiversity
Education and Training	Train professionals in bioeconomy	Offer capacity-building courses
Research and Innovation	Foster research and innovation	Encourage research in bioeconomy
Governance and Policies	Develop public policies for bioeconomy	Develop state-level bioeconomy policies

Source: The authors

The actions taken in both Portugal and the state of Pará to promote the bioeconomy reflect distinct approaches based on their respective regional needs and characteristics. Portugal emphasizes broadly applied sustainable practices, while Pará focuses on specific strategies tailored to its context, such as implementing agroforestry systems and restoring degraded areas—both critical for Amazon conservation. Additionally, Pará's creation of bioindustry hubs leverages local biodiversity to drive regional economic development and the creation of innovative bioproducts.

Both locations emphasize biodiversity preservation and professional training, although Pará requires a stronger focus on environmental education and sustainability practices aligned with the Amazonian reality.

Table 2 | Bioeconomy Plans of the State of Pará and Portugal

Aspects	State of Pará Plan	Portugal Plan
Objectives	Sustainable development of the Amazon	Transition to a sustainable and circular economy
	Valuation and conservation of biodiversity	Efficient use of biological resources
	Shift from extractive model	Reduction of carbon emissions
Main Sectors	Sustainable agriculture	Forestry sector
	Silviculture	Agrifood sector
	Aquaculture	Fisheries and aquaculture
	Biotechnology	Biotechnology
Key Actors	Universities and research institutes	Universities and research institutes
	Companies and industries	Companies and industries
	Government and public institutions	Government and public institutions
	Civil society	Civil society
Strategies & Policies	Infrastructure development	Development of technology clusters
	Investment in education and training	Promotion of R&D and innovation
	Entrepreneurship incentives	Tax incentives and credit access
	Fiscal decentralization	Sustainability and environmental conservation policies
Incentives & Financing	Government subsidies	European Union funds
	Public-private partnerships	Robust tax incentives
	State and federal credit lines	Facilitated access to credit
R&D and Innovation	Biodiversity research projects	Advanced research centers
	Technological innovation incentives	International R&D collaboration
	Technology transfer	Continuous innovation programs

Source: The authors

Research and innovation are essential to both contexts, but in Pará, they must be directed toward the conservation and sustainable use of biodiversity. In terms of governance and public policies, developing strategies tailored to local specificities is vital for the success of bioeconomy initiatives. As such, Pará's strategy - more focused and oriented toward the sustainable use of Amazonian resources - can be considered more effective for regional development than Portugal's broader, more technology-driven approach.

However, Portugal's bioeconomy policy benefits from a mix of factors, including effective integration and coordination among universities, research centers, industry, and government. This collaboration is supported by the development of technology clusters and advanced infrastructure. Moreover, Portugal has robust financial resources, including European Union funding, enabling significant investment in R&D.

Portugal also has a longstanding tradition in the forestry, agrifood, and fisheries sectors, with well-regulated and established practices, which facilitates the transition to a bio-based economy (Silva; Marques, 2019). Furthermore, it offers a favorable regulatory environment, with tax incentives, subsidies, and access to financing that support the growth of the bioeconomy (European Commission, 2019).

In contrast, the state of Pará is in a transition phase - shifting from an extractive model to a knowledge-based and sustainable economy. It faces significant structural and financial challenges, particularly in remote areas of the Amazon. The region's infrastructure is less developed, and access to financial resources is limited (Pará, 2022). Its public policies and incentives are also less robust and often face bureaucratic and financial barriers, which reduce the level of support available for bioeconomy initiatives.

4.2. INNOVATION ECOSYSTEM ACTORS IN WESTERN PARÁ AND PORTUGAL

The following table presents a detailed comparison of the actors involved in the innovation ecosystems of Western Pará and Portugal, highlighting their roles and contributions to bioeconomy development. In Western Pará, academic institutions such as the Federal University of Western Pará (Ufopa) and the Federal Institute of Pará (IFPA) play crucial roles in education, research, and extension, helping train qualified professionals and develop innovative technologies. Local businesses and startups are essential for driving innovation and economic growth through the creation of new products and services.

The political system in Western Pará, represented by bodies such as the State Government of Pará (through Sectet[1] and Fapespa[2]) and the Municipal Government of Santarém (through GGI-DRS[3] and Semdec[4]), plays a fundamental role in promoting research and innovation, financing projects, and implementing public policies. Civil society, including NGOs and local cooperatives, is also key to sustainability promotion and community-based economic organization.

In Portugal, institutions such as the National Innovation Agency (ANI) and the National Institute for Agricultural and Veterinary Research (INIAV) are pivotal in promoting applied research and business innovation. Portuguese civil society, represented by organizations like Quercus and various cooperatives, also contributes significantly to environmental conservation and the promotion of sustainable practices.

1 Secretariat of Science, Technology, and Higher, Professional, and Technological Education of the State of Pará.
2 Amazon Foundation for the Support of Studies and Research of Pará.
3 Integrated Management Group for Sustainable Regional Development.
4 Municipal Secretariat of Planning, Economic Development, Industry, Commerce, and Technology of Santarém, Pará.

Table 3 | Innovation Ecosystem Actors in Western Pará and Portugal

Sector	Pará – Actors and Roles	Portugal – Actors and Roles
Government	**State Secretariats**: Promote research, innovation, project funding, and public science and technology policy development.	**Innovation Agencies & Ministries**: Foster business innovation and manage R&D funding programs.
	Technical Assistance and Rural Extension Company (EMATER): Rural extension, technical assistance and agricultural technologies development.	**National Institute of Agricultural and Veterinary Research (INIAV)**: Applied research in agriculture and livestock.
	Municipal Governments: Implement integrated public policies.	**City Councils**: Local public policy implementation.
	The "S" System: Support for SME entrepreneurship and industry innovation.	**IAPMEI / Agency for Competitiveness and Innovation (COTEC Portugal)**: Support for SME competitiveness and innovation.
Academia & R&D	**Federal University of Western Pará (Ufopa), Federal Institute of Pará (IFPA)**: Teaching, research, extension, innovation projects.	**Lisbon School of Economics & Management (ISEG ULisboa), NOVA Lisbon**: Teaching, applied research, partnerships with industry.
	Brazilian Agricultural Research Corporation (EMBRAPA): Research in sustainable agriculture and livestock.	**Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB UTAD)**: Applied research agriculture and livestock
		Higher Institute of Agronomy (ISA ULisboa): Research and development in the forestry sector; promoting sustainability and innovation.
	National Institute for Amazonian Research (INPA): Scientific research on the Amazon, sustainable tech and practices development.	**University of Évora, Faculty of Science and Technology of the University of Coimbra (FCTUC)**: Research collaboration with industries.
Business	**Santarém Business and Commerce Association (ACES)**: Local development, business support.	**Portuguese Startups**: innovative product/ service development.
	Local Businesses & Startups: innovative product/service development.	
Civil Society	**Bioeconomy-focused NGOs**: entrepreneurship and economic development.	**Environmental NGOs**: Conservation, environmental advocacy, sustainability education.
	Associations and Cooperatives: Support small producers, solidarity economy, market and technology access.	**Portuguese Cooperatives and associations**: Support small producers, solidarity economy, promote sustainable agricultural and business practices.

Source: The authors

The innovation ecosystem in Western Pará faces several structural challenges, including the scarcity of innovation environments, research centers, and consistent investment in R&D - all crucial for generating innovative technologies in the region. Moreover, the formation and retention of qualified human capital is limited, especially in remote areas, which makes implementing complex innovation projects difficult (CGEE, 2018; Homma, 2022).

The interaction between universities, businesses, and government - known as the Triple Helix model - remains underdeveloped in Western Pará. This collaboration is vital for fostering innovation, facilitating knowledge flow, and promoting the adoption of new technologies and production processes. However, the lack of consistent public policies, a cooperation culture, and fiscal incentives hinders the establishment of a robust innovation ecosystem in the region. Nevertheless, despite these obstacles, Western Pará's innovation ecosystem holds great development potential. Key local actors - such as universities, bioproduct companies, development banks, government agencies, NGOs, and civil associations - can be mobilized. The main gaps include lack of coordination among actors, limited integration with other regional ecosystems, and the absence of a shared vision for regional development.

These institutions are essential for strengthening the bioeconomy through innovation because of their capacity to promote sustainable development by integrating scientific research, technological development, and practical applications in key sectors. Institutions like Ufopa, IFPA, Embrapa, and INPA play vital roles in knowledge generation and the training of professionals to meet bioeconomy challenges. They not only develop new technologies and sustainable practices but also serve as intermediaries in transferring innovations to the production sector, enhancing economic and environmental impact in the region.

Portugal's innovation ecosystem is characterized by its relative homogeneity and the expansion of centers of excellence beyond major urban hubs such as Lisbon and Porto. A notable example is Biocant Park, a biotechnology park located in Cantanhede, which stands out as an innovation hub outside traditional centers (Simão, 2016; Relatório CAP, 2023). Biotechnology and bioeconomy are deeply interconnected in Portugal and have been key drivers of innovation and sustainability (European Commission, 2012).

In 2019, Portugal had 98 companies focused primarily on R&D in biotechnology, employing over 600 workers and generating more than €36 million in revenue (P-BIO, 2019). Additionally, 116 companies engaged in biotech R&D as a secondary activity, demonstrating a diversified and growing sector. The proximity of these companies to universities and research centers reflects a strong connection between academia and industry, which is essential for fostering innovation (Relatório CAP, 2023).

The Portuguese ecosystem comprises a network of companies, universities, research institutions, government bodies, support organizations, and nonprofits, aiming to promote sustainable development and competitiveness through bio-based innovation (Simão, 2016; Relatório CAP, 2023; European Commission, 2012). Startups and small companies based in tech parks at the University of Porto and at ULisboa, and institutions such as the Institute of Molecular and Cell Biology (IBMC) at ULisboa and the Institute of Chemical and Biological Technology (ITQB) at NOVA stand out.

Entities such as the Portuguese National Innovation Agency (ANI) and the National Institute of Agricultural and Veterinary Research (INIAV) are essential to promoting business innovation and creating an environment conducive to advanced technology development in Portugal. These institutions provide funding for R&D projects, encourage collaboration between companies and research centers, and implement public policies that enhance competitiveness and sustainability. By strengthening cooperation among government, academia, industry, and civil society in both Western Pará and Portugal, these institutions ensure robust innovation ecosystems that advance the bioeconomy and promote sustainable economic growth and environmental conservation.

4.3. BIOECONOMY BENCHMARKING IN PORTUGAL

According to the report Mapping Portugal's Bio-Based Potential (BBI, 2021), the main drivers of the Portuguese economy include the agri-food, forestry, marine (fisheries, algae, and aquaculture), and chemical industries. Within the bio-based processing sectors, the food and beverage industry, pulp and paper, and wood processing industries stand out as leaders in terms of production value.

The report on Circular and Digital Bioeconomy by IAPMEI (2024) highlights exemplary practices in Portugal's bioeconomy. These include the wood industry, which excels in wealth creation across the supply and usage chain; the bio-based textile industry, which contributes to the national economy through the production of textiles made from biological materials; and the development of new biomaterials and bioproducts derived from forest resources, with applications in construction, textiles, and plastics. In addition, food biotechnology has driven innovation in the food sector through the development of new bioactive and functional ingredients sourced from olive oil industry residues. The recycling and reuse industry focuses on waste reduction and enhanced sustainability, while sustainable construction uses biomaterials to foster circular economy practices and competitiveness in key sectors.

The blue economy is highlighted as a strategic sector in Portugal, encompassing a wide range of activities related to marine and coastal resources and promoting economic growth, social inclusion, and environmental sustainability (Choudhary et al., 2021). This sector includes fisheries and aquaculture, which are evolving through more sustainable practices; coastal and maritime tourism, which is undergoing a sustainable transformation; renewable marine energy, with increasing investments in wave and offshore wind energy; and marine biotechnology, which explores new products derived from marine organisms for pharmaceutical, cosmetic, and food applications.

Portugal's primary and processing sectors generate significant flows of bio-based residues, especially during the transformation phases. The pulp and paper industry is the largest producer of residual biomass, followed by the food and beverage industries. According to the OECD (2023), less than 1% of these residues are used for energy production, while 82% are recovered for low-value applications and 18% are discarded. There is a potential of over 1 million tons of waste that could be converted into high-value bio-based operations, adding greater value across multiple sectors (OECD, 2023).

Portugal has made substantial advances in bioeconomy research, particularly in municipalities with high volumes of bio-waste - estimated at 2.7 million tons in 2018, of which approximately 38% went to landfills. As landfill use is progressively reduced, this waste is increasingly being redirected toward value-added applications in the bio-based industry (OECD, 2023).

Biotechnology in Portugal has grown with strong support for high-tech startups and university spin-offs, along with participation in EU-funded projects that utilize biomass as raw material and employ biotechnologies. One such example is the MULTI-STR3AM project, which received €6.6 million to demonstrate a model for microalgae production (IAPMEI, 2024).

In the Douro Valley, modern viticulture techniques, aligned with bioeconomic principles, have enhanced grape production and quality while preserving genetic resources. Vine conservation programs - including varietal cataloging and germplasm banks - are fundamental to this process (Sampaio et al., 2024). Additionally, the management of agri-food waste, focusing on thermochemical processes and circular bioeconomy principles, emphasizes the reuse of by-products as valuable resources, promoting sustainability and circularity (Bento et al., 2024).

Another relevant example is the management of genetic diversity in chestnut trees in Portugal, using molecular markers to preserve genetic variability and improve nut production, which faces both climatic and economic challenges (Braga et al., 2023; Barros, 2024).

Bioeconomy also plays a significant role in the management of planted forests, which are increasingly viewed as a solution to climate change challenges and the transition to a circular economy. Forest-based products offer renewable and sustainable alternatives to petrochemical-based products, contributing to the reduction of greenhouse gas emissions (Barros, 2024; Bioeconomy Plan, 2021).

Lastly, the Alentejo region stands out for its agroforestry and agro-industrial production, which generates biomass residues with the potential for conversion into new products. Regional development policies have promoted sustainable technologies for the valorization of this biomass, contributing to the emergence of a robust bioeconomy (Rijo et al., 2023; Abreu et al., 2020; Cardoso et al., 2021).

Collaboration with Portuguese institutions could provide technical expertise, management methodologies, and innovative business models tailored to the specific context of the Amazon. One promising example is the partnership with the Group for Research in Systems Interoperability (UNINOVA/GRIS at NOVA), which manages one of Portugal's Digital Innovation Hubs[5] (DIHs). This collaboration aims

5 Digital Innovation Hubs (DIHs) are collaborative networks that encompass centers of expertise in specific digital competencies, aimed at promoting the dissemination and adoption of advanced digital technologies by businesses—particularly small and medium-sized enterprises (SMEs)—through the development, testing, and experimentation of those technologies.

to develop a pilot for the Amazon Bioeconomy Hub (PABI) to be implemented by Ufopa. The project will enable cooperation with DIHs, facilitating knowledge exchange and best practices, particularly in the areas of "test-before-invest" approaches and solving environmental challenges specific to the region.

Such partnerships could also enhance access to international funding, research networks, and global commercial partners and markets, promoting technology transfer and the training of local human resources. The exchange of experiences and the implementation of joint projects could accelerate the development of innovative solutions to the region's socioeconomic and environmental challenges, in alignment with the principles of sustainable bioeconomy (Nobre, 2019).

5. CONCLUSION

The objective of this study was to identify strategies for the regional development of Pará, a Brazilian state located in the Amazon, through a benchmarking analysis of innovation ecosystems focused on the bioeconomy in both the Brazilian Amazon and Portugal. This article contributes to the literature by presenting: (i) the state of the art on regional development, the economy, and innovation ecosystems; and (ii) the establishment of a typology that addresses the research's central questions.

A crucial consideration in comparing the two regions is that Portugal benefits from an established network of research and funding among ecosystem actors, largely due to consolidated European funds. In contrast, the Amazon region exhibits lower territorial governance and a broader, more fragmented network of actors within its innovation ecosystem.

On one hand, the European bioeconomy has gained prominence, particularly following the 2018 EU Bioeconomy Strategy (European Commission, 2018) and the European Green Deal (European Commission, 2019), which place the bioeconomy at the heart of political agendas to foster sustainable and circular development. On the other hand, Brazil's context highlights specific missions related to the country's broader industrial revitalization. According to Brasil (2024), the Action Plan for Neoindustrialization—Missions of the New Industrial Policy—positions the Nova Indústria Brasil (NIB) as an industrial policy framework built on six strategic missions. This framework aims to address structural challenges and promote sustainable industrial development, with an estimated investment of R$300 billion. Within the scope of this article, the plan includes goals such as economic decarbonization, bioeconomy, circular

economy, carbon market regulation, and forest conservation.

The article posits that, given these characteristics, public policies, regulatory frameworks, and financing instruments for regional development through the bioeconomy play a central role in supporting production chains and the companies that operate within them. These mechanisms include a diverse set of financial tools: non-repayable grants, capital investments via venture capital or private equity funds targeting specific strategic goals, university-led research, technical assistance, and government procurement policies that stimulate the bioeconomy innovation ecosystem. Additionally, integration into the European single market offers expanded market opportunities for these products.

There is no doubt about the magnitude of the bioeconomy industry in the Amazon and its potential as a sustainable regional development strategy. The region already exports more than seventy products - some of them manufactured - despite facing limitations such as restricted financing, underdeveloped industrial plants, limited financial sector engagement, and bottlenecks in infrastructure and taxation systems. In contrast, Portugal's bioeconomy has evolved based on biological resources and biotechnology, and is increasingly integrated into national policies and practices to promote sustainability, reduce fossil dependency, and mitigate climate change. Although not highly diversified, Portugal's bioeconomy includes sectors that use biological resources - such as agriculture, fisheries, and forestry - as well as industrial sectors producing bioproducts, bioenergy, and biotechnological innovations.

This research provided a stronger theoretical foundation and helped generate greater academic interest in the concepts examined. It encouraged further investigation into the topic, despite limitations in the breadth of existing publications - particularly due to a narrow base of available studies. Notably, the number of relevant publications has increased over the past three years. This work, therefore, offers a contribution to the conceptual and thematic literature, serving as an exploratory basis for future research.

The findings of this study do not lead to definitive conclusions. Rather, they underscore the need for additional lines of inquiry, which should be developed through continued academic and policy dialogue. These future research paths may give rise to policies that incorporate a range of themes, including education, innovation, and innovation policy.

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