CHALLENGES FACED BY THE CHEMICAL INDUSTRY IN STRENGTHENING THE BIOECONOMY IN BRAZIL

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ABSTRACT

Objective: This study aims to discuss the chemical industry's role in developing new bioeconomic systems in Brazil.

Theoretical Framework: The bioeconomy provides significant opportunities for Brazil. By exploring the country's biodiversity and environmental resources, bioeconomic systems can drive the development of innovative technologies and high-value products across various sectors. Additionally, the bioeconomy plays a crucial role in generating quality employment and preserving ecosystems. Achieving this optimistic scenario depends on the efforts of the Brazilian chemical industry in research and development (R&D).

Method: This research is documental and descriptive. We reviewed several sectoral reports focusing on the obstacles to using renewable inputs from Brazilian biodiversity in the chemical sector's value chains.

Results and Discussion: Brazil's bioeconomy systems face limited R&D investments due to structural bottlenecks related to the national tax system, logistical infrastructure, and high energy costs. These issues have reduced the competitiveness of the Brazilian chemical industry. Furthermore, increased imports of Chinese chemical products following the Ukraine War and the subsequent industry idleness can exacerbate these structural constraints and further erode the chemical sector's R&D funds.

Research Implications: The structural problems described in this article can delay the development of renewable energy sources and innovative bioproducts.

Originality/Value: We show that the chemical industry possesses the technology and scale necessary to integrate into Federal Government programs in the bioeconomy field. However, the sector's structural problems and low R&D investments tend to inhibit the development of new bioeconomic systems. Brazil must overcome these challenges to establish itself as a global bioeconomy powerhouse.

Keywords: biodiversity, chemical products, research and development, structural bottlenecks

OS DESAFIOS ENFRENTADOS PELA INDÚSTRIA QUÍMICA NO FORTALECIMENTO DA BIOECONOMIA NO BRASIL

RESUMO

Objetivo: Discutir o papel da indústria química no desenvolvimento de novos sistemas bioeconômicos no Brasil.

Referencial Teórico: A bioeconomia oferece grandes oportunidades para o Brasil, mediante o uso da biodiversidade e dos recursos naturais para desenvolver tecnologias inovadoras e produtos de alto valor. A
bioeconomia também é importante para geração de empregos e para preservação de ecossistemas. O sucesso da bioeconomia depende, contudo, dos esforços de pesquisa e desenvolvimento (P&D) da indústria química.

**Método:** A pesquisa é documental e descritiva, com revisão de relatórios setoriais sobre os obstáculos ao uso de recursos da biodiversidade brasileira nas cadeias produtivas da indústria química.

**Resultados e Discussão:** O baixo nível dos investimentos em P&D nos sistemas bioeconômicos brasileiros resulta de gargalos estruturais, como o sistema tributário, a infraestrutura logística deficiente e os altos custos de energia. Esses gargalos reduzem a competitividade da indústria química. Ademais, o aumento das importações de produtos químicos chineses após a Guerra da Ucrânia e a crescente ociosidade do setor tendem a agravar tais entraves e a corroer ainda mais as fontes de P&D da indústria química.

**Implicações da Pesquisa:** Os problemas estruturais descritos neste artigo atrasam o desenvolvimento de novas fontes de energia e de bioproductos inovadores.

**Originalidade/Valor:** O estudo mostra que a indústria química tem potencial tecnológico para apoiar os programas de bioeconomia do governo. Contudo, os seus problemas estruturais e os baixos investimentos em P&D inibem o desenvolvimento dos sistemas bioeconômicos. O Brasil precisa superar esses desafios para se estabelecer como uma potência global em bioeconomia.

**Palavras-chave:** Biodiversidade, Produtos Químicos, Pesquisa e Desenvolvimento, Gargalos Estruturais.

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**LOS DESAFÍOS DE LA INDUSTRIA QUÍMICA PARA EL FORTECIMIENTO DE LA BIOECONOMÍA EN BRASIL**

**RESUMEN**

**Objetivo:** Este estudio discute el papel de la industria química en el desarrollo de sistemas bioeconómicos en Brasil.

**Marco Teórico:** La bioeconomía presenta grandes oportunidades para Brasil mediante el uso de su biodiversidad y recursos ambientales, permitiendo la creación de tecnologías innovadoras y productos de alto valor agregado. Además, la bioeconomía es crucial para la generación de empleo y la conservación de ecosistemas. Sin embargo, su éxito depende de los esfuerzos de investigación y desarrollo (I+D) de la industria química brasileña.

**Método:** La investigación es documental y descriptiva, basada en la revisión de informes sectoriales sobre los obstáculos al uso de la biodiversidad brasileña en la industria química.

**Resultados y Discusión:** Las inversiones en I+D en bioeconomía son bajas debido a problemas estructurales como el sistema tributario nacional, la infraestructura logística deficiente y los altos costos energéticos, lo que reduce la competitividad de la industria química. La guerra en Ucrania ha aumentado las importaciones de productos químicos chinos, exacerbando estos problemas y erosionando las fuentes de I+D.

**Implicaciones de la investigación:** Los problemas estructurales descritos en este artículo ralentizan el desarrollo de fuentes de energía renovables y bioproductos inovadores.

**Originalidad/Valor:** El estudio muestra que la industria química brasileña tiene el potencial tecnológico y la escala para apoyar los programas de bioeconomía del gobierno. No obstante, los problemas estructurales y las bajas inversiones en I+D inhiben el desarrollo de nuevos sistemas bioeconómicos. Brasil necesita superar estos desafíos para convertirse en una potencia global en bioeconomía.

**Palabras clave:** Biodiversidad, Productos Químicos, Investigación y Desarrollo, Obstáculos Estructurales.
1 INTRODUCTION

Discussions about climate change, new renewable energy sources, and global health conditions have become increasingly prominent. Despite the complexity of these challenges and the uncertainties surrounding their solutions, there is a firm conviction that transitioning from a petroleum-based energy matrix to a bioeconomy system is crucial for addressing many environmental problems (Bugge et al., 2016).

The bioeconomy utilizes renewable biological resources to produce food, inputs, bioproducts, bioenergy, and animal feed. These solutions benefit manufacturing, agricultural activities, and power generation (Dal Poz et al., 2022). According to Bugge et al. (2016), the concept of bioeconomy encompasses three main dimensions:

- **Biotechnology**: This dimension involves research and development (R&D) activities in human health and plant genetics.
- **Bioresources**: This dimension focuses on developing new biological raw materials and renewable sources for the industry, agriculture, and power sectors. It also involves establishing new value chains based on bioproducts.
- **Bioecology**: The final dimension encompasses ecological processes that can help rationalize energy use, reduce industrial and agricultural waste, and prevent soil degradation.

However, there is a perception that the second dimension mentioned above has been advancing slowly in North America. Devaney and Iles (2019) explain that one of the factors contributing to the low relevance of bioresources in the United States value chains is the increasing concentration of corporate investments in the exploitation of shale gas and the resulting supply of petrochemical derivatives rather than the development of new products from renewable sources. Similarly, a case study in Ontario, Canada, identified two key factors inhibiting investments in new value chains based on bioeconomic systems: i) weak integration among input sectors linked to the chemical industry and follow-on sectors that use biological resources; ii) lack of funding sources capable of jointly covering the downstream and upstream links of production chains (Mertens et al., 2019).

In the developed economies, the funding obstacles highlighted by Mertens et al. (2019) have recently declined. In 2019, the European Union (EU) introduced a new growth strategy for the continent known as the European Green Deal. This initiative comprises a comprehensive plan that spans all sectors of the economy, aiming to enhance resource efficiency, promote
circularity, reverse biodiversity loss, and mitigate climate change and pollution impacts. In this context, the bioeconomy plays a strategic role in meeting the ambitious goal of becoming the world’s first climate-neutral continent by 2050 (European Commission, 2019).

The EU funds research and development of sustainable, inclusive, and circular solutions based on renewable sources. From 2021 to 2027, the European Commission will allocate €10 billion for the Horizon Europe program for food, natural resources, and the bioeconomy (Ronzon and M’Barek, 2018). In 2022, the United States launched the National Biotechnology and Biomanufacturing Initiative, a two-billion-dollar program aimed at supporting the production of bio-based inputs and encouraging innovations in the fields of human health, renewable energy, and agriculture (Carrez and Rupp, 2023).

Discussions on funding sources and other obstacles to strengthening bioeconomic systems are highly relevant to Brazil. According to several reports, the country's abundant biodiversity provides significant opportunities for bioeconomy exploitation. The rational and balanced use of Brazil’s environmental resources can drive the development of innovative technologies and high-value products across various sectors. Additionally, the bioeconomy plays a crucial role in generating quality employment and preserving ecosystems. Achieving this optimistic scenario will demand substantial investments in R&D across several economic sectors, particularly in the national chemical industry (Instituto Escolhas, 2019; CNI, 2023).

Chemical products are crucial for meeting fundamental human needs, enhancing the quality of life, and sustaining our modern lifestyle. These reasons help to explain the increasing demand for these products (Galembeck et al., 2007). Simultaneously, the Brazilian chemical industry possesses the technological capabilities to develop biodiversity-based products (Wongtschowski, 2011). However, despite this recognition, a significant research question remains: What are the primary challenges the Brazilian chemical industry must address to contribute more effectively to local bioeconomic systems?

We aim to address this research question. Hence, our main objective is to discuss the Brazilian chemical industry's role in developing new bioeconomic systems. This research is documental and descriptive. In sum, we reviewed several sectoral reports focusing on the obstacles to using renewable inputs from Brazilian biodiversity in the chemical sector's production chains.

We structured this study as follows: Section 2 revisits and expands on the discussion initiated in this introduction regarding the potential applications of the bioeconomy for Brazil and the federal support programs for such activities. Section 3 presents the methodology. Following this, Section 4 discusses the primary obstacles to expanding the chemical industry's
R&D investments in new renewable sources and bioproducts from Brazilian biodiversity. Finally, Section 5 concludes the paper.

2 THEORETICAL FRAMEWORK.

2.1 UNLOCKING THE ECONOMIC POTENTIAL OF BIOECONOMY APPLICATIONS IN BRAZIL

In 2016, domestic sales within the Brazilian bioeconomy reached US$285.9 billion. Additionally, foreign economic activities related to local biodiversity contributed US$40.2 billion, bringing the total to US$326.1 billion (Silva et al., 2018). Looking ahead to the coming decades, the Associação Brasileira de Bioinovação (ABBI) projects that by 2040, industrial biotechnology - one segment of the bioeconomy - could contribute an additional US$53 billion annually to the Brazilian economy. Of this, 37% is expected to come from second-generation ethanol production, while 63% will be derived from cellulose-based bioproducts (Oliveira, 2020).

The latest report by ABBI (2022) identifies the energy transition as a crucial opportunity for the chemical industry. This transition encompasses the generation of energy from biomass, the advancement of biorefineries\(^5\), and the replacement of fossil-based raw materials with renewable sources. This study emphasizes that conventional industrial chemical processes are significant energy consumers, while processes utilizing renewable sources demand less energy than traditional methods.

It is essential to recognize the potential of biorefineries for biofuel production using major agricultural commodities like soybeans and sugarcane. One significant advantage of biorefineries is their regional scope. Unlike fossil fuel refineries, biorefineries do not require massive investments in petrochemical hubs or complex distribution logistics (ABBI, 2022).

Regarding the economic potential of Brazilian biodiversity, a study coordinated by the Instituto Escolhas has identified the most promising activities for developing sustainable bioeconomic systems in the Amazon region. The combined sectors of food, beverages, and cosmetics have the potential to create 218,000 jobs and attract approximately R$7.15 billion in...
private investments over ten years (Instituto Escolhas, 2019). The report "New economy of the Amazon" predicts that by 2050, the GDP generated by the bioeconomy will reach R$38.5 billion, creating 950,000 jobs in the Amazon region (Nobre et al., 2023).

Estimates like these bolster the propositions outlined in the document "Bioeconomia e a Indústria Brasileira" (CNI, 2020). According to the document, Brazil stands out as one of the global players best positioned to advance sustainable development through the bioeconomy, thanks to its abundant natural resources. However, the study identifies several critical areas that urgently require improvement for the country to develop its bioeconomy effectively. These problems include regulatory issues, scientific and technological development support systems, and limited credit sources available for R&D investments.

CNI (2020) propositions have had a significant impact, inspiring the launch of the "Programa de Cadeias Produtivas da Bioeconomia" by the Ministério da Ciência, Tecnologia e Inovação (MCTI) and the "Programa Nacional de Bioinsumos" by the Ministério da Agricultura e Pecuária (MAPA). The MCTI-sponsored program aims to stimulate scientific research and technological development, enhance the value of Brazilian biodiversity's value chains, and improve the quality of life for populations dependent on these chains. Initially, the program focused on three pilot projects in the Amazon region, targeting the production chains of açaí, cupuaçu, and pirarucu, with a combined budget of 5.6 million Brazilian reals.

The National Program for Bio-inputs aims to explore Brazil's biodiversity to develop new biofertilizers, inoculants, plant nutrition products, and natural pesticides for pest control. The program hopes to increase rural producers' income and quality of life and reduce Brazil's reliance on imported agricultural inputs. The MCTI and MAPA will strengthen their support programs for the bioeconomy in the coming years with additional funds from three new government initiatives. Decree 12.044/2024 of June 5, 2024, establishes the “Estratégia Nacional de Bioeconomia” (Presidência da República, 2024), which aims to:

1. Promote national, regional, and local development through the sustainable use of biological resources to contribute to the population's water, food, and energy security.

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6 "Bioeconomia e a Indústria Brasileira" (Bioeconomy and the Brazilian Industry)
7 "Programa de Cadeias Produtivas da Bioeconomia" (Bioeconomy Production Chains Program)
8 MCTI: Ministry of Science, Technology and Innovation (Ministério da Ciência, Tecnologia e Inovação). MCTI Ordinance No. 3.877/2020
9 "Programa Nacional de Bioinsumos" (National Program for Bio-inputs).
11 “Estratégia Nacional de Bioeconomia” (National Bioeconomy Strategy).
2. Promote the forest and socio-biodiversity, with an emphasis on increasing the participation in markets and income for traditional communities, and small farmers.
3. Strengthen the competitiveness of national biological-based production, particularly Brazilian biodiversity, in transitioning to a low-carbon and climate-resilient economy.
4. Develop innovation ecosystems, scientific and technological knowledge, and entrepreneurship.
5. Develop the National System of Information and Knowledge about the Bioeconomy.
6. Propose the creation and direction of financial and economic instruments to stimulate and promote the bioeconomy.
7. Expand the integration of bioeconomy products into national markets and global value chains.

The Brazilian Chamber of Deputies is discussing Complementary Law (PLP) 150/22 in 2024. This bill aims to establish new funding sources for the "Política Nacional de Bioeconomia" 12 by redirecting resources from the “Fundo Nacional Sobre Mudança do Clima”13. Additionally, a joint program involving three public entities - the Ministério do Desenvolvimento e Assistência Social, Família e Combate à Fome (MDS14), Ministério do Meio Ambiente e Mudança do Clima (MMA15), and Ministério do Desenvolvimento Agrário e Agricultura Familiar (MDA16) - has the initial goal of supporting 200 bioeconomy businesses by 2024 (MMA, 2024).

3 METHODOLOGY

This research is documental and descriptive. We reviewed several sectoral reports focusing on the obstacles to using renewable inputs from Brazilian biodiversity in the chemical sector's value chains.

12 “Política Nacional de Bioeconomia” (National Bioeconomy Policy).
13 “Fundo Nacional Sobre Mudança do Clima” (National Climate Change Fund).
14 MDS: Ministry of Social Development and Assistance, Family, and Fight Against Hunger (Ministério do Desenvolvimento e Assistência Social, Família e Combate à Fome).
15 MMA: Ministry of the Environment and Climate Change (Ministério do Meio Ambiente e Mudança do Clima).
16 MDA: Ministry of Agrarian Development and Family Agriculture (Ministério do Desenvolvimento Agrário e Agricultura Familiar).
4 RESULTS AND DISCUSSIONS.

4.1 THE ESCALATING TRADE DEFICIT IN THE BRAZILIAN CHEMICAL INDUSTRY

In 2013, the Banco Nacional de Desenvolvimento Econômico e Social (BNDES) sponsored a study titled "Estudo do potencial de Diversificação da Indústria Química Brasileira". This study categorized the chemical industry into 66 segments based on technological complexity. It analyzed the trade balance of each segment, covering 57% of the industry's imports and exports in 2012. The 21 technology-intensive segments, with higher added value, generated a trade deficit of 8.9 billion dollars in 2012, accounting for 72% of the total deficit reported (Bain & Company, 2014).

The situation described by Bain & Company (2014) deteriorated significantly in the decade following their study. As shown in Table 1, the chemical products trade balance recorded a deficit of US$63 billion in 2022, reflecting a 96.88% increase over the decade. This substantial deficit growth resulted from stable export revenues at 2013 levels, while imports of chemical products nearly doubled between 2021 and 2022.

Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Exports (in billion USD)</th>
<th>Imports (in billion USD)</th>
<th>Trade Deficit (in billion USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>14.2</td>
<td>46.1</td>
<td>-31.9</td>
</tr>
<tr>
<td>2014</td>
<td>14.5</td>
<td>45.7</td>
<td>-31.2</td>
</tr>
<tr>
<td>2015</td>
<td>12.8</td>
<td>38.3</td>
<td>-25.5</td>
</tr>
<tr>
<td>2016</td>
<td>12.1</td>
<td>34.2</td>
<td>-22.1</td>
</tr>
<tr>
<td>2017</td>
<td>13.7</td>
<td>37.2</td>
<td>-23.5</td>
</tr>
<tr>
<td>2018</td>
<td>13.7</td>
<td>43.3</td>
<td>-29.6</td>
</tr>
<tr>
<td>2019</td>
<td>12.7</td>
<td>44.1</td>
<td>-31.4</td>
</tr>
<tr>
<td>2020</td>
<td>11.0</td>
<td>41.4</td>
<td>-30.4</td>
</tr>
<tr>
<td>2021</td>
<td>14.5</td>
<td>60.7</td>
<td>-46.2</td>
</tr>
<tr>
<td>2022</td>
<td>17.3</td>
<td>80.3</td>
<td>-63.0</td>
</tr>
<tr>
<td>2023</td>
<td>14.9</td>
<td>61.9</td>
<td>-47.0</td>
</tr>
</tbody>
</table>

Note: Adapted from data provided in ABIQUIM (2023, p.9).

In 2023, the significant drop in international prices of chemical products led to a decrease in the national industry's trade deficit to US$47 billion. However, the physical deficit

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17 BNDES: Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social).
18 "Estudo do potencial de Diversificação da Indústria Química Brasileira" (Study on the potential for diversifying the Brazilian chemical industry).
19 In 2023, some chemical industry segments experienced international prices up to 30% lower than their historical averages (Fontes, 2024).
in product tonnage increased by 8.3% compared to 2022 (ABIQUIM, 2023). As a result, imported chemical and petrochemical products, mainly from China and the USA, accounted for a record 47% share of Brazilian domestic demand in 2023 (Fontes, 2024).

The period covered in Table 1 coincides with the revitalization of the US petrochemical complex due to shale gas exploration (Devaney and Illes, 2019). As a result, some American products, such as resins, began to be offered in Brazil at prices lower than local production costs, contributing to the growing imports described in Table 1. Another significant factor driving the expansion of the trade deficit was the rise of the Chinese chemical industry in the 21st century. As shown in Table 2, in just 20 years, China became the world's largest producer of chemicals, surpassing the combined production of the United States and Europe in 2022.

Table 2

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Global</td>
<td>1352</td>
<td>100%</td>
<td>5434</td>
<td>100%</td>
<td>402%</td>
</tr>
<tr>
<td>USA</td>
<td>338</td>
<td>25%</td>
<td>606</td>
<td>11%</td>
<td>179%</td>
</tr>
<tr>
<td>European Union (EU27)</td>
<td>363</td>
<td>27%</td>
<td>760</td>
<td>14%</td>
<td>209%</td>
</tr>
<tr>
<td>China</td>
<td>122</td>
<td>9%</td>
<td>2390</td>
<td>44%</td>
<td>1959%</td>
</tr>
<tr>
<td>Latin America</td>
<td>50</td>
<td>4%</td>
<td>193</td>
<td>4%</td>
<td>386%</td>
</tr>
</tbody>
</table>

Source: European Chemical Industry Council (CEFIC).

The surge in Brazilian imports of chemical products aligns with the onset of the Ukraine War in February 2022. As a direct consequence of this conflict, the Chinese chemical industry, already the world leader in the 2010s, gained access to Russian gas and oil at significantly lower prices than those on the international market. This cost reduction occurred alongside a slowdown in domestic Chinese consumption due to the real estate crisis triggered by the bankruptcy of the Evergrande company. In response, the Chinese chemical industry redirected the surplus from its massive production to the international market. According to Fontes (2024), in some cases, a kilogram of Chinese chemical products is being offered in Brazil at a price three times lower than similar American products, which were already more affordable than domestically manufactured products.

These events have plunged the national chemical industry into an unprecedented crisis. Due to the increasing influx of Chinese chemical and petrochemical products in the Brazilian market, the sector is experiencing one of the highest rates of idleness in its history in 2024, with some segments operating at around 40% of installed capacity (Fontes, 2024). Considering that some imported chemical products arrive in Brazil, often at prices lower than those in their...
countries of origin, domestic producers have requested temporary increases in import tariffs for
dozens of chemical products from the Chamber of Foreign Trade, with some tariff asks reaching
up to 35%.

Furthermore, broader issues are likely to exacerbate the current concerns raised by the
Ukraine War. The Brazilian chemical industry has lost ground to imported products for several
decades. Consequently, the sector's chronic trade deficits and its loss of competitiveness in both
domestic and international markets are also attributable to long-standing structural problems
that remain unaddressed (Zanatta, 2022). Section 4.2 outlines these bottlenecks, while Section
5 discusses the obstacles they may pose to developing new renewable sources and inputs
derived from Brazilian biodiversity.

4.2 STRUCTURAL CHALLENGES CONFRONTING THE BRAZILIAN CHEMICAL
INDUSTRY

The study "Um Outro Futuro é Possível: Perspectivas para o Setor Químico no Brasil" highlights the main challenges affecting the competitiveness of the national chemical industry. These challenges include high raw material costs, which account for up to 80% of a petrochemical plant's production expenses, and energy costs, which account for around 20%. Additionally, the industry faces the complexities of the tax system, inefficiencies in existing infrastructure, and the bureaucratic business environment in Brazil (Deloitte, 2018).

Considering these challenges, high energy costs continue to impact the competitiveness
of the Brazilian chemical industry. In 2024, the chemical sector's natural gas price was US$14
per million BTUs (British Thermal Unit), significantly higher than the US average of US$2 per
million BTUs (Fontes, 2024).

Alongside these energy-related issues, logistic costs have historically strained the
profitability of the chemical industry. According to Deloitte (2018), from 2015 to 2018, these
costs in Brazil increased by 7.4%, resulting in a total expenditure of R$15.5 billion for
companies. Most logistic costs (63.5%) stem from transportation activities, which rely heavily
on a road network that lacks quality. Furthermore, recurrent cycles of currency depreciation
negatively impact supply chain logistics due to the need to import specific chemical compounds

20 "Um Outro Futuro é Possível: Perspectivas para o Setor Químico no Brasil" (Another Future is Possible: Perspectives for the Chemical Industry in Brazil).
quoted in foreign currency. Additionally, the depreciation of the local currency tends to increase the cost of equipment and technological fees from other countries.

The high costs of raw materials, logistics, and energy erode the competitiveness of the Brazilian chemical industry, adversely affecting companies' profitability and the sector's attractiveness. Consequently, low profitability limits internal resources available for financing R&D investments. From 2010 to 2018, R&D expenses accounted for only 0.7% of the Brazilian chemical industry's revenue (Deloitte, 2018). In contrast, the average R&D investment in the United States from 2014 to 2018 was 2%, with the specialty chemicals segment reaching 3% (ACC, 2019). Similarly, the European Union's average R&D investment from 2009 to 2018 was 2% of sales, totaling 10 billion euros in 2018 (CEFIC, 2020).

Globally, the chemical industry falls under medium-high-intensity sectors for R&D activities, with a weighted R&D allocation rate of 6.52% of Gross Value Added (Galindo-Rueda, 2016). Therefore, R&D investments are crucial for ensuring the industry's future and enhancing its role in addressing society's environmental challenges21.

Simultaneously, R&D investments are crucial to avoid the risk of commoditization, a concern that has plagued the industry for over a decade. A study published in 2014 by Roland Berger Consulting highlights the efforts of various chemical companies to differentiate themselves from the competition and escape the commoditization trap. Despite these efforts, 69% of the companies participating in the study had already experienced commoditization of their products, more intensely in the budget/low-end segments and less in the premium segments. One alternative to overcome the commoditization trap is the development of specialty chemicals. However, it is essential to consider that as one moves toward the final consumer in value chains, regulatory requirements intensify, making regulatory issues increasingly significant in new product projects (Zollenkopf and Rinn, 2014).

The Brazilian chemical industry supplies essential inputs for various products, including food, cosmetics, pharmaceuticals, lubricants, and biofuels. Consequently, chemical companies must engage with numerous government agencies and regulatory bodies. This complex regulatory landscape raises significant challenges and barriers to developing chemical compounds, particularly innovative bioproducts (Zanatta, 2022).

The chemical industry faces significant challenges due to regulatory complexity and tax uncertainties, which impact its competitiveness and business environment. Recent authoritative

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21 The chemical industry is pivotal in providing sustainable innovations to downstream sectors through its products, inputs, and technologies (Zanatta, 2022).
decisions have created confusion regarding the federal taxes owed by the chemical industry, particularly conflicting decrees about the continuation of the Regime Especial da Indústria Química (REIQ\textsuperscript{22}). The REIQ exempts the industry from paying 2.19\% of PIS/Cofins on essential input acquisitions, and the uncertainty surrounding its status poses additional hurdles for the sector.

In March 2021, the Federal Government issued a decree that abolished the REIQ. At that time, a study sponsored by Associação Brasileira da Indústria Química (ABIQUIM\textsuperscript{23}) estimated that this measure would lead to a 5.4 percentage point drop in production, threatening 85,000 jobs. Debates in Congress surrounding these estimates resulted in the enactment of Law No. 14.183 in June 2021, temporarily reinstating the REIQ and setting a four-year timeline for its definitive extinction. However, Decree No. 1.095 of December 31, 2021, again suspended the Special Regime (ABIQUIM, 2022). The fiscal uncertainty surrounding these conflicting guidelines continued in the following years until a presidential decree in August 2023 stipulated the definitive resumption of the REIQ.

In Brazil, 980 companies are classified as part of the "chemical industry" according to the Instituto Brasileiro de Geografia e Estatística (IBGE\textsuperscript{24}) economic activity classification criteria. ABIQUIM members represents 111 of these companies, accounting for over 85\% of chemical products sold for industrial use and 48\% of the total chemical industry. Approximately 70\% of ABIQUIM's industry members are multinational companies that allocate resources based on global investment strategies (ABIQUIM and CNI, 2017). Considering that sources for investment are costly, allocating them to markets with the best returns is a fundamental principle of business strategy. Consequently, this combination of global value chains and internal structural problems diminishes Brazil's attractiveness for new foreign investments in the chemical sector\textsuperscript{25}.

5 CONCLUSIONS: THE LONG ROAD AHEAD FOR RENEWABLE CHEMISTRY

The document "Plano de Retomada da Indústria"\textsuperscript{26} emphasizes crucial elements for moving towards a low-carbon economy. These factors include replacing fossil fuels with

\begin{footnotesize}
\begin{itemize}
  \item REIQ: Special Regime for the Chemical Industry (Regime Especial da Indústria Química)
  \item ABIQUIM: Brazilian Chemical Industry Association (Associação Brasileira da Indústria Química).
  \item IBGE: Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística)
  \item The entire Latin American continent seems to be experiencing a situation like Brazil's. As shown in Table 2, over the past 20 years, Latin America's share in global chemical product sales has remained stagnant at 3.6\% of global sales.
  \item "Plano de Retomada da Indústria" (Industrial Recovery Plan).
\end{itemize}
\end{footnotesize}
renewable energy sources and increasing the sustainable use of Brazilian biodiversity by creating new value chains (CNI, 2023).

These propositions are not new. The "Pacto Nacional da Indústria Química National"27, published by ABIQUIM in 2010, highlighted the benefits of better utilizing biomass resources by developing a renewable chemical industry. The document also discussed the potential for reversing the trade deficit of chemical products and expanding the renewable base chemical industry segment, indicating a potential investment of around US$167 billion in new capacity between 2010 and 2020. Additionally, there was a forecast of new investments in R&D amounting to approximately US$32 billion, equivalent to about 1.5% of the projected net revenue for the period. The study also estimated that renewable chemicals would account for at least 10% of the overall supply of petrochemical products, with Brazil capturing a significant portion of that total. These achievements could have positioned the Brazilian chemical industry among the world's top five, making the country a net exporter of chemical products by the end of the 2020s (ABIQUIM, 2010).

Nearly fifteen years after the ABIQUIM (2010) report, the optimistic forecasts for massive R&D investments and the expansion of green chemistry in Brazil have yet to materialize fully. This shortfall is partly due to the structural problems presented in Section 4.2. The low intensity of R&D efforts in the bioeconomy field reflects chronic bottlenecks associated with the national tax system, logistical infrastructure, and high energy costs, all of which erode the competitiveness of the Brazilian chemical industry. Furthermore, two circumstantial factors described in Section 4.1 - the intensification of Chinese chemical imports following the onset of the Ukraine War and the consequent increase in industry idleness - are likely to exacerbate these structural bottlenecks, further reducing the sector's profitability.

Low profitability limits the internal resources available for funding R&D investments and delays the development of renewable energy sources and innovative bioproducts. Therefore, while the virtuous goals proposed by CNI (2023) are praiseworthy, there remains a long road ahead to achieve the sustainable exploration of local biodiversity by structuring new value chains.

In summary, the Brazilian chemical industry possesses the technology and scale necessary to integrate into Federal Government programs in the bioeconomy field, such as the National Program for Bio-inputs and the National Bioeconomy Strategy. However, the sector's structural problems and low R&D investments tend to inhibit the development of new

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27 “Pacto Nacional da Indústria Química” (Chemical Industry National Pact)
bioeconomic systems. Brazil must address these challenges to establish itself as a global bioeconomy powerhouse.

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