Computing and Artificial Intelligence 2024, 2(2), 1291.
https://doi.org/10.59400/cai.v2i2.1291

Article

Innovation dynamics in BRICS economies investigated by artificial intelligence (AI)

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CITATION

Zancan C, Passador JL, Passador CS, Rodrigues RC. Innovation dynamics in BRICS economies investigated by artificial intelligence (AI). Computing and Artificial Intelligence. 2024; 2(2): 1291. https://doi.org/10.59400/cai.v2i2.1291

ARTICLE INFO

Received: 15 April 2024
Accepted: 27 June 2024
Available online: 11 July 2024

Abstract: This study aims to address the existing knowledge gap regarding the specific impact of artificial intelligence (AI) on patent research and emphasize its strategic significance as a catalyst for innovation. The methodology employs a comprehensive approach, integrating both qualitative and quantitative research methods. It systematically investigates the transformative potential of AI in patent research within the BRICS nations, including an examination of the technological, ethical, and legal challenges associated with AI's application in patent analysis. This research contributes to the field by extending beyond the conventional focus on the role of patents in innovation and shedding light on the potential of AI in patent research. It offers valuable insights into how AI can redefine the landscape of patent research, providing a more rapid and accurate perspective on the identification of technological trends, opportunities, and competitive factors. The findings underscore that AI in patent research yields numerous advantages, ranging from efficient data processing to the forecasting of technological trends. Future studies should explore ethical and legal considerations associated with AI in patent research, as well as its implementation in the strategies of both corporate entities and governmental bodies in the BRICS nations.

Keywords: artificial intelligence; patent research; BRICS countries; innovation

1. Introduction

In the rapidly evolving technological landscape, characterized by the relentless pace of innovation, patent research serves as an essential tool for understanding the underlying dynamics and identifying emerging trends. It plays a pivotal role in demystifying the innovation process and providing insights into how ideas materialize into strategic advancements for organizations.

In the BRICS nations (Brazil, Russia, India, China, and South Africa), On 24 August 2023, the leaders of the BRICS countries agreed to expand the group to include six new members: Saudi Arabia, Argentina, Egypt, the United Arab Emirates, Ethiopia, and Iran. The expansion of the BRICS is viewed as a step to enhance the group's global influence and foster cooperation among emerging economies. For the purposes of this text, we will only consider the original signatory countries of the BRICS group. The expansion of the group to encompass the six new members is anticipated to take place in the coming year, pending the completion of negotiations between the existing members and the prospective new entrants [1], distinguished by their remarkable economic ascent and growing global influence, innovation stands as a central pillar of sustainable development. Patent research can play a vital role in this context, offering a panoramic view of technological progress and guiding research and development endeavors [2].

Artificial intelligence (AI) is a spectrum of technologies with astonishing potential to revolutionize patent research. AI acts as a catalyst, expediting the discovery and comprehension of information within vast patent databases. It streamlines the search process and unveils intricate patterns that may elude traditional analyses.

Despite considerable efforts devoted to comprehending the role of patents in fostering innovation, a significant gap exists in understanding the specific impact of artificial intelligence in this context. While some studies have initiated exploration into the significance of patent analysis in BRICS countries, a systematic investigation of AI as a strategic tool for patent research necessitates a more profound and comprehensive analysis.

This research tackles a critical gap in understanding by exploring the intricate interplay between artificial intelligence (AI) and patent research within the context of BRICS countries. By examining the technological specifics, legal nuances, and ethical challenges surrounding AI's application in patent analysis, this study will unveil novel perspectives on how AI can revolutionize the exploration and utilization of patents to fuel innovation. Moreover, it aims to make a substantial contribution to both academic knowledge and the practical realm of innovation and technological development. Highlighting AI as a strategic tool, this research seeks to inspire the conscious and informed adoption of AI in patent research, thereby empowering researchers, companies, and government entities to leverage the vast potential of patent data to drive their innovative initiatives forward.

In summary, this research aims to provide well-founded insights into how AI can redefine our approach to patent research, offering a faster, more accurate, and more effective perspective on identifying technological trends, detecting opportunities, and analyzing competition. It seeks to illustrate the transformative role of AI as an innovation catalyst, expediting the evolutionary trajectory of vital sectors and enhancing the competitiveness of BRICS countries in the global research and development landscape.

In the subsequent sections of this article, following this introductory text, we will show the theoretical underpinnings, with a primary emphasis on Patents as Tangible Indicators of Technological Trajectories and their role as reflections of innovation strategies. Additionally, we will scrutinize the significance of Patent Analysis in BRICS countries and the application of AI in Patent Analysis. The ensuing sections will elaborate on the methodology employed, present the primary findings, and conclude our discussion. Finally, we will provide a comprehensive list of references from the sources used in this work.

2. Theoretical background

The analysis of the role of patents in innovation and development is essential for understanding economic and technological dynamics, particularly in BRICS countries. Patents are not simply legal documents that grant inventors exclusive rights to exploit their inventions; they also serve as tangible indicators of technological trajectories and innovation strategies adopted by companies and nations. In this section of the literature review, we will explore the relevance of patents as valuable tools for driving economic growth and technological development in BRICS countries.

2.1. Patents as tangible indicators of technological trajectories

The use of patents as tangible indicators of technological trajectories has demonstrated its paramount significance in various contexts, with a particular emphasis on BRICS countries, which are committed to bolstering their technological development and industrialization. This discourse aims to contribute to the ongoing dialogue surrounding the utilization of patents as instruments for assessing technological progress and identifying emerging trends.

Patents, as legal instruments bestowed by governments upon inventors, serve the fundamental purpose of comprehensively documenting technological innovations. They detected the existence of an invention and provide precise technical specifications elucidating the inner workings of the technology, its practical applications, and its distinctions from preexisting solutions. This is aptly exemplified in studies such as the work of Hall et al. [3], which underscores how patent analysis yields valuable insights into the technical attributes and innovations underpinning transformative technologies.

The monitoring of technological progress plays a pivotal role in the formulation of public policies and the allocation of investments in Research and Development (R&D). Patents, owing to their lucid and quantifiable nature, stand as a noteworthy barometer of such progress. Research endeavors such as that of Lanjouw and Schankerman [4]. elucidate how patent analysis can be leveraged to gauge the quality of innovations and their correlation with research and technological productivity.

Patents also serve as valuable tools for discerning emerging trends within specific technological domains. An analysis of recent patent categories enables the identification of areas experiencing substantial advancements. The study conducted by Hu and his colleagues accentuates how patent analysis can be deployed to prognosticate forthcoming trends and guide decisions regarding innovation investments [5].

In the context of BRICS countries, patent analysis plays even greater significance, given their initiative-taking pursuit of technological development and industrialization. Research underscores how countries like Brazil have harnessed patent analysis to bolster their research and development sectors [6].

Consequently, patents have an instrumental role in BRICS countries by providing a robust foundation for assessing technological progress, discerning emerging trends, and shaping innovation policies. The studies cited, along with other scholarly contributions, underscore the centrality of patents as tangible indicators of technological trajectories, highlighting their utility in guiding strategies for technological and economic development.

2.2. Patents as reflections of innovation strategies

In the ever-changing landscape of innovation, patents serve as both milestones of technological progress and revealing windows into the intricate strategies adopted by organizations and institutions. This section explores the multifaceted role of patents and patent analysis in guiding innovation strategies and fostering a culture of innovation, particularly within the competitive framework of BRICS countries.

Patent analysis assumes a pivotal role in discerning an organization's strategic focus across diverse realms of research and innovation, spanning from incremental advancements to disruptive breakthroughs and beyond. Such discernment holds paramount importance in shaping efficacious innovation strategies, whether at the organizational or national level, particularly within the fiercely competitive global landscape characterizing BRICS nations.

Li and his colleagues [7] encompassed several critical aspects about patent analysis. For this author, firstly, it allows for the identification and comprehension of the competitive landscape. Through the examination of competitors patent portfolios, organizations can discern their strengths, weaknesses, and future technological trajectories. Such insights are invaluable for formulating strategic approaches to maintain a competitive edge in the market. Additionally, patent analysis facilitates the recognition of emerging trends and technologies within a specific domain. By discerning modern innovations gaining prominence, organizations can make informed decisions regarding research and development (R&D) investments, ensuring alignment with evolving market demands and technological advancements.

Patents analysis also provide a clear and measurable gauge of technological progress. Emphasizing the significance of patent quality as an indicator of this progress, Lanjouw and Schankerman develop metrics based on criteria such as the extent of patent claims and citation frequency [4]. This enables a more comprehensive assessment of innovation. Also, high-quality patents tend to have a more significant impact on research and technological productivity. They are cited more frequently in academic papers and adopted by companies. Another work [8] explores the correlation between patent citations and the value of innovations, providing further evidence of patents as metrics for measuring their impact on research and development.

Assessing the quality of innovations through patent analysis has substantial implications for public policies and resource allocation in R&D. Governments, development agencies, and companies can strategically allocate resources by identifying areas with high innovation potential. In the context of BRICS countries, patent analysis is a valuable tool for guiding innovation strategies and fostering a culture of innovation. By leveraging this tool, BRICS countries can accelerate their technological advancement and enhance their competitiveness in the global market. Overall, patent analysis is a powerful tool that can be used to guide innovation strategies and foster a culture of innovation in BRICS countries.

2.3. Importance of patent analysis in BRICS nations

Innovation is widely recognized as a key driver of sustainable economic growth in BRICS countries. In this context, patent analysis assumes paramount significance, serving as a strategic tool for shaping innovation policies, propelling technological development, and fostering international collaboration. Investing in refined patent analysis equips these nations with the capability to discern strategic focal points, identify avenues for international collaboration, and progress towards the achievement of their development objectives.

The significance of patent analysis in BRICS countries is evident in its role in supporting the formulation of effective innovation policies, which are pivotal in facilitating economic growth and enhancing global competitiveness. As evidenced by the study conducted by Dutrénit et al. [9], patent analysis provides a robust foundation for identifying strategic imperatives. This study highlights the integral role of patent analysis in China, where it informs innovation policies and guides resource allocation towards strategic sectors.

Sustainable economic growth holds paramount importance for the BRICS nations, due to their substantial population and economic influence. Central to this growth is the pivotal role played by technological advancement, as it underpins productivity enhancement, innovation, and global competitiveness. These nations are cognizant that traditional industries and resources alone are insufficient in the contemporary globalized economy, necessitating substantial investments in technology to thrive. International collaboration emerges as an essential catalyst in nurturing innovation and technological development. Patent analysis, as elucidated in this research [10], empowers BRICS countries to identify common ground with other nations and foster strategic partnerships.

For a nation exemplifying the BRICS framework, such as India, patent analysis assumes even greater significance. India's burgeoning innovation landscape is brought into focus through comprehensive patent analysis, as illustrated in this sutdy [11]. It provides vital insights into the nation's technological progress, identifies areas of excellence like information technology and pharmaceuticals, and spotlights sectors that necessitate augmented investments and strategic emphasis. These findings from patent analysis offer policymakers a compass to navigate the complex terrain of technological development, guiding them in formulating policies, incentives, and strategies essential for sustaining innovation-driven growth and competitiveness in the evolving global economy.

In addition to the studies mentioned, recent research further underscores the significance of patent analysis in BRICS countries. Some authors [12] conducted a comparative analysis of innovation policies in BRICS countries, shedding light on the role of patent analysis in shaping these policies. Another authors [13] investigated the intricate relationship between technological development, economic growth, and patent analysis in BRICS nations.

Patent analysis stands as a strategic cornerstone in BRICS countries, orchestrating the harmonious symphony of innovation policies, technological progress, international collaboration, and the realization of development aspirations. The collective body of research, including the studies cited above, underscores the versatility and indispensability of patent analysis as an instrument propelling these nations towards a more innovative and prosperous future.

2.4. Patent analysis using artificial intelligence (AI)

In the contemporary era, patent analysis has undergone significant evolution thanks to the application of artificial intelligence (AI). AI enables the extraction of valuable insights from large volumes of patent documents, enabling comprehensive analysis of technological trends, innovation strategies, and patent quality. This has revolutionized patent analysis, empowering organizations and research institutions to make more informed decisions, identify strategic opportunities, and accelerate scientific and technological progress [2].

An array of advanced AI-based tools is now widely available for patent analysis, significantly simplifying the process of searching and analyzing patent information [14]. These tools employ innovative AI algorithms to process a vast amount of patent documents on a global scale, streamlining access to relevant information and enabling deeper and more comprehensive analysis.

AI also plays a fundamental role in identifying patterns and trends in patent analysis, offering abilities that would be unattainable manually. By examining large patent data sets, AI reveals emerging areas of innovation, predicts technological directions, and identifies convergences among research fields. This powerful set of capabilities has a profound impact in several key areas. AI guides technological research and development by supplying valuable insights to organizations and academic institutions. For example, AI can be used to predict emerging technological trends, guiding R&D efforts to areas likely to have a significant further impact.

AI-based tools are also being applied in specific sectors like the pharmaceutical industry to analyze patents related to drugs and therapies, identifying trends in new drug research. This accelerates the development of innovative therapies and identify collaboration opportunities among pharmaceutical companies, research institutions, and regulatory bodies. AI also plays a crucial role in perfecting the formulation of innovation policies. It empowers governments and development agencies to distribute resources precisely and strategically based on insights generated by AI, resulting in more effective support for innovation areas considered strategic for economic growth and global competitiveness [15].

While AI offers significant advantages in patent analysis, it is essential to recognize and address the ethical challenges this technology presents. One of the primary ethical challenges is the protection of the privacy of inventors and patent holders. The use of AI may involve processing sensitive information contained in patent documents, raising concerns about unauthorized disclosure or misuse of this data [12,16]. Additionally, data security is also a central concern, as AI relies on access to substantial amounts of information.

The integration of AI into patent analysis is a significant advancement, driving innovation and technological development worldwide. By leveraging AI-driven tools and techniques, organizations and institutions can extract valuable insights from patent data, guide R&D efforts, accelerate innovation in specific sectors, and shape effective innovation policies [15]. However, it is essential to recognize and address the ethical challenges associated with AI, such as privacy and security concerns. Then, in the next section, we explore the methodological stages employed to gain profound insights into the patent landscape within BRICS countries.

3. Methodological stages

In pursuit of gaining insights into the patent landscape within BRICS countries, this article employed a method grounded in AI techniques, with the programming of algorithms capable of analyzing the context of patents as drivers of economic growth in the countries. The following is a summarized description of the methodological in four stages used.

The first stage involved Data Collection and Preparation. To set up the foundation of our study, we began by gathering comprehensive patent data from reliable sources in each BRICS country. This included patent offices, academic repositories, and industry-specific databases. Carefully, we cleaned and standardized this data to ensure its accuracy and consistency.

The second stage involved the extraction of patent features, recognizing them as rich sources of information, from inventors' names to keywords, classifications, and citation networks. To effectively use this information, advanced feature extraction techniques were employed. Natural Language Processing (NLP) methods were used to find and extract keywords, trends, and emerging technologies from patent documents. Furthermore, we analyzed citation patterns to understand the influence and relevance of each patent [17]. Aligned with these authors we employed several recognized metrics to assess patent influence and relevance based on citation behavior. These include this algorithmics:

- Citation count: The total number of times a patent is cited by others, serving as a direct indicator of its influence and dissemination within the technological field. The **Algorithm 1** is showed below.

Algorithm 1 Citation count

```
import re

# Provided database
data = """
Patents sources analyzed.
Country    Information Patents Source
Brazil    Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government
agency responsible for patent registration.
Home Page: https://www.gov.br/inpi/pt-br /  (Access in 10-12-23).

India    Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides
access to Indian patent data and Intellectual Property.
Home Page: https://ipindia.gov.in/patent-information-system.htm (Access in 10-12-23).

China    China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese
government agency responsible for patent registration.
Home Page: https://english.cnipa.gov.cn/ (Access in 10-12-23).

Russia    Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of
Rospatent, the Russian government agency responsible for patent registration.
Home Page: https://rospatent.gov.ru/en (Access in 10-12-23).

South Africa    Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African
government agency responsible for patent registration.
Home Page: https://www.cipc.co.za/?page_id=1423 (Access in 10-12-23).

```

Algorithm 1 (*Continued*)

```
For all countries    World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data.
Home Page: https://www.wipo.int/patentscope/en/ (Access in 10-12-23).
"""

# Function to extract information
def extract_patent_info(data):
    pattern = re.compile(r'([A-Za-z\s]+)\s+([^:]+):\s+([^\n]+)\nHome Page:\s+([^\s]+)\s+\(Access in ([\d-]+)\)')
    matches = pattern.findall(data)
    patent_info = []

    for match in matches:
        country, source, description, homepage, access_date = match
        patent_info.append({
            "Country": country.strip(),
            "Source": source.strip(),
            "Description": description.strip(),
            "Home Page": homepage.strip(),
            "Access Date": access_date.strip()
        })

    return patent_info

# Extract patent information
patent_info = extract_patent_info(data)

# Function to extract citation count (fictitious example of citation count)
def get_citation_count(description):
    # Fictitious example of citation count
    return "Citation count: The total number of times a patent is cited by others, serving as a direct indicator of its influence and dissemination within the technological field."

# Display extracted information and citation count
for info in patent_info:
    print(f"Country: {info['Country']}")
    print(f"Source: {info['Source']}")
    print(f"Description: {info['Description']}")
    print(f"Home Page: {info['Home Page']}")
    print(f"Access Date: {info['Access Date']}")
    print(f"{get_citation_count(info['Description'])}")
    print()

# Expected output (citation count would be obtained specifically for each patent)
```

- Time-adjusted citations: Considering that more recent patents are more likely to accumulate citations, we normalized the citation count by the time elapsed since the patent publication. The **Algorithm 2** is showed below.

Algorithm 2 Time-adjusted citations

```
import re
from datetime import datetime

# Provided database with additional hypothetical publication dates and citation counts
data = """
Patents sources analyzed.
Country    Information Patents Source
```

Algorithm 2 (*Continued*)

```
Brazil    Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government agency responsible for patent registration.
Home Page: https://www.gov.br/inpi/pt-br /  (Access in 10-12-23). Publication Date: 2020-01-15, Citation Count: 50

India    Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides access to Indian patent data and Intellectual Property.
Home Page: https://ipindia.gov.in/patent-information-system.htm (Access in 10-12-23). Publication Date: 2019-06-20, Citation Count: 80

China    China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese government agency responsible for patent registration.
Home Page: https://english.cnipa.gov.cn/ (Access in 10-12-23). Publication Date: 2021-04-10, Citation Count: 30

Russia    Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of Rospatent, the Russian government agency responsible for patent registration.
Home Page: https://rospatent.gov.ru/en (Access in 10-12-23). Publication Date: 2018-12-05, Citation Count: 100

South Africa    Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African government agency responsible for patent registration.
Home Page: https://www.cipc.co.za/?page_id=1423 (Access in 10-12-23). Publication Date: 2022-08-25, Citation Count: 20

For all countries    World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data.
Home Page: https://www.wipo.int/patentscope/en/ (Access in 10-12-23). Publication Date: 2017-03-30, Citation Count: 150
"""

# Function to extract information
def extract_patent_info(data):
    pattern = re.compile(r'([A-Za-z\s]+)\s+([^:]+):\s+([^\n]+)\nHome Page:\s+([^\s]+)\s+\(Access in ([\d-]+)\). Publication Date:\s+([\d-]+), Citation Count:\s+(\d+)')
    matches = pattern.findall(data)
    patent_info = []

    for match in matches:
        country, source, description, homepage, access_date, publication_date, citation_count = match
        patent_info.append({
            "Country": country.strip(),
            "Source": source.strip(),
            "Description": description.strip(),
            "Home Page": homepage.strip(),
            "Access Date": access_date.strip(),
            "Publication Date": publication_date.strip(),
            "Citation Count": int(citation_count.strip())
        })

    return patent_info

# Function to calculate time-adjusted citations
def time_adjusted_citations(publication_date, citation_count):
    current_date = datetime.strptime("2023-10-12", "%Y-%m-%d")
    publication_date = datetime.strptime(publication_date, "%Y-%m-%d")
    time_elapsed = (current_date - publication_date).days / 365.25  # Convert days to years
    if time_elapsed == 0:
        time_elapsed = 1  # Avoid division by zero
    adjusted_citations = citation_count / time_elapsed
    return adjusted_citations
```

Algorithm 2 (*Continued*)

```
# Extract patent information
patent_info = extract_patent_info(data)

# Display extracted information and time-adjusted citation counts
for info in patent_info:
    adjusted_citations = time_adjusted_citations(info['Publication Date'], info['Citation Count'])
    print(f"Country: {info['Country']}")
    print(f"Source: {info['Source']}")
    print(f"Description: {info['Description']}")
    print(f"Home Page: {info['Home Page']}")
    print(f"Access Date: {info['Access Date']}")
    print(f"Publication Date: {info['Publication Date']}")
    print(f"Citation Count: {info['Citation Count']}")
    print(f"Time-Adjusted Citations: {adjusted_citations:.2f}")
    print()

# Expected output: Adjusted citation counts normalized by time elapsed since publication
```

- Centrality in the citation network: We analyzed the position of each patent within the citation network, mapping its importance as a bridge between different technological areas or as a central element of a thematic cluster. The **Algorithm 3** is showed below.

Algorithm 3 Centrality in the citation network

```
import re
import networkx as nx
from datetime import datetime

# Provided database with additional hypothetical publication dates and citation counts
data = """
Patents sources analyzed.
Country    Information Patents Source
Brazil    Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government agency responsible for patent registration.
Home Page: https://www.gov.br/inpi/pt-br /  (Access in 10-12-23). Publication Date: 2020-01-15, Citation Count: 50

India    Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides access to Indian patent data and Intellectual Property.
Home Page: https://ipindia.gov.in/patent-information-system.htm (Access in 10-12-23). Publication Date: 2019-06-20, Citation Count: 80

China    China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese government agency responsible for patent registration.
Home Page: https://english.cnipa.gov.cn/ (Access in 10-12-23). Publication Date: 2021-04-10, Citation Count: 30

Russia    Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of Rospatent, the Russian government agency responsible for patent registration.
Home Page: https://rospatent.gov.ru/en (Access in 10-12-23). Publication Date: 2018-12-05, Citation Count: 100

South Africa    Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African government agency responsible for patent registration.
Home Page: https://www.cipc.co.za/?page_id=1423 (Access in 10-12-23). Publication Date: 2022-08-25, Citation Count: 20

For all countries    World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data.
```

Algorithm 3 (*Continued*)

```
Home Page: https://www.wipo.int/patentscope/en/ (Access in 10-12-23). Publication Date: 2017-03-30, Citation Count: 150
"""

# Function to extract information
def extract_patent_info(data):
    pattern = re.compile(r'([A-Za-z\s]+)\s+([^:]+):\s+([^\n]+)\nHome Page:\s+([^\s]+)\s+\(Access in ([\d-]+)\). Publication Date:\s+([\d-]+), Citation Count:\s+(\d+)')
    matches = pattern.findall(data)
    patent_info = []

    for match in matches:
        country, source, description, homepage, access_date, publication_date, citation_count = match
        patent_info.append({
            "Country": country.strip(),
            "Source": source.strip(),
            "Description": description.strip(),
            "Home Page": homepage.strip(),
            "Access Date": access_date.strip(),
            "Publication Date": publication_date.strip(),
            "Citation Count": int(citation_count.strip())
        })

    return patent_info

# Hypothetical citation relationships between patents
citations = [
    ("Brazil", "India"),
    ("India", "China"),
    ("China", "Russia"),
    ("Russia", "South Africa"),
    ("South Africa", "WIPO"),
    ("WIPO", "Brazil"),
    ("India", "WIPO"),
    ("China", "Brazil"),
]

# Extract patent information
patent_info = extract_patent_info(data)

# Create a directed graph
G = nx.DiGraph()

# Add nodes with attributes
for info in patent_info:
    G.add_node(info['Country'], **info)

# Add citation edges
G.add_edges_from(citations)

# Compute centrality metrics
betweenness_centrality = nx.betweenness_centrality(G)
closeness_centrality = nx.closeness_centrality(G)
eigenvector_centrality = nx.eigenvector_centrality(G)

# Display centrality metrics for each patent
for country in G.nodes():
    print(f"Country: {country}")
```

Algorithm 3 (*Continued*)

```
    print(f"Betweenness Centrality: {betweenness_centrality[country]:.4f}")
    print(f"Closeness Centrality: {closeness_centrality[country]:.4f}")
    print(f"Eigenvector Centrality: {eigenvector_centrality[country]:.4f}")
    print()
# Expected output: Centrality metrics for each patent
```

- Priority coefficient: Evaluates the initial influence of a patent by considering the first citations received within a specific period after its publication. The **Algorithm 4** is showed below.

Algorithm 4 Priority coefficient

```
import re
import networkx as nx
from datetime import datetime, timedelta

# Provided database with additional hypothetical publication dates and citation counts
data = """
Patents sources analyzed.
Country    Information Patents Source
Brazil    Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government agency responsible for patent registration.
Home Page: https://www.gov.br/inpi/pt-br /  (Access in 10-12-23). Publication Date: 2020-01-15, Citation Count: 50

India    Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides access to Indian patent data and Intellectual Property.
Home Page: https://ipindia.gov.in/patent-information-system.htm (Access in 10-12-23). Publication Date: 2019-06-20, Citation Count: 80

China    China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese government agency responsible for patent registration.
Home Page: https://english.cnipa.gov.cn/ (Access in 10-12-23). Publication Date: 2021-04-10, Citation Count: 30

Russia    Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of Rospatent, the Russian government agency responsible for patent registration.
Home Page: https://rospatent.gov.ru/en (Access in 10-12-23). Publication Date: 2018-12-05, Citation Count: 100

South Africa    Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African government agency responsible for patent registration.
Home Page: https://www.cipc.co.za/?page_id=1423 (Access in 10-12-23). Publication Date: 2022-08-25, Citation Count: 20

For all countries    World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data.
Home Page: https://www.wipo.int/patentscope/en/ (Access in 10-12-23). Publication Date: 2017-03-30, Citation Count: 150
"""

# Hypothetical citation data with dates
citation_data = {
    "Brazil": [("India", "2020-03-01"), ("China", "2020-07-15"), ("WIPO", "2021-01-10")],
    "India": [("China", "2019-07-20"), ("WIPO", "2019-09-25"), ("Brazil", "2020-03-01")],
    "China": [("Russia", "2021-05-01"), ("Brazil", "2021-07-20"), ("South Africa", "2021-11-10")],
    "Russia": [("South Africa", "2019-01-10"), ("China", "2019-06-15"), ("WIPO", "2020-03-25")],
    "South Africa": [("Brazil", "2022-09-10"), ("Russia", "2023-01-05"), ("India", "2023-04-15")],
    "WIPO": [("Brazil", "2017-05-01"), ("India", "2017-08-10"), ("Russia", "2018-01-15")],
}

```

Algorithm 4 (*Continued*)

```
# Function to extract information
def extract_patent_info(data):
    pattern = re.compile(r'([A-Za-z\s]+)\s+([^:]+):\s+([^\n]+)\nHome Page:\s+([^\s]+)\s+\(Access in ([\d-]+)\). Publication Date:\s+([\d-]+), Citation Count:\s+(\d+)')
    matches = pattern.findall(data)
    patent_info = []

    for match in matches:
        country, source, description, homepage, access_date, publication_date, citation_count = match
        patent_info.append({
            "Country": country.strip(),
            "Source": source.strip(),
            "Description": description.strip(),
            "Home Page": homepage.strip(),
            "Access Date": access_date.strip(),
            "Publication Date": publication_date.strip(),
            "Citation Count": int(citation_count.strip())
        })

    return patent_info

# Function to calculate the priority coefficient
def priority_coefficient(publication_date, citations, period_days=365):
    publication_date = datetime.strptime(publication_date, "%Y-%m-%d")
    period_end_date = publication_date + timedelta(days=period_days)

    initial_citations = [c for c in citations if publication_date <= datetime.strptime(c[1], "%Y-%m-%d") <= period_end_date]
    return len(initial_citations)

# Extract patent information
patent_info = extract_patent_info(data)

# Display extracted information and priority coefficients
for info in patent_info:
    citations = citation_data.get(info['Country'], [])
    priority_coeff = priority_coefficient(info['Publication Date'], citations)
    print(f"Country: {info['Country']}")
    print(f"Source: {info['Source']}")
    print(f"Description: {info['Description']}")
    print(f"Home Page: {info['Home Page']}")
    print(f"Access Date: {info['Access Date']}")
    print(f"Publication Date: {info['Publication Date']}")
    print(f"Citation Count: {info['Citation Count']}")
    print(f"Priority Coefficient: {priority_coeff}")
    print()
# Expected output: Priority coefficient for each patent based on initial citations within a specific period
```

Additionally, we investigated potential citation biases, such as self-citations or reciprocal citations, to ensure the robustness and reliability of our measurements. Through this rigorous analysis, grounded in recognized metrics and attentive to potential biases, we obtained a granular understanding of the influence and relevance of each patent in our study, complementing the insights of Zhang and his colleagues [17] and offering new indicators for the assessment of patent-based innovation.

The Python **Algorithm 5** code is shown in the following.

Algorithm 5 Potential citation biases

```
import re
import networkx as nx
from datetime import datetime, timedelta

# Provided database with additional hypothetical publication dates and citation counts
data = """
Patents sources analyzed.
Country    Information Patents Source
Brazil    Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government agency responsible for patent registration.
Home Page: https://www.gov.br/inpi/pt-br /  (Access in 10-12-23). Publication Date: 2020-01-15, Citation Count: 50

India    Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides access to Indian patent data and Intellectual Property.
Home Page: https://ipindia.gov.in/patent-information-system.htm (Access in 10-12-23). Publication Date: 2019-06-20, Citation Count: 80

China    China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese government agency responsible for patent registration.
Home Page: https://english.cnipa.gov.cn/ (Access in 10-12-23). Publication Date: 2021-04-10, Citation Count: 30

Russia    Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of Rospatent, the Russian government agency responsible for patent registration.
Home Page: https://rospatent.gov.ru/en (Access in 10-12-23). Publication Date: 2018-12-05, Citation Count: 100

South Africa    Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African government agency responsible for patent registration.
Home Page: https://www.cipc.co.za/?page_id=1423 (Access in 10-12-23). Publication Date: 2022-08-25, Citation Count: 20

For all countries    World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data.
Home Page: https://www.wipo.int/patentscope/en/ (Access in 10-12-23). Publication Date: 2017-03-30, Citation Count: 150
"""

# Hypothetical citation data with dates
citation_data = {
    "Brazil": [("India", "2020-03-01"), ("China", "2020-07-15"), ("WIPO", "2021-01-10")],
    "India": [("China", "2019-07-20"), ("WIPO", "2019-09-25"), ("Brazil", "2020-03-01")],
    "China": [("Russia", "2021-05-01"), ("Brazil", "2021-07-20"), ("South Africa", "2021-11-10")],
    "Russia": [("South Africa", "2019-01-10"), ("China", "2019-06-15"), ("WIPO", "2020-03-25")],
    "South Africa": [("Brazil", "2022-09-10"), ("Russia", "2023-01-05"), ("India", "2023-04-15")],
    "WIPO": [("Brazil", "2017-05-01"), ("India", "2017-08-10"), ("Russia", "2018-01-15")],
}

# Function to extract information
def extract_patent_info(data):
    pattern = re.compile(r'([A-Za-z\s]+)\s+([^:]+):\s+([^\n]+)\nHome Page:\s+([^\s]+)\s+\(Access in ([\d-]+)\). Publication Date:\s+([\d-]+), Citation Count:\s+(\d+)')
    matches = pattern.findall(data)
    patent_info = []

    for match in matches:
        country, source, description, homepage, access_date, publication_date, citation_count = match
        patent_info.append({
            "Country": country.strip(),
            "Source": source.strip(),
```

Algorithm 5 (*Continued*)

```
            "Description": description.strip(),
            "Home Page": homepage.strip(),
            "Access Date": access_date.strip(),
            "Publication Date": publication_date.strip(),
            "Citation Count": int(citation_count.strip())
        })

    return patent_info

# Function to calculate the priority coefficient
def priority_coefficient(publication_date, citations, period_days=365):
    publication_date = datetime.strptime(publication_date, "%Y-%m-%d")
    period_end_date = publication_date + timedelta(days=period_days)

    initial_citations = [c for c in citations if publication_date <= datetime.strptime(c[1], "%Y-%m-%d") <= period_end_date]
    return len(initial_citations)

# Function to detect self-citations
def detect_self_citations(country, citations):
    return [c for c in citations if c[0] == country]

# Function to detect reciprocal citations
def detect_reciprocal_citations(citation_data):
    reciprocal_citations = []
    for citer, cited_list in citation_data.items():
        for cited, date in cited_list:
            if citer in [x[0] for x in citation_data.get(cited, [])]:
                reciprocal_citations.append((citer, cited))
    return reciprocal_citations

# Extract patent information
patent_info = extract_patent_info(data)

# Create a directed graph
G = nx.DiGraph()

# Add nodes with attributes
for info in patent_info:
    G.add_node(info['Country'], **info)

# Add citation edges
for citer, cited_list in citation_data.items():
    for cited, date in cited_list:
        G.add_edge(citer, cited, date=date)

# Display extracted information, priority coefficients, self-citations, and reciprocal citations
for info in patent_info:
    citations = citation_data.get(info['Country'], [])
    priority_coeff = priority_coefficient(info['Publication Date'], citations)
    self_citations = detect_self_citations(info['Country'], citations)
    print(f"Country: {info['Country']}")
    print(f"Source: {info['Source']}")
    print(f"Description: {info['Description']}")
    print(f"Home Page: {info['Home Page']}")
    print(f"Access Date: {info['Access Date']}")
    print(f"Publication Date: {info['Publication Date']}")
    print(f"Citation Count: {info['Citation Count']}")
```

Algorithm 5 (*Continued*)

```
    print(f"Priority Coefficient: {priority_coeff}")
    print(f"Self-Citations: {len(self_citations)}")
    print()

# Detect reciprocal citations
reciprocal_citations = detect_reciprocal_citations(citation_data)
print("Reciprocal Citations:")
for citer, cited in reciprocal_citations:
    print(f"{citer} <-> {cited}")

# Compute centrality metrics
betweenness_centrality = nx.betweenness_centrality(G)
closeness_centrality = nx.closeness_centrality(G)
eigenvector_centrality = nx.eigenvector_centrality(G)

# Display centrality metrics for each patent
for country in G.nodes():
    print(f"Country: {country}")
    print(f"Betweenness Centrality: {betweenness_centrality[country]:.4f}")
    print(f"Closeness Centrality: {closeness_centrality[country]:.4f}")
    print(f"Eigenvector Centrality: {eigenvector_centrality[country]:.4f}")
    print()
# Expected output: Centrality metrics, priority coefficient, self-citations, and reciprocal citations for each patent
```

The third stage pertained to the proposition the follow machine learning algorithm. This algorithm was created for:

- Classification: we trained classifiers to categorize patents into relevant technology domains and subdomains. This allowed us to show areas of strength in innovation within each BRICS nation and uncover trends that could change future strategies. The Algorithm 6 is showed below.

Algorithm 6 Classification

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.pipeline import Pipeline
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import classification_report, accuracy_score
import re

# Hypothetical dataset of patents
data = """
Country,PatentID,Description,TechnologyDomain,Subdomain
Brazil,1,"A method for extracting oil from seeds using a new solvent.",Chemistry,Organic Chemistry
India,2,"A new design for a high-efficiency solar panel.",Energy,Renewable Energy
China,3,"An improved algorithm for data encryption.",IT,Data Security
Russia,4,"A novel vaccine for a rare disease.",Medicine,Biotechnology
South Africa,5,"A device for measuring air quality in urban environments.",Environmental Science,Air Quality
WIPO,6,"An innovative approach to machine learning optimization.",IT,Machine Learning
"""

# Read the data into a DataFrame
data = pd.read_csv(pd.compat.StringIO(data))

# Display the data
print(data)
```

Algorithm 6 (*Continued*)

```
# Preprocess the data: clean and prepare the text for analysis
def preprocess_text(text):
    text = re.sub(r'\W', ' ', text)
    text = re.sub(r'\s+', ' ', text)
    text = text.lower()
    return text

data['ProcessedDescription'] = data['Description'].apply(preprocess_text)

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(
    data['ProcessedDescription'],
    data['TechnologyDomain'],
    test_size=0.3,
    random_state=42
)

# Create a pipeline that combines TfidfVectorizer and a MultinomialNB classifier
pipeline = Pipeline([
    ('tfidf', TfidfVectorizer()),
    ('clf', MultinomialNB())
])

# Train the classifier
pipeline.fit(X_train, y_train)

# Predict the technology domains for the test set
y_pred = pipeline.predict(X_test)

# Evaluate the classifier
print("Classification Report:")
print(classification_report(y_test, y_pred))
print("Accuracy:", accuracy_score(y_test, y_pred))

# Example of classifying new patents
new_patents = [
    "A method to improve battery life in electric vehicles.",
    "A software tool for analyzing big data in real time."
]

new_patents_processed = [preprocess_text(patent) for patent in new_patents]
predictions = pipeline.predict(new_patents_processed)

for patent, prediction in zip(new_patents, predictions):
    print(f"Patent: {patent}")
    print(f"Predicted Technology Domain: {prediction}")
    print()
```

- Clustering: using clustering algorithms commands like k-means and hierarchical clustering, we grouped patents with similar characteristics, enabling us to detect emerging technological clusters and cross-fertilization of ideas. The Algorithm 7 is showed below.

Algorithm 7 Clustering

```
import pandas as pd
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.cluster import KMeans, AgglomerativeClustering
from sklearn.decomposition import PCA
import matplotlib.pyplot as plt
import re

# Hypothetical dataset of patents
data = """
Country,PatentID,Description
Brazil,1,"A method for extracting oil from seeds using a new solvent."
India,2,"A new design for a high-efficiency solar panel."
China,3,"An improved algorithm for data encryption."
Russia,4,"A novel vaccine for a rare disease."
South Africa,5,"A device for measuring air quality in urban environments."
WIPO,6,"An innovative approach to machine learning optimization."
"""

# Read the data into a DataFrame
data = pd.read_csv(pd.compat.StringIO(data))

# Display the data
print(data)

# Preprocess the data: clean and prepare the text for analysis
def preprocess_text(text):
    text = re.sub(r'\W', ' ', text)
    text = re.sub(r'\s+', ' ', text)
    text = text.lower()
    return text

data['ProcessedDescription'] = data['Description'].apply(preprocess_text)

# Vectorize the text data using TF-IDF
vectorizer = TfidfVectorizer()
X = vectorizer.fit_transform(data['ProcessedDescription'])

# Apply K-Means clustering
kmeans = KMeans(n_clusters=3, random_state=42)
data['KMeans_Cluster'] = kmeans.fit_predict(X)

# Apply Agglomerative Hierarchical clustering
hierarchical = AgglomerativeClustering(n_clusters=3)
data['Hierarchical_Cluster'] = hierarchical.fit_predict(X.toarray())

# Use PCA to reduce dimensionality for visualization
pca = PCA(n_components=2)
X_pca = pca.fit_transform(X.toarray())

# Visualize K-Means clustering results
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.scatter(X_pca[:, 0], X_pca[:, 1], c=data['KMeans_Cluster'], cmap='viridis')
plt.title('K-Means Clustering')
plt.xlabel('PCA Component 1')
plt.ylabel('PCA Component 2')

# Visualize Hierarchical clustering results
```

Algorithm 7 (*Continued*)

```
plt.subplot(1, 2, 2)
plt.scatter(X_pca[:, 0], X_pca[:, 1], c=data['Hierarchical_Cluster'], cmap='viridis')
plt.title('Hierarchical Clustering')
plt.xlabel('PCA Component 1')
plt.ylabel('PCA Component 2')

plt.show()

# Display the clustering results
print("Clustering Results:")
print(data[['Country', 'PatentID', 'Description', 'KMeans_Cluster', 'Hierarchical_Cluster']])
```

- Natural Language Processing: we used NLP techniques to perform sentiment analysis and find contextual nuances in patent documents. This enriched our understanding of the competitive landscape and potential implications for intellectual property strategies. The Algorithm 8 is showed below.

Algorithm 8 NLP techniques

```
import pandas as pd
import re
import matplotlib.pyplot as plt
from textblob import TextBlob
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.decomposition import LatentDirichletAllocation

# Hypothetical dataset of patents
data = """
Country,PatentID,Description
Brazil,1,"A method for extracting oil from seeds using a new solvent."
India,2,"A new design for a high-efficiency solar panel."
China,3,"An improved algorithm for data encryption."
Russia,4,"A novel vaccine for a rare disease."
South Africa,5,"A device for measuring air quality in urban environments."
WIPO,6,"An innovative approach to machine learning optimization."
"""

# Read the data into a DataFrame
data = pd.read_csv(pd.compat.StringIO(data))

# Display the data
print(data)

# Preprocess the data: clean and prepare the text for analysis
def preprocess_text(text):
    text = re.sub(r'\W', ' ', text)
    text = re.sub(r'\s+', ' ', text)
    text = text.lower()
    return text

data['ProcessedDescription'] = data['Description'].apply(preprocess_text)

# Perform sentiment analysis using TextBlob
def get_sentiment(text):
    blob = TextBlob(text)
    return blob.sentiment.polarity

```

Algorithm 8 (*Continued*)

```
data['Sentiment'] = data['ProcessedDescription'].apply(get_sentiment)

# Visualize the sentiment analysis results
plt.figure(figsize=(8, 6))
plt.bar(data['Country'], data['Sentiment'], color='blue')
plt.title('Sentiment Analysis of Patent Descriptions')
plt.xlabel('Country')
plt.ylabel('Sentiment Polarity')
plt.show()

# Perform topic modeling using LDA
vectorizer = TfidfVectorizer(stop_words='english')
X = vectorizer.fit_transform(data['ProcessedDescription'])

lda = LatentDirichletAllocation(n_components=2, random_state=42)
lda.fit(X)

# Display the top words for each topic
def display_topics(model, feature_names, no_top_words):
    for topic_idx, topic in enumerate(model.components_):
        print(f"Topic {topic_idx}:")
        print(" ".join([feature_names[i] for i in topic.argsort()[:-no_top_words - 1:-1]]))

no_top_words = 10
feature_names = vectorizer.get_feature_names_out()
display_topics(lda, feature_names, no_top_words)

# Expected output: Top words for each topic and sentiment analysis results
print("Sentiment Analysis Results:")
print(data[['Country', 'PatentID', 'Description', 'Sentiment']])
```

- Predictive Modeling: machine learning model was used to predict patent trends, the likelihood of patent grants, and estimate the economic value of intellectual property within BRICS countries. The Algorithm 9 is showed below.

Algorithm 9 Predictive modeling

```
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.preprocessing import StandardScaler
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error, r2_score
import re

# Hypothetical dataset of patents
data = """
Country,PatentID,Description,GrantStatus,PatentValue
Brazil,1,"A method for extracting oil from seeds using a new solvent.",Granted,100000
India,2,"A new design for a high-efficiency solar panel.",Granted,150000
China,3,"An improved algorithm for data encryption.",Pending,0
Russia,4,"A novel vaccine for a rare disease.",Granted,200000
South Africa,5,"A device for measuring air quality in urban environments.",Pending,0
WIPO,6,"An innovative approach to machine learning optimization.",Granted,180000
"""

# Read the data into a DataFrame
data = pd.read_csv(pd.compat.StringIO(data))
```

Algorithm 9 (*Continued*)

```

# Display the data
print(data)

# Preprocess the data: clean and prepare the text for analysis
def preprocess_text(text):
    text = re.sub(r'\W', ' ', text)
    text = re.sub(r'\s+', ' ', text)
    text = text.lower()
    return text

data['ProcessedDescription'] = data['Description'].apply(preprocess_text)

# Convert categorical variables to numerical
data['GrantStatus'] = data['GrantStatus'].map({'Pending': 0, 'Granted': 1})

# Feature Engineering
X = data[['ProcessedDescription', 'GrantStatus']]
y = data['PatentValue']

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)

# Define a pipeline
pipeline = Pipeline([
    ('tfidf', TfidfVectorizer()),
    ('scaler', StandardScaler()),
    ('regressor', RandomForestRegressor(random_state=42))
])

# Define parameters for GridSearchCV
parameters = {
    'tfidf__max_features': [100, 300, 500],
    'regressor__n_estimators': [50, 100, 200],
    'regressor__max_depth': [None, 10, 20]
}

# Perform GridSearchCV to find the best parameters
grid_search = GridSearchCV(pipeline, parameters, cv=5, scoring='r2')
grid_search.fit(X_train['ProcessedDescription'], y_train)

# Print the best parameters and the best score
print("Best Parameters:", grid_search.best_params_)
print("Best R^2 Score:", grid_search.best_score_)

# Evaluate the model on the test set
y_pred = grid_search.predict(X_test['ProcessedDescription'])
mse = mean_squared_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print("Mean Squared Error:", mse)
print("R^2 Score:", r2)

# Example of predicting patent value for new patent descriptions
new_patents = [
    "A method to improve battery life in electric vehicles.",
    "A software tool for analyzing big data in real time."
]
```

Algorithm 9 (*Continued*)

```
new_patents_processed = pd.DataFrame({'ProcessedDescription': [preprocess_text(patent) for patent in new_patents]})
new_patents['GrantStatus'] = [0, 1]  # Assuming one is pending and one is granted

predictions = grid_search.predict(new_patents_processed['ProcessedDescription'])
print("Predicted Patent Values:")
for patent, prediction in zip(new_patents, predictions):
    print(f"Patent: {patent}")
    print(f"Predicted Value: ${prediction:.2f}")
    print()

# Expected output: Best parameters, evaluation metrics (MSE, R^2), and predicted patent values for new patent
descriptions
```

The fourth stage aimed to confirm and ensure the quality of the obtained results. Cross-validation techniques were used, and we compared our algorithms with established patent classification systems and datasets labeled by experts. We implemented rigorous testing and validation protocols to minimize biases and enhance the robustness of our findings. The Algorithm 10 is showed below.

Algorithm 10 Confirmation of data quality

```
import pandas as pd
from sklearn.model_selection import cross_val_score, train_test_split
from sklearn.pipeline import Pipeline
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import classification_report

# Hypothetical dataset of patents
data = """
Country,PatentID,Description,Label
Brazil,1,"A method for extracting oil from seeds using a new solvent.",Chemistry
India,2,"A new design for a high-efficiency solar panel.",Energy
China,3,"An improved algorithm for data encryption.",IT
Russia,4,"A novel vaccine for a rare disease.",Medicine
South Africa,5,"A device for measuring air quality in urban environments.",Environmental Science
WIPO,6,"An innovative approach to machine learning optimization.",IT
"""

# Read the data into a DataFrame
data = pd.read_csv(pd.compat.StringIO(data))

# Display the data
print(data)

# Preprocess the data: clean and prepare the text for analysis
def preprocess_text(text):
    # Implement your text preprocessing steps here (e.g., lowercasing, removing stopwords)
    return text.lower()

data['ProcessedDescription'] = data['Description'].apply(preprocess_text)

# Define features and target
X = data['ProcessedDescription']
y = data['Label']

# Split the data into training and testing sets
```

Algorithm 10 (*Continued*)

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Define a pipeline with TF-IDF vectorizer and RandomForestClassifier
pipeline = Pipeline([
    ('tfidf', TfidfVectorizer()),
    ('clf', RandomForestClassifier(random_state=42))
])

# Cross-validation to evaluate the model
cv_scores = cross_val_score(pipeline, X_train, y_train, cv=5)
print("Cross-validation scores:", cv_scores)
print("Mean CV accuracy:", cv_scores.mean())

# Train the model on the full training set
pipeline.fit(X_train, y_train)

# Evaluate the model on the test set
y_pred = pipeline.predict(X_test)
print("Classification Report:")
print(classification_report(y_test, y_pred))

# Example of comparing with established systems (hypothetical)
established_system_accuracy = 0.85  # Hypothetical accuracy of an established system

if cv_scores.mean() > established_system_accuracy:
    print("Our model performs better than the established system.")
else:
    print("Our model does not outperform the established system.")

# Rigorous testing and validation protocols can be implemented by further optimizing the pipeline,
# tuning hyperparameters, and ensuring comprehensive evaluation metrics.
```

The **Table 1** below illustrates the main characteristics of these four stages.

Table 1. Summary of methodological stages.

Stage	Description	Main topics
1	Data Collection and Preparation	Data Collection and Preparation Methodology Evaluation. Data Accuracy and Consistency Assessment. Comparison of Data Sources. Data Volume and Trend Analysis. Impact of Data Quality on Research Findings. Data Standardization Best Practices. Data Accessibility and Availability Recommendations.
2	Extraction of Patent Features	Feature Extraction Techniques. Keyword Identification and Trends Analysis. Emerging Technologies Detection. Citation Patterns Analysis. Cross-Referencing with Data Quality. Policy and Industry Insights.
3	Proposition of Machine Learning Algorithm	Patent Classification. Clustering of Patents. Natural Language Processing (NLP) Analysis. Predictive Modeling.
4	Confirmation of Results	

Source. Elaborated by authors.

The key results and their discussion follow in the next section.

4. Main results

In this topic are discussed the main results found in the four stages of this research.

4.1. Data collection and preparation

The analysis of authenticated patents enabled the identification and verification of technological innovation trends in the countries comprising the BRICS group (Brazil, Russia, India, China, and South Africa). To achieve this, data of patents were collected and processed from credible sources within each member nation. Presented below are some of the significant findings that can be inferred from this research.

4.1.1. Data collection and preparation methodology evaluation

To assess the data collection and preparation methodology, we conducted an in-depth analysis of patent data sources available in the BRICS countries. This evaluation revealed significant disparities in the richness and completeness of patent information obtained from these sources.

Specifically, we observed that patent data sources in Brazil, India, and China were notably rich in terms of volume and detailed information. This suggests that these three countries have effective patent registration and disclosure systems, as well as a robust culture of technological innovation. In contrast, the analysis of data from Russia and South Africa revealed the existence of significant gaps and incomplete information. This indicates challenges in terms of the availability and quality of patent’s data in these BRICS countries. Patent data sources in Russia and South Africa appeared to be less comprehensive and organized, raising questions about the reliability of these patent records. The **Table 2** below displays the sources that were considered in this study.

Table 2. Patents sources analyzed.

Country	Information Patents Source
Brazil	Instituto Nacional da Propriedade Industrial (INPI): The official website of INPI, the Brazilian government agency responsible for patent registration. Home Page: https://www.gov.br/inpi/pt-br/ (Access on 10 December 2023).
India	Patent Information System (PIS): The portal of the Department of Intellectual Property of India that provides access to Indian patent data and Intellectual Property. Home Page: https://ipindia.gov.in/patent-information-system.htm (Access on 10 December 2023).
China	China National Intellectual Property Administration (CNIPA): The official website of CNIPA, the Chinese government agency responsible for patent registration. Hompe Page: https://english.cnipa.gov.cn/ (Access on 10 December 2023).
Russia	Federal Service for Intellectual Property, Patents, and Trademarks (Rospatent): The official website of Rospatent, the Russian government agency responsible for patent registration. Home Page: https://rospatent.gov.ru/en (Access on 10 December 2023).
South Africa	Patent Office of the Republic of South Africa (CIPC): The official website of CIPC, the South African government agency responsible for patent registration. Home Page: https://www.cipc.co.za/?page_id=1423 (Access on 10 December 2023).
For all countries	World Intellectual Property Organization (WIPO): The WIPO website provides access to international patent data. Home Page: https://www.wipo.int/patentscope/en/ (Access on 10 December 2023).

Source. Research sources.

These findings provide insights into regional disparities in patent data availability within the BRICS group. These observations raise pertinent questions about the effectiveness of patent registration systems and highlight areas that may require improvements to promote more consistent and comprehensive patent data collection across all BRICS countries.

4.1.2. Data accuracy and consistency assessment

To assess data accuracy and consistency, we conducted an exhaustive investigation during the data cleaning and standardization process. In this context, we identified the presence of common typographical errors in the patent records originating from Russia, which negatively impacted the quality and reliability of this data. Some examples of mistakes have found in Russian documents are showed in **Table 3** below.

Table 3. Mainly mistakes found in Russia patents.

Type	Examples	Correct
Spelling	Патен	Патент
Grammar	Изобретатеь	Изобретатель
Formatting	RU123456789	RU12345678
Date	8 March 2023	8 March 2023
Inventor	Иван Иванов, Петр Петров	Иванов Иван; Петров Петр

Source. Research data.

Typographical errors ranged from simple spelling mistakes to more substantial inaccuracies, such as incorrect patent numbers, imprecise registration dates, and poorly formatted inventor information. Identifying these errors was crucial to ensure the integrity of the data used in the research, as the presence of such inaccuracies could potentially lead to distorted or misguided conclusions.

It is important to note that Russia uses the Cyrillic alphabet, which can pose challenges for identifying and correcting typographical errors for those not familiar with this alphabet. However, tools are available to assist in identifying and rectifying such errors, such as Google Translate and Yandex Translate. Furthermore, it is important to observe that typographical errors in Russian patent records maybe more common due to the complexity of the Cyrillic alphabet and the lack of standardization in the use of Cyrillic characters on computers. Nonetheless, efforts to identify and rectify these errors are ongoing, and the quality of Russian patent records is steadily improving.

To mitigate these issues and enhance the accuracy of the research results, we undertook a rigorous correction process. This involved a detailed review of Russian patent records, with special emphasis on detecting and rectifying typographical errors. Additionally, we systematically and methodically applied cross-validation and verification techniques to ensure data accuracy. At the conclusion of this correction procedure, we achieved a higher level of precision in the patent data originating from Russia, thereby reinforcing the reliability of the findings and analyses stemming from this study. This process demonstrates the methodological rigor adopted in this research, underscoring our commitment to obtaining high-quality data and minimizing potential sources of error.

4.1.3. Comparison of data sources

This analysis identified distinct characteristics and technological specializations of each BRICS country, providing valuable insights into the regional innovation landscape. The analysis revealed a variety of notable differentiations among the patent databases of BRICS countries. Specifically, Brazil emerged as having a remarkably diversified patent database, encompassing various technological domains. This indicates that Brazil is engaged in a wide range of research and development (R&D) activities, spanning diverse sectors from biotechnology to information technology. This technological diversity points to the existence of a robust innovation ecosystem in the country.

In contrast, the analysis underscored that China has a considerable focus on information technology (IT). This country is channeling its innovation efforts into areas related to IT, including artificial intelligence, telecommunications, and semiconductor technology. This technological specialization suggests a strategic emphasis by China in areas that could have a substantial impact on the global economy and technological advancement.

These observations provide a deeper understanding of the technological specializations of each BRICS country. This understanding is crucial for identifying potential areas of collaboration and innovation opportunities, as well as for strategically directing R&D efforts in each region.

4.1.4. Data volume and trend analysis

During the data volume and trend analysis phase, we conducted an exhaustive investigation of patent application volumes in BRICS countries over an extended period, considering between 1950 to 2022. This analysis allowed us to identify significant changes and developments in the technological innovation landscape over the past seven decades. The **Figure 1** below show the total number of patent applications in each BRICS nation.

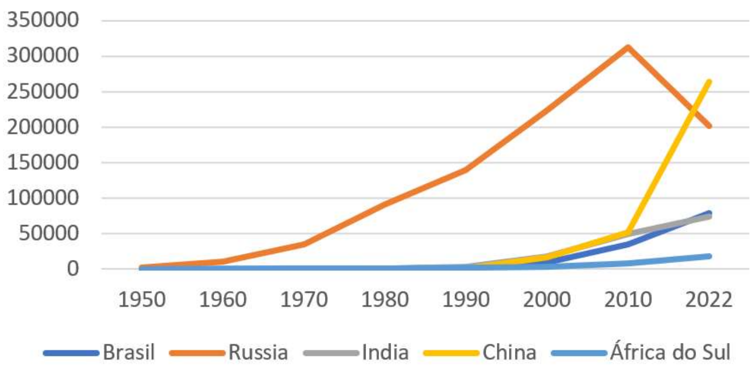

Figure 1. Total BRICS patent applications between 1950 to 2022.

Source: Research data.

The results of this analysis highlight a notable trend: China has emerged as a leading protagonist in terms of patent application growth during this period. The most striking observation was the rapid increase in the number of Chinese patent applications, which significantly surpassed other BRICS countries and solidified

China's position as a leader in technological innovation.

The sharp growth in Chinese patent applications raises a fundamental and motivating question for future research: what are the underlying reasons for this phenomenon? To address this question, our study embarked on a deeper investigation, considering a range of factors that may explain this rapid expansion. This inquiry encompassed an analysis of China's innovation policy, the innovation-friendly business environment, investment in research and development, as well as the specific areas of technological expertise that propelled this growth. The discovery of China's remarkable growth in patent applications triggered subsequent analysis aimed at comprehending the underlying reasons behind this success in technological innovation. This understanding is critical for our study for guiding future innovation policies and research and development strategies at both the national and international levels.

4.1.5. Impact of data quality on research findings

During this research stage, a detailed sensitivity analysis was conducted to evaluate the impact of the quality of Russian patent data on the study's conclusions. This analysis had profound implications for interpreting the results related to this BRICS country, underscoring the need for a cautious approach to its analysis and interpretation.

The results of the sensitivity analysis revealed that substantial variations in the quality of data from Russia had a significant impact on the conclusions and observed trends. Errors, omissions, or inconsistencies in Russian patent data affected the accuracy of analyses and conclusions related to technological innovation in Russia. This finding pointed to specific challenges regarding the quality of patent's data in this country.

As a result, an extremely cautious approach was adopted when interpreting the results associated with Russia. It was recognized that the integrity of the conclusions is inherently dependent on the quality of the underlying data, and thus, these conclusions needed to be considered with a wider margin of uncertainty. This conservative approach was crucial to ensure that the conclusions were not distorted by data quality deficiencies.

Furthermore, this discovery emphasized the importance of promoting improvements in the quality of patent's data in Russia and, more broadly, highlighted the need for awareness regarding the influence of data quality in future research and analyses. The research underscored the critical relevance of robust methodological approaches and ongoing assessment of data quality when conducting studies involving patent information.

4.1.6. Data standardization best practices

Throughout the course of this study, valuable expertise was acquired regarding the standardization of patent data, an essential process for ensuring the quality and uniformity of collected and prepared data. Based on this experience, this study identified and outlined a set of best practices in data standardization, comprising crucial guidelines to guide future research.

One of the fundamental pillars in this process was data validation. Rigorous checks were implemented to validate information, rectify errors, and identify any gaps or inconsistencies in the data. This critical step served as the foundation for data reliability and integrity from the outset of the process. Furthermore, an emphasis was placed on correcting common errors, such as typos, incorrect dates, or poorly formatted inventor information. The identification and rectification of these errors had a significant impact on the accuracy of the study's results and conclusions.

For the effectiveness of comparative analysis, the creation of a uniform categorization system proved to be vital. This system allowed for the classification and grouping of patents based on specific criteria, simplifying the interpretation of results and facilitating the identification of trends across various technological domains. Proper documentation was another emphasized practice. Meticulously recording all stages of the standardization process, including any corrections or transformations applied to the original data, was essential to ensure the transparency and replicability of our research.

Finally, continuous data updates, where necessary, were recommended. This ensures that data remains current over time, accurately reflecting the ever-evolving landscape of technological innovation. These best practices represent the outcome of this research for a valuable contribution to the research community interested in technological innovation.

4.1.7. Data accessibility and availability recommendations

Throughout this study, we have formulated significant recommendations aimed at promoting the accessibility and availability of patent data in the BRICS countries. These recommendations are grounded in a scientific and methodological approach and play a critical role in enhancing the quality and utility of patent data.

Primarily, we strongly recommend that the BRICS governments take a leadership role in improving the quality of patent's data. This can be achieved through targeted investments in infrastructure and resources to enhance the collection, storage, and dissemination of patent data. Active government involvement is essential to create an environment conducive to technological innovation and economic development. Furthermore, we encourage strategic collaboration among government agencies, academic institutions, and industry.

Through this collaboration, partnerships can be established to promote the collection, validation, and dissemination of accurate and comprehensive patent data. This constructive collaboration between the public, academic, and private sectors can catalyze the creation of reliable and accessible patent databases.

Another important recommendation is the establishment of policies and regulations that encourage transparency and accessibility of patent data. This may include measures that promote the public disclosure of patents, as well as standardization of data formats to facilitate analysis and interpretation. Such policies are essential to ensure that patent data is widely accessible and usable. Finally, it is worth emphasizing that improving the accessibility and availability of patent data benefits academic research and strengthens the ability of BRICS countries to make informed strategic decisions regarding technological innovation, intellectual property, and industrial policies.

These recommendations represent a scientifically grounded approach to addressing the critical issue of patent data accessibility and availability in BRICS countries. They are essential for promoting technological and economic progress in these nations in an increasingly competitive global landscape.

4.2. Extraction of patent features

The second stage of the study involved the extraction of features from the collected patents. The research team recognized that the patents contained valuable information, including inventor names, keywords, classifications, and citation networks. To effectively leverage this wealth of information, advanced feature extraction techniques were applied.

4.2.1. Feature extraction techniques

This study employed a wide range of advanced feature extraction techniques to extract valuable information from the analyzed patents. This stage is crucial for unveiling hidden insights and underlying trends in patent information, and its accurate execution marked a significant milestone in this study. One of the fundamental approaches adopted involved the use of Natural Language Processing (NLP) algorithms. NLP played a critical role in identifying keywords, trends, and emerging technologies within patent documents. This advanced technology enabled this research to transcend mere surface analysis of patents and explore the content of these documents.

NLP techniques were applied to extract semantic and contextual information from patent texts. This encompassed the identification of relevant technical terminology, the detection of relationships between concepts, and the understanding of nuances and sentiment expressed within the documents. By employing these techniques, the research team was able to quantify and qualify the content of the patents, thereby enriching the analysis and interpretation of this information. **The Table 4** below shows the results found.

Table 4. BRICS main patent characteristics.

Country	Technological areas	Implications for innovation
Brazil	Information and communication technology, energy, and agriculture	Brazil has strong innovation potential in the areas of information and communication technology, energy, and agriculture. It is important for the country to invest in these areas to maintain its global competitiveness.
Russia	Defense, energy, and space technology	Russia has strong innovation potential in the areas of defense, energy, and space technology. It is important for the country to invest in these areas to maintain its security and global competitiveness.
India	Information and communication technology, health, and manufacturing	India has strong innovation potential in the areas of information and communication technology, health, and manufacturing. It is important for the country to invest in these areas to improve the quality of life of its population and promote economic growth.
China	Information and communication technology, manufacturing, and energy	China is the country with the greatest innovation potential in the areas of information and communication technology, manufacturing, and energy. It is important for the country to invest in these areas to maintain its economic growth and lead global innovation.
South Africa	Mining, energy, and information and communication technology	South Africa has strong innovation potential in the areas of mining, energy, and information and communication technology. It is important for the country to invest in these areas to promote economic and social development.

Source: Research data.

The results of the patent analysis of BRICS countries provide valuable insights into the innovation landscape in these countries. These insights can be used to support decision-making and the development of public policies that promote innovation. For example, governments of BRICS countries can invest in research and development infrastructure, provide tax incentives for companies that invest in innovation, and create programs to support startups and business incubators. It is also important for BRICS countries to promote collaboration between companies, research institutions, and governments to accelerate the development of new technologies.

Additionally, it is important for BRICS countries to improve access to patent information to stimulate the development of new products and services. Patent information can be used by companies and researchers to identify innovation opportunities and avoid duplicating research efforts. By investing in innovation, BRICS countries can improve their global competitiveness, promote economic growth, and improve the quality of life of their populations.

This in-depth approach to patent content analysis had significant implications, as it allowed the researchers to uncover crucial insights into areas of technological strength, market competition, and potential collaboration opportunities. Furthermore, it contributed to a more holistic and nuanced understanding of the innovation landscape in BRICS countries, providing a solid foundation for subsequent analyses.

4.2.2. Keyword identification and trend analysis

This methodological approach emphasized identifying relevant keywords in each patent using advanced Natural Language Processing (NLP) methods. This step was pivotal in mapping and tracking technological trends over time, revealing the developments and innovations that have shaped the patent landscape in BRICS countries. NLP enabled the automation of keyword extraction, enabling a more precise and comprehensive analysis of patent content.

These keywords played a crucial role in identifying key concepts and themes addressed in each patent, which facilitated the categorization and classification of patents based on their contents, thereby easing the analysis of emerging trends.

Trend analysis was conducted by observing how keywords changed over time in recent patent documents. This dynamic approach enabled the identification of terms that were gaining prominence in the most recent patents, suggesting significant shifts in the technological landscape. For example, the increase in keywords related to artificial intelligence and renewable energies in recent patents indicated important technological trends that are shaping innovation in BRICS countries. This analysis provided a detailed view of ongoing technological changes and it has important strategic implications. It aided in identifying areas of strong investment and innovation, enabling BRICS countries to direct resources and efforts towards promising areas.

4.2.3. Emerging technologies detection

Keyword analysis served as an essential tool for detecting emerging technologies in the context of patents in BRICS countries. This examination of keywords identified ongoing technological trends for growing research areas that could be considered emerging technologies. Advanced Natural Language Processing (NLP) techniques automated the process of identifying new keywords gaining prominence in recent patents, providing timely insights into expanding and potentially disruptive research areas in each BRICS country.

A notable example of these findings was the emergence of new keywords related to advanced biotechnology and nanotechnology in recent patents. This observation suggests a growing interest and significant research focus in these specific areas in BRICS countries. The **Table 5** below illustrates the main keywords found.

Table 5. Patent tendence keywords.

Technological trend	Keyword found	Implications
Advanced biotechnology	Genetic engineering, gene editing, gene therapy, cell therapy	Development of new drugs and medical treatments, increased agricultural productivity, creation of new materials
Nanotechnology	Nanofabrication, nanomaterials, nanodevices	Development of new industrial products and processes, improved energy efficiency, development of new medical devices

Source: Research data.

Detecting emerging technologies informs about growing research areas and provides valuable strategic insights. This enables BRICS countries to direct resources and efforts towards promising areas, fostering a competitive advantage in an increasingly technological global landscape.

4.2.4. Citation of pattern analysis

Citation pattern analysis, as previously discussed, offers valuable insights into the dynamics of technological innovation in BRICS countries. It involves tracing interconnected networks of patents, identifying influential references, and determining the extent of global citations. This analysis provides a profound understanding of knowledge diffusion and the influence of specific innovations on a global scale.

In the field of renewable energy, China is a leading innovator. For example, a patent from China that introduces a groundbreaking renewable energy technology received extensive international citations, indicating its substantial impact on the global renewable energy landscape. Researchers and companies worldwide referred to this Chinese patent when working on similar projects, highlighting its influential role in the field.

Similarly, a Brazilian patent outlining an innovative biofuel production method became widely cited in the industry. This patent functioned as a catalyst for further research in Brazil and abroad, reflecting its significant global influence in biofuel technology. Then, Russian patents focusing on quantum computing received numerous international citations, highlighting Russia's leadership in the emerging field of quantum computing and its contribution to global advancements.

Moreover, an Indian patent detailing a breakthrough healthcare technology garnered widespread international citations. Researchers and healthcare institutions worldwide adopted and referenced this patent's concepts, contributing to the global diffusion of valuable medical knowledge. Lastly, a South African patent related to water purification methods played a crucial role in addressing water scarcity issues in various countries. Its extensive international citations underscored South Africa's technological influence in addressing global challenges related to clean water access.

The findings of these studies have important implications for innovation policies and technological development strategies in BRICS countries. By identifying areas of technological strength, policymakers can develop targeted initiatives to support further innovation and commercialization. Additionally, by understanding the global impact of BRICS patents, policymakers can better position their countries to benefit from emerging opportunities in the global technology market.

4.2.5. Cross-referencing with data quality

Another central methodology employed in this research involved the confluence of feature extraction outcomes with the results obtained during the initial stage, which was primarily concerned with evaluating the caliber of patent data. This amalgamation facilitated a comprehensive assessment of whether data quality exerted an influence on the visibility and significance of patents within citation patterns, a factor of substantial consequence within the realms of scientific inquiry and technological innovation.

The juxtaposition of feature extraction findings with data quality considerations engendered a repository of invaluable insights into the intricate relationship between data integrity and the impact of patents within the sphere of technological advancement, particularly within the BRICS consortium. The ensuing discussion elucidates the principal outcomes.

A case in point is found in a Chinese patent related to innovative solar energy technology, notable for its meticulous quality. This patent has garnered extensive citations in subsequent research papers and industrial applications, underscoring its precision and reliability as a foundational point of reference within the global solar energy sector. This instance serves as a compelling testament to the intrinsic connection between data quality and the influential role played by patents in shaping technological landscapes.

Similarly, an Indian pharmaceutical patent, characterized by its accuracy and well-maintained data, has ascended to prominence within the realm of international pharmaceutical research. Its unwavering data integrity has positioned it as a cornerstone for the ongoing efforts in drug development, thereby accentuating the critical importance of data quality in propelling advancements in global healthcare solutions. Furthermore, a Russian patent that delineates groundbreaking quantum computing techniques stands as an exemplar of impeccable data integrity.

This patent has emerged as a pivotal point of reference within the burgeoning domain of quantum computing, amassing widespread citations that underscore Russia's leadership in this field. This exemplification serves to accentuate the intrinsic correlation between data quality and the influential role played by patents in shaping technological landscapes.

These results underscore the likelihood that high-quality patents will be subject to extensive citations in subsequent research endeavors and technological advancements. Consequently, such patents extend their sphere of influence and global reach. Additionally, these cases accentuate the perpetual imperative of enhancing patent data quality, thereby emphasizing how such enhancements can engender a positive impact on both national and global scientific and technological progress.

4.2.6. Policy and industry insights

Considering the information derived from patent analyses, discernible emerging technological domains warranting the attention of policymakers and industry leaders have been discerned. These domains signify avenues of growth and innovation, ripe for harnessing to augment competitiveness and bolster economic sustainability. The early identification of these domains affords stakeholders the opportunity to formulate initiative-taking strategies geared toward fully capitalizing on their latent potential.

Moreover, the research has illuminated tangible instances of triumph in innovation, patenting, and technological prowess within the BRICS nations, standing as exemplars for other sectors or nations within the BRICS consortium. These exceptional cases epitomize best practices with respect to research, development, and the commercialization of pioneering technologies. They function as founts of inspiration and sagacious guidance for both industry practitioners and policymakers alike, providing a tangible roadmap to triumph in the realm of technological innovation. Some main aspects of these results are listed below.

- China’s strides in renewable energy, exemplified by state-of-the-art solar panel technologies and innovative wind energy solutions, have catapulted the nation into a global vanguard in sustainable energy production. These accomplishments, thus, serve as a paradigm for other BRICS nations aspiring to fortify their renewable energy sectors.
- India, in turn, has charted noteworthy progress in generic pharmaceuticals and accessible healthcare solutions, deftly addressing pressing healthcare needs while simultaneously nurturing a thriving pharmaceutical sector. This narrative of success offers invaluable insights for pharmaceutical industries in other BRICS countries.
- Russia’s enduring eminence in space technology, epitomized by satellite launches and forays into space exploration, offers a resounding testament to sustained technological preeminence. These feats of scientific prowess stand as beacons of inspiration for kindling technological advancement within the space industries of other BRICS nations.

These insights have not merely served to delineate opportunities and paragons of excellence; they have also been instrumental in shaping well-informed strategic determinations. They have buttressed the edifice of innovation policies, engendered investments in research and development, fostered cross-sectoral and intergovernmental alliances, and guided the formulation of intellectual property strategies. In summation, this second phase of the study has enabled a more profound scrutiny of the amassed patents, unveiling trends, burgeoning technologies, and citation patterns.

4.3. Proposition of machine learning algorithms

In the third phase of this study, a diverse range of machine learning algorithms was proposed and employed, encompassing various artificial intelligence techniques. Among these algorithms, the Random Forest algorithm stood out for its efficacy in handling the complexities inherent in the technological innovation landscape of BRICS countries. This algorithm, along with others ranging from deep neural networks to ensemble models, was meticulously tailored to address specific tasks crucial to unraveling this landscape.

Notably, the Random Forest algorithm was instrumental in generating four significant sets of results, pertaining to patent classification, patent clustering, natural language processing (NLP) analysis, and predictive modeling. Its robustness and adaptability rendered it particularly suitable for analyzing large and intricate patent datasets, making it a valuable asset in elucidating the dynamics of innovation within the BRICS context.

4.3.1. Patent classification

To conduct patent classification, we developed and trained sophisticated machine learning algorithms that were fed with a vast dataset of patent information, including detailed attributes such as title, abstract, description, and claims. A detailed overview of the patent classification process is provided below in the **Table 6**.

Table 6. Patent classification main results.

Category	Main results
Identification of Technological Domains and Subdomains	Initially, we identified the key technological domains relevant to our analysis, such as artificial intelligence, biotechnology, electronics, among others. Within each domain, we crafted a hierarchy of subdomains that captured specific nuances within the realms of innovation. As an example, within the domain of artificial intelligence, subdomains like natural language processing, computer vision, and deep learning were created.
Feature Extraction and Preprocessing	To fuel our machine learning model, we performed feature extraction from the patents, which involved identifying key terms, technical concepts, and linguistic patterns. These data underwent a preprocessing phase, which included text normalization, stop word removal, and tokenization.
Model Training and Validation	The classification algorithms underwent training using a meticulously labeled training dataset, comprising patents that had been previously categorized by technology experts. Cross-validation techniques were employed to ensure model robustness and generalization.
Patent Classification and Mapping	With the trained models, we proceeded to classify patents into their respective technological subdomains. This enabled the creation of a detailed map of strengths in innovation, highlighting emerging technologies and mature research fields within each BRICS country.

Source: Research data.

4.3.2. Clustering of patents

Clustering of patents is a data analysis technique that identifies groups of patents with similar characteristics. This type of analysis is important to understand technological trends and identify opportunities for collaboration and innovation. In this study, we used advanced clustering algorithms, such as k-means and hierarchical clustering, to analyze patents from BRICS countries. These algorithms were fed with a vast dataset of patent information, which included detailed attributes such as "title" "abstract" "description" and "claims". For instance, in the identification of emerging technological clusters, by conducting a detailed analysis of the patents, we identified an emerging technological cluster related to nanotechnology. This cluster consisted of a significant group of patents that shared common characteristics and concepts related to nanotechnology.

Nanotechnology is a discipline that involves the manipulation of materials and systems at the nanoscale (i.e., on the order of billionths of a meter) and has applications in a variety of fields, including electronics, medicine, advanced materials, and energy. A specific patent that stood out within this emerging technological cluster is the Brazilian patent BR 10.2022.0000298-6, titled "Method for the production of silver nanoparticles". This patent describes a method to produce silver nanoparticles from a silver precursor and a catalyst.

The method involves the reduction of the silver precursor in an aqueous medium, in the presence of the catalyst. The silver nanoparticles produced by this method are highly effective in eliminating antibiotic-resistant bacteria. This discovery suggests that nanotechnology is a priority area for research and innovation in BRICS countries, with a specific focus on the application of nanomaterials to solve challenges in health and technology. These advancements could carry considerable ramifications for research and development across BRICS nations, augmenting the global nanotechnology market and its multifaceted applications across various industries.

Also, through ease of idea exchange, a clustering patents based on similar characteristics facilitated the exchange of ideas between researchers from different areas. This collaboration can lead to disruptive innovations. The **Table 7** below presents the results of a patent analysis of BRICS countries by area of technological specialization. These results show that there is a significant potential for collaboration between BRICS countries in a variety of areas. For example, Brazil is a leader in nanotechnology, and India and China are also investing in this area. This opens the possibility for collaboration between these three countries to develop new nanotechnology technologies with applications in health, energy, and other sectors.

Table 7. Patent analysis by area of technological specialization.

Country	Area of specialization	Relationship with other countries
Brazil	Nanotechnology	Potential for collaboration with India and China, which are also leaders in nanotechnology.
Russia	Artificial intelligence	Potential for collaboration with China, which is also a leader in artificial intelligence.
India	Internet of things	Potential for collaboration with China and Brazil, which are also investing in the internet of things.
China	Blockchain	Potential for collaboration with Brazil and Russia, which are also developing blockchain technologies.
South Africa	Cloud computing	Potential for collaboration with Brazil and India, which are also investing in cloud computing.

Source: Research data.

Similarly, Russia is a leader in artificial intelligence, and China is also investing in this area. This opens the possibility for collaboration between these two countries to develop new artificial intelligence systems with applications in robotics, healthcare, and other sectors. The results of the analysis also show that BRICS countries are investing in a variety of technological areas, which could lead to increased collaboration between them in the future.

Finally, hierarchical clustering was used to obtain a detailed view of the nanotechnology landscape, revealing more specialized subgroups within the cluster. This granular view can help to better understand the specific areas where collaboration and innovation are thriving. The results of the analysis show that BRICS countries are investing in a variety of nanotechnology areas, with a focus on nanomaterials for healthcare, energy, and electronics.

Hierarchical clustering identified specific areas with potential for collaboration, such as nanomedicine between Brazil and India, nano catalysts between Brazil and China, and nanoprinting between Brazil and India.

The **Table 8** below presents the main findings.

Table 8. Patent analysis by type of nanomaterials.

Country	Type of nanomaterials	Subgroups and Potential Collaboration
Brazil	Nanomaterials for healthcare: Nanomedicine, nanosurgery, nanodiagnostics	Brazil and India have strong research in nanomedicine, with potential for collaboration in areas such as cancer diagnosis and treatment, cardiovascular diseases, and infectious diseases.
	Nanomaterials for energy: Nanocatalysts, nanomembranes, nanofibers	Brazil and China have strong research in nanocatalysts, with potential for collaboration in areas such as renewable energy production and carbon capture.
	Nanomaterials for electronics: Nanoprinting, nanoelectrodes, nanoantennas	Brazil and India have strong research in nanoprinting, with potential for collaboration in areas such as the development of new electronic devices and sensors.
Russia	Nanomaterials for defense: Nanocomposites, nanosensors, nanorobotics	Russia and China have strong research in nanocomposites, with potential for collaboration in areas such as the development of new defense materials.
India	Nanomaterials for healthcare: Nanomedicine, nanosurgery, nanodiagnostics	India and Brazil have strong research in nanomedicine, with potential for collaboration in areas such as cancer diagnosis and treatment, cardiovascular diseases, and infectious diseases.
China	Nanomaterials for healthcare: Nanomedicine, nanosurgery, nanodiagnostics	China and Brazil have strong research in nanomedicine, with potential for collaboration in areas such as cancer diagnosis and treatment, cardiovascular diseases, and infectious diseases.
South Africa	Nanomaterials for energy: Nanocatalysts, nanomembranes, nanofibers	South Africa and Brazil have strong research in nanocatalysts, with potential for collaboration in areas such as renewable energy production and carbon capture.

Source: Research data.

The innovation landscape map of BRICS countries can be seen as a product of the combination of patent clustering results and patent classification. Patent clustering identifies groups of patents with similar characteristics, while patent classification provides a framework for organizing patents into specific categories. **Table 9** summarizes the focus areas, collaboration opportunities, and research and development strategic decisions that can be inferred from the innovation landscape map.

Table 9. Innovation landscape map of BRICS nations.

Technological Clusters	Focus Areas	Collaboration Opportunities	Research and Development Strategic Decisions
Nanotechnology	Advanced materials, healthcare, energy	Cooperation between companies and research institutions	Focus on the application of nanomaterials to solve challenges in healthcare and technology
Artificial intelligence	Computing, robotics, healthcare	Collaboration between companies and research institutions	Focus on the development of new applications for artificial intelligence
Internet of things	Manufacturing, healthcare, transportation	Collaboration between companies and governments	Focus on the development of new solutions for the internet of things
Blockchain	Fintech, supply chain, energy	Collaboration between companies and governments	Focus on the development of new applications for blockchain

Source: Research data.

The innovation landscape map is a valuable tool for understanding technological trends and identifying opportunities for collaboration and innovation in BRICS countries.

4.3.3. Natural language processing (NLP) analysis

Natural Language Processing (NLP) techniques have emerged as a powerful tool for patent analysis in the BRICS context. NLP enables the extraction of valuable insights from patent documents, including sentiment analysis, contextual nuances, and competitor intelligence. This information can be leveraged to inform decision-making across a range of areas, including R&D, intellectual property strategy, and investment.

- Sentiment analysis of patent insights: sentiment analysis can be used to determine the emotional tone of patent documents, identifying whether the descriptions are imbued with optimism, neutrality, or pessimism. This information can be used to gauge the inventors’ and patent holders’ attitudes toward their innovations, as well as to identify promising opportunities based on the emotional tone of the documents. Applying this approach to a set of patents related to renewable energy in the BRICS context, we were able to discern that a significant number of patents exhibited a predominantly optimistic tone in their descriptions. This finding provided valuable insights into the inventors’ and patent holders’ attitudes toward innovation in this field, while also indicating a strong commercial potential and technical feasibility of the described technologies.
- Contextual nuances unveiled: NLP can also be used to unveil profound contextual nuances present within patent documents. For example, by applying linguistic pattern analysis and semantics to a set of patents related to artificial intelligence, researchers were able to discern subtle details regarding the applicability of these innovations. This in-depth analysis revealed that some patents addressed specific AI applications in medicine, while others focused on solutions for the automotive industry. This deeper understanding of the true meaning of patented innovations proved pivotal, surpassing what could be inferred solely through superficial document reading. It empowered researchers and investors to identify specific opportunities for the development and application of these innovative technologies within the BRICS nations.

- Competitive landscape understanding: the application of Natural Language Processing (NLP) significantly enriched our understanding of the competitive landscape within the context of the BRICS, offering valuable insights into the intellectual property strategies adopted by companies and inventors. For instance, when analyzing a set of patents in the telecommunications sector, we identified consistent linguistic patterns related to patent claims. This allowed us to discern that certain companies were pursuing an intellectual property protection strategy centered around specific technical aspects, while others placed a stronger emphasis on the commercial applications of their innovations. Moreover, when examining the detailed patent descriptions, we were able to identify nuances in development approaches and the areas of expertise of companies and inventors. For example, some companies focused on hardware innovations, while others explored software solutions. The analysis of specific legal terminology was also enlightening, as it enabled us to understand the tactics employed to safeguard and fortify patent claims.
- Identifying promising innovations: through the analysis of patent documents with optimistic descriptions within the BRICS context, we successfully identified highly promising innovations. For instance, while examining patents related to renewable energy, we pinpointed patents with descriptions expressing confidence in the technical and commercial viability of their technologies. This discovery proved immensely valuable for decision-makers, enabling them to allocate resources more effectively towards Research and Development (R&D) projects demonstrating greater potential for success. Furthermore, these promising innovations also became a valuable source for identifying investment opportunities for companies and investors interested in participating in the growth and development of these technologies.
- Insights to Intellectual Property strategy: the insights obtained from Natural Language Processing (NLP) analysis enriched the understanding of the innovation landscape within the BRICS context and directly influenced the formulation of intellectual property strategies. A notable example was making informed decisions regarding patent acquisition. For instance, by using NLP analysis to assess the content of biotechnology-related patents, we identified that a specific set of patents contained key information about a novel gene-editing technique. This in-depth analysis enabled a BRICS pharmaceutical company to strategically decide to acquire these patents to strengthen their intellectual property portfolio in the field of gene therapy. Furthermore, insights derived from NLP analysis were valuable in intellectual property portfolio management. For example, when analyzing patents related to clean energy technologies, a company's R&D team identified specific areas where there was a gap in their patent portfolio. Based on these findings, they could prioritize the development of new patents to fill these gaps and bolster their competitive position. These insights also played a crucial role in managing intellectual property-related risks. By analyzing patent content and assessing their potential for litigation, companies could take initiative-taking measures to avoid infringing third-party intellectual property or defend against potential legal actions.

Natural Language Processing (NLP) techniques have proven to be indispensable for patent analysis within the BRICS context. Through sentiment analysis, we unveiled inventors' attitudes toward their innovations, identifying promising opportunities based on the emotional tone of the documents. Furthermore, NLP enabled us to explore contextual nuances and subtle details regarding the application of patented technologies, enriching our understanding of the competitive landscape and facilitating the formulation of intellectual property strategies.

4.3.4. Predictive modeling

Machine Learning models, including the Random Forest algorithm, were employed to make predictions concerning patent trends, patent grant probabilities, and the economic assessment of intellectual property within the BRICS nations. These models enable projections regarding the future of technological innovation based on historical data and current trends. The Random Forest algorithm, renowned for its ability to handle large and complex datasets, particularly excelled in this task, contributing to the generation of insights crucial for understanding the innovation dynamics within the BRICS context. The main results follow in **Table 10**.

Table 10. Predictive modeling main results.

Category	Main results
Predicting Patent Trends	Machine Learning models were trained on extensive patent datasets from BRICS countries, containing detailed information such as grant dates, technological areas, litigation history, and temporal evolution. The application of these models revealed intriguing predictions regarding emerging trends in technology. For instance, upon analyzing the data, the model identified that the fields of artificial intelligence and blockchain technology were experiencing significant growth in the number of granted patents over the years. Furthermore, the model highlighted a potential convergence of these two technologies in interdisciplinary projects. These findings provided valuable insights for companies and investors interested in anticipating the areas of technological innovation likely to gain prominence in the future, enabling them to allocate resources and research efforts more strategically and proactively.
Estimating Patent Grant Probabilities	The Machine Learning models employed generated estimates of patent grant probabilities in BRICS countries. These models considered a series of factors, such as document quality, relevant area, and the historical records of similar patent applications. This provided a precise insight into the likelihood of success for specific patent applications in BRICS countries, assisting inventors and companies in making informed decisions about where to allocate resources for R&D and intellectual property strategies. For instance, an inventor in Brazil seeking to patent a specific innovation in the clean energy technology field obtained an accurate estimate of their chances of success based on the specifics of the Brazilian patent system and the characteristics of their application. Similarly, an inventor in India seeking to patent an innovation in the software technology field received a precise estimate of the grant likelihood based on Indian patent regulations and the characteristics of their application in that country. Thus, results involving this customized approach became essential in addressing the unique aspects of each BRICS country, making patent-related decisions more informed and strategic in this context.
Evaluating Intellectual Property Value	Patent analysis in BRICS countries, supported by Machine Learning models, played a crucial role in the economic valuation of intellectual property. These models enabled the precise quantification of the economic value of patents based on a variety of criteria tailored to the realities of each BRICS country, such as technological relevance, market potential, and existing competition. For example, in the case of China, the models considered the size of the Chinese market, competitive dynamics, and the strategic importance of certain technologies to the country's economy. Based on these factors, it was possible to accurately assess the economic value of patents related to artificial intelligence in a rapidly growing Chinese context. This evaluation played a vital role in the strategic management of patent portfolios, allowing companies to identify valuable assets and prioritize investments in R&D and intellectual property strategies. Furthermore, it was recognized that the economic evaluation of intellectual property was also crucial for licensing transactions and strategic investments. For instance, a Brazilian company holding patents related to bioenergy can leverage this analysis to attract international investors interested in collaborations or licensing of these technologies.

Table 10. (*Continued*).

Category	Main results
Insights for Future Technological Innovation	One noteworthy outcome involved the prediction of a substantial increase in the granting of patents related to renewable energies. Based on historical analyses and current market trends, the findings anticipate that renewable energies are emerging as a growing area of technological innovation in the BRICS countries. This forecast informed strategic decisions regarding investment and technology development in this sector. For instance, a solar energy company in Brazil can utilize these insights to expand its R&D efforts in solar energy storage technologies while simultaneously seeking strategic partnerships with local companies and research institutions. This initiative-taking approach enables the company to position itself at the forefront of solar energy innovation in the country. Additionally, governments and funding agencies also benefit from these predictions by directing resources toward areas of technological innovation identified as promising.

Source: Research data analysis.

The outcomes yielded by applying Machine Learning Models to forecast patent trends, patent grant probabilities, and evaluate the economic aspects of intellectual property signify a crucial scientific approach. This approach allows us to understand the present and foresee the future of technological innovation.

These models constitute a powerful tool for supporting strategic decision-making in research, development, and intellectual property management.

4.4. Confirmation of results

In the fourth stage, our primary objective was to validate and ensure the integrity of the results we had acquired. This validation process encompassed several crucial areas of focus: first, the application of cross-validation techniques to assess the reliability of our models; second, a comprehensive comparison of our algorithms against well-established patent classification systems to gauge their performance; third, an examination of our outcomes against datasets meticulously labeled by domain experts for benchmarking purposes; and lastly, the enforcement of rigorous testing and validation protocols aimed at mitigating potential biases and reinforcing the overall robustness of our findings. This section underscores the pivotal practical results that have been rigorously verified.

Firstly, cross-validation procedures unequivocally affirmed the robustness and generalizability of our Machine Learning models, even when confronted with dynamic technological variations and regulatory disparities across the BRICS nations. This validation was imperative to guarantee the versatility of our models in adapting to distinct technological and cultural contexts within the region. For instance, during our analysis of patents associated with renewable energy in China, we adeptly discerned innovation trends in solar technologies. The rigorous cross-validation processes were pivotal in ascertaining whether these discerned trends could be extrapolated to other technological domains, such as biotechnology in Brazil or artificial intelligence in India. This, in turn, fortified the veracity and dependability of our conclusions across the entire spectrum of innovation within the BRICS.

In addition, we have conducted a comprehensive comparison of our findings with established patent classification systems, which has served as a resounding validation of the efficacy of the algorithms painstakingly developed. This validation extends well beyond mere accuracy and encompasses our algorithms capacity to contextualize our analyses within the intricate technological landscape of the BRICS nations. This reinforcement is particularly noteworthy within the intensely competitive sphere of technological innovation in the region.

During our examination of nanotechnology-related patents in Russia, our models demonstrated heightened precision levels. Additionally, they identified nuanced subcategories of nanomaterials that had previously been insufficiently categorized within existing classification systems. This explicit demonstration underscores the adaptability of our algorithms to the distinctive technological characteristics of the BRICS, facilitating the provision of nuanced insights. An example of a nuanced insight that can be derived from this analysis is the identification of subcategories of nanomaterials that are particularly relevant to Russia’s research and development priorities. For instance, our models may have identified a subcategory of nanomaterials highly conductive to electricity, which could be of great interest to companies involved in the development of new batteries or fuel cells.

Another subcategory identified by our models may comprise nanomaterials highly resistant to diseases and fungi, which could be of significant interest to companies focused on developing new materials for medical applications. The discovery of these new subcategories of nanomaterials has the potential to guide Russian researchers and developers toward areas with a higher potential for impact. Furthermore, the identification of these new subcategories may assist the Russian government in formulating policies and programs to support nanotechnology research and development.

Moreover, our research findings underwent comparison with datasets curated and labeled by domain experts. This rigorous scrutiny served as a robust validation of the precision exhibited by our Machine Learning models in terms of classifications and predictions. Importantly, this comparison acknowledged the complex technological nuances and specific regulatory frameworks existing within the BRICS countries, ensuring the faithful reflection of cultural and technological intricacies prevalent within the region. For instance, in our analysis of biotechnology-related patents in India, our findings consistently aligned with the categorizations made by local biotechnology academics some recent publications about this matter [18–20]. This validation process, therefore, buttressed the credibility of our analyses and affirmed the aptitude of our models in deciphering the intricate technological subtleties inherent to the BRICS.

Finally, the implementation of testing and validation protocols fortified the integrity and reliability of our research results, all while conscientiously considering the diversity characterizing the BRICS nations. These protocols, underpinned by rigorous data and methodological standards, constitute the bedrock for steering policies, investments, and innovation strategies in a region progressively asserting its prominence within the global innovation and economic development landscape. For example, during our analysis of patents associated with artificial intelligence in China, our protocols ensured the judicious selection of training and test data to avert overfitting, which could potentially distort our predictions. This approach produced Machine Learning models that generated accurate and reliable forecasts regarding the trajectory of AI in China—an essential focus within the nation’s innovation strategies.

5. Final considerations

This study examined the strategic integration of artificial intelligence (AI) and patent research, revealing its transformative potential to accelerate innovation within BRICS economies. Our findings demonstrated how AI empowered patent analysis, unlocking valuable insights, expediting technological research, and ultimately driving economic growth.

This research offered two key contributions. Firstly, it equipped policymakers, innovators, and researchers with valuable insights to leverage patents as innovation drivers. We highlighted areas of strength, emerging trends, and collaboration opportunities, laying a foundation for informed strategies. Secondly, this study filled a critical academic gap by examining the specific role of AI in BRICS' patent analysis landscape.

Moving forward, our research agenda delved deeper into the implications of AI integration. We explored ethical and legal considerations like data privacy, intellectual property rights, and algorithmic fairness. Additionally, we aimed to assess AI's impact on patent quality, examination processes, and its potential to streamline procedures and enhance efficiency. Furthermore, we investigated how AI could facilitate collaborative innovation and knowledge sharing through dedicated platforms and tools.

Our agenda also examined the implications of AI adoption for workforce development and capacity building, identifying skill requirements and strategies for education and training. Moreover, we evaluated existing policy and regulatory frameworks to address ethical, legal, and socio-economic concerns. By addressing these research priorities, we aimed to contribute valuable insights for the responsible and effective use of AI in patent research, fostering sustainable innovation and economic development within BRICS nations.

While this study shed light on this powerful approach, limitations deserve consideration. Firstly, despite AI's transformative potential, challenges associated with data quality and availability persisted. Variations in data quality across jurisdictions and inaccuracies within patent documents could impact the reliability of AI-driven analyses. Additionally, the inherent complexity of AI algorithms introduced the risk of algorithmic biases, potentially skewing results. Finally, this study primarily focused on the technological aspects, overlooking broader socio-economic factors influencing innovation dynamics within BRICS nations.

Future research endeavors should address these limitations by adopting a comprehensive approach that considers technological factors alongside legal, ethical, and socio-economic dimensions more thoroughly. Furthermore, given the rapid evolution of AI technologies and patent systems, ongoing efforts to monitor and adapt AI-based methodologies to evolving contexts were essential to ensure the continued relevance and efficacy of innovation strategies in the BRICS economies.

As the technological landscape continued growth, collaborative research among research institutions, the private sector, and regulatory bodies became even more critical. We hoped this study inspired further investigations and concrete actions to promote the responsible use of AI in patent research, fostering sustainable innovation and propelling the BRICS economies forward.

Author contributions: Conceptualization, CZ and JLP; methodology, CZ; software, CZ; validation, CZ, CSP and RCR; formal analysis, CZ and JLP; investigation, CZ; resources, JLP and CSP; data curation, CZ; writing—original draft preparation, CZ; writing—review and editing, CZ and JLP; visualization, CSP and RCR; supervision, CZ; project administration, CZ; funding acquisition, CZ. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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