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Biotechnology Patenting in the BRICS Countries: Strategies and Dynamics

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The BRICS countries (Brazil, Russia, India, China, South Africa) account for 25% of global biotechnology patents. To understand the current and future landscape of the domain, it is important to better understand the capacity of these contributors. Here, we consider the thematic priorities, strategies, and key players of the BRICS countries in biotechnology patenting.

Patents are traditionally utilized to study technology development [1–3]. In domains such as biotechnology, patenting is often preferred to other methods of protecting new technologies (e.g., trade secrets). As a result, patent data provide insight into the actual level of inventive activity, illustrating the dynamics of technology invention in a given domain [4]. Moreover, patents precede the introduction of goods and services, thus forecasting the development and commercialization of new products and technological innovations [5]. Considering the BRICS (Brazil, Russia, India, China, South Africa) countries' patent activities gives some insight into their potential for development, competition, and leadership in future biotechnology markets.

This article is based on data derived from World Intellectual Property Organization (WIPO) IP Statistics Data Center (https://www3.wipo.int/ipstats/keyindex.htm) and the Orbit database (www.orbit.com). The provided patent application statistics are the most up-to-date indicators (in contrast to patent grants that are issued after about a 3-year delay). Patent applications are ascribed to biotechnology based on a unified and internationally followed approach [6] – using the International Patent Classification (IPC) codes (Box 1). An article by Streltsova [7] gives further information on the methodology used for patent analysis of biotechnology.

Dynamics of BRICS Patent Activity in Biotechnology

Biotechnology patent applications filed by the BRICS countries have increased rapidly over the last two decades (Figure 1). This tremendous growth has resulted in the BRICS countries accounting for 25% of biotechnology-related patent applications worldwide in 2014.

While the BRICS countries have all increased activity in biotechnology patenting, they differ in consistency, growth rate, and the underlying factors. In 1994, China was the 16th ranked country in terms of the number of patent applications filed by its residents. As of 2017, it is ranked 2nd globally and the most active of the BRICS group. The biggest factor in this increase is a strong incentive for Chinese researchers to patent: the country's higher education system uses patents as one of the indicators of individual and organizational R&D performance. As domestic patents are easier to obtain than academic publications in high-impact journals, filing domestic applications is a sensible tactic for many Chinese academics [8,9]. The presence of biotechnology patents registered by Chinese firms is obscured by the tremendous activity by academic researchers from numerous Chinese universities.

Brazil and India have also had rapid growth in biotechnology patent activity but are still far from being among the global top 10. Russia and South Africa have experienced less rapid growth recently, but Russia is in the 2nd position among the BRICS countries.

BRICS Capacity and Potential in Biotechnology: Searching for Similarity

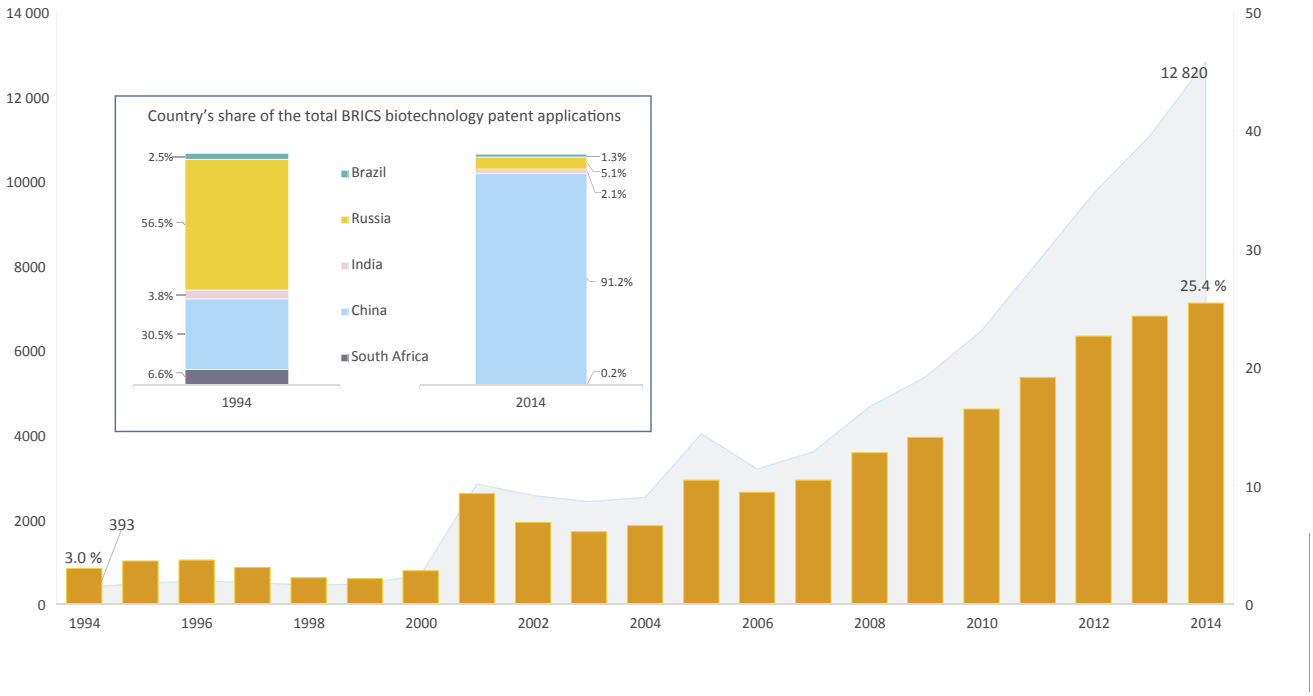
Intellectual Property Protection Strategies

The BRICS countries are diverse in their new biotechnology intellectual property (IP) protection strategies. Chinese and Russian patent applications are predominantly domestic (filed to their national patent offices). Just 4% (in 2014) of China's biotechnology patent applications were filed abroad. For Russia, nondomestic patenting is somewhat higher (17.4%), though still relatively small. Among the many possible explanations for a focus on domestic patenting are a rational IP protection strategy oriented toward exercising IP rights in national markets and/or low-quality inventions that are perceived uncompetitive in global markets [10].

Brazilian patent activity in biotechnology is more balanced – patents registered

Box 1. What Is Considered a Biotechnology Patent?

Items belong to the biotechnology domain if they are registered under one or more of the following IPC codes [6]: C07G 'Compounds of unknown constitution', C07K 'Peptides', C12M 'Apparatus for enzymology and microbiology', C12N 'Microorganisms or enzymes, compounds thereof', C12P 'Fermentation of enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture', C12Q 'Measuring or testing processes involving enzymes or microorganisms; compositions or test papers thereof; processes of preparing such compositions; condition-responsive control in microbiological or enzymological processes', C12R 'Indexing scheme associated with subclasses C12C-C12Q, relating to microorganisms' (http://web2.wipo.int/classifications/ipc/ipcpub/). The list does not include the IPC code A61K 'Preparations for medical, dental, or toilet purposes', to avoid an overlap of biotechnology and medical technology.



Trends in Biotechnology

Figure 1. Dynamics of BRICS Patenting in Biotechnology. The left axis shows the total number of biotechnology patent applications in the BRICS countries, and the right axis shows the BRICS share, in percent, of worldwide biotechnology patent applications. BRICS, Brazil, Russia, India, China, South Africa.

both domestically and internationally (66% vs. 34% in 2014). South African and Indian biotechnology patent holders focus on the international IP market. In fact, in 2014 all South African patent applications were filed abroad. As the South African patent office does not review biotechnology applications to assure quality of claims and novelty of contribution, the validity of their domestic patents must be decided in court [11]. South African biotechnology patent holders appear to value patent offices with an internal review (or invigilation) process, such as the US Patent and Trademark Office (USPTO). India is unique as it is the only BRICS country with commercial interests in patenting abroad, not only based on the high proportion of Indian nondomestic biotechnology patent applications, but also because leading Indian actors in the domain include for-profit firms.

Key National Players in Biotechnology

BRICS biotechnology activity is driven by government policy and funding. IP rights are for the most part held by state-funded organizations: research institutes, universities, and enterprises. This heavy government involvement is apparent in the list of top patent assignees (Table 1).

In Brazil and China the dominant biotechnology players are universities. However, there is considerable difference in the number of entities involved. The patent (inventive) capabilities of China are distributed across many universities, each holding a tiny share of national biotechnology-related patents. Interorganizational cooperation is rare. By contrast, Brazilian patent activity is concentrated in a small number of universities.

India and South Africa are similar, as patents involving state funding appear to be partially or fully assigned to governmental bodies, which thus rank highly among biotechnology patent assignees. One difference is that there is a strong involvement of universities in South Africa and pharmaceutical corporations in India. Indian for-profit pharmaceutical firms (often generic focused) have a large portfolio of biotech-related patents.

Specialized research institutes (of the Russian Academy of Sciences) are at the core of Russia's biotechnology patenting activity. As with China, patent activity is diffuse – there is no clear leading organization.

While the dominance of state-funded organizations in biotechnology patenting demonstrates the interest and support of national governments, it is risky in terms of translation of technology from invention to commercialized innovation. These

Table 1. BRICS National Leaders in Biotechnology Patent Applications from 2010 to 2014

	Brazil		Russia		India		China		South Africa	
	Name	%[a]	Name	%	Name	%	Name	%	Name	%
1.	University of Sao Paulo	8.3	Institute for Genetics and Selection of Industrial Microorganisms	2.7	Council of Scientific and Industrial Research	13.2	Jiangnan University	2.3	University of Stellenbosch	22.1
2.	The Brazilian Agricultural Research Corporation (Embrapa)	6.9	Research Center for Virology and Biotechnology "Vector"	2.0	Dr. Reddy's Laboratories	4.5	Zhejiang University	1.6	Council of Scientific and Industrial Research	18.6
3.	University of Campinas	6.7	Moscow State University	1.8	Biocon	2.9	China Agricultural University	1.4	University of Cape Town	18.6
4.	Federal University of Minas Gerais	5.1	Research Center for Applied Microbiology and Biotechnology	1.6	Indian Council for Agricultural research	2.2	Nanjing Agricultural University	0.9	University of Pretoria	12.8
5.	Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa em Engenharia (Federal University of Rio de Janeiro)	4.5	Institute for Bioorganic Chemistry, named after academicians M. M. Shemyakin and U.A. Ovchinnikov	1.5	Department of Biotechnology (Ministry of Science and Technology)	2.0	Shanghai Jiao Tong University	0.9	University of the Free State	8.1

[a]Share in the total number of biotechnology patent applications filed by the states' residents, adapted from the Orbit database.

stated-funded players have weak incentives for IP utilization and lack production capacity. Factors other than the possibility of generating economic benefit through patenting generally influence government-supported research organizations [12].

Thematic Priorities

Biotechnology includes a variety of domains. In addition to universal biotechnological solutions that do not involve specific applications, there are more targeted inventions. The key domains most frequently referred to (based on IPC code co-occurrence) are analysis of biological materials, basic materials chemistry, chemical engineering, environmental technology, food chemistry, measurement, organic fine chemistry, and pharmaceuticals.

The BRICS countries differ in their choice of thematic priorities and develop their capacities accordingly. 'Pharmaceuticals' – one of the largest biotech-driven fields – is the top priority for India and South Africa. In India's case, pharmaceuticals make up almost one quarter of recent (2010–2014) biotechnology-related patent applications. Russia and China differ greatly with a very low share of their patent portfolios focused on pharmaceuticals (2.8% and 1.1%, respectively).

Biotechnology applications in 'food chemistry' are substantial in Brazil and China (17.7% and 11.7%, respectively). Russia's key thematic priority in biotechnology is the analysis of biological materials (10.2%), also a high thematic priority for other BRICS countries. Finally, 'basic materials chemistry' is an important focus for all five BRICS countries.

Also worth noting is that Brazil, India, and South Africa are now filing more patent applications on 'organic fine chemistry'. While 'environmental technology' is not a top priority for any BRICS country, it has substantial attention from both Russian and Chinese inventors. By contrast, the top thematic priorities in the biotechnology domain for the leading biotechnology patenting countries – US, Japan, Germany, Republic of Korea, Switzerland, France – are analysis of biological materials and food chemistry. They stand out from the others by their share of

'targeted' (nonuniversal) biotechnology-related patent applications. Finally, biotechnology is actively used to develop new solutions in organic fine chemistry, chemical engineering, and basic materials chemistry.

Conclusion

While the BRICS countries differ in their biotechnology patenting strategies, dynamics, and drivers, some similarities are shared:

- Applied research capacity and biotechnology progress has increased significantly, which is reflected in the patent activity dynamics.
- The global biotechnology IP market is not yet realigning, as the BRICS countries tend to patent domestically. The number of international biotechnology-related patent applications is still small.
- Substantial participation of state-supported actors suggests that many patent-protected inventions will not be translated into commercially successful innovations. Consequently, the increased patenting activity in the BRICS countries may not transfer economic activity away from traditional biotechnology centers.
- Each of the BRICS countries has a number of organizations that successfully develop and patent new biotechnologies, which offer the potential of new partners for international collaboration.

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Forum

Therapeutic Opportunities in Intestinal Microbiota–Virus Interactions

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The host microbiota has emerged a third player in interactions between hosts and viral pathogens. This opens new possibilities to use different tools to modulate the intestinal microbial composition, aimed at reducing the risk of or treating viral enteric infections.

Gut Microbiota Shape Enteric Virus Infection

Classically, virologists have considered viral infection a bidirectional (virus–host cell) process with no participation of external factors other than the immune system. However, this classical picture is changing in view of how some viruses exploit specific and direct interactions with the commensal microbiota from the mucosal niches they infect.

Accumulating evidence has demonstrated a key interaction between gut microbiota and intestinal viruses that leads to infection in mouse models. For example, the infection of mice by intestinal-replicating poliovirus [1] depended on the presence of intestinal bacteria. A similar situation has been recently described for the two viral groups responsible for the major percentage of acute gastroenteritis (AGE) worldwide: rotavirus (RV) and norovirus (NoV). RV infections are the leading cause of deaths due to AGE in children under the age of 5, while NoVs are associated with approximately 20% AGE episodes globally. Experiments in gnotobiotic models or animals with depleted intestinal microbiota have demonstrated the role of enteric bacteria in the infections of both viruses. Mice treated with antibiotics showed a decreased infectivity of murine RV [2], and this treatment also caused a similar effect in the murine NoV (MNoV) model [3]. Reinforcing this concept, it has been recently shown that the gut microbiota prompt MNoV replication through an antagonistic mechanism to interferon-lambda (IFN-λ) [4]. These facts conflict with the generally accepted role of the microbiota as a shield against pathogen infection, owing to their immunoregulatory functions and colonization-resistance effect (Box 1).