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Acknowledgement

The International Multilateral and Regional Cooperation Division of Department of Science and Technology (DST) acknowledges the significant contribution of the BRICS STEP document towards developing and amplifying BRICS' efforts to create new ideas, new science and new concepts to relate to the world. The evidence-based analysis in the document provides sufficient ground for creating a product-driven BRICS S&T Enterprise, thereby creating a new identity and global leadership for BRICS. The document will provide significant and insightful inputs for the 4th BRICS STI Ministerial Meeting scheduled at Jaipur on 8th October, 2016.

International Multilateral and Regional Cooperation Division
Department of Science and Technology
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Foreword

सत्यमेव जयते
प्रो. आशुतोष शर्मा
Prof. Ashutosh Sharma

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Foreword

With the motto of "Bringing Responsive, Inclusive and Cohesive Solutions" BRICS is poised to take on a new, challenging but growth oriented role. In this context the initiative of a BRICS Science &Technology Enterprise Partnership (BRICS-STEP) is not only timely but full of promises and new hopes. With the strong and growing evidence of effective scientific collaboration among its scientists, BRICS can realize its potential with bold, responsive, inclusive and cohesive solutions through BRICS-STEP effectively

It is very encouraging to note that this first document on BRICS-STEP has addressed essentially all the important issues related to the feasibility and the success of an S&T enterprise. The document also clearly distinguishes the traditional, on-going scientific collaborations from the proposed enterprise-mode initiative through STEP; such an initiative can clearly provide BRICS a new identity, and can become the model for growing economies.

BRICS-STEP, while recognizing the diverse developmental trajectories among the BRICS nations, strives to leverage the similarities. I hope BRICS-STEP will soon be a reality, and will provide an effective platform for rapid transformation of all the BRICS nations, and thus create world leadership.

(Prof. Ashutosh Sharma)

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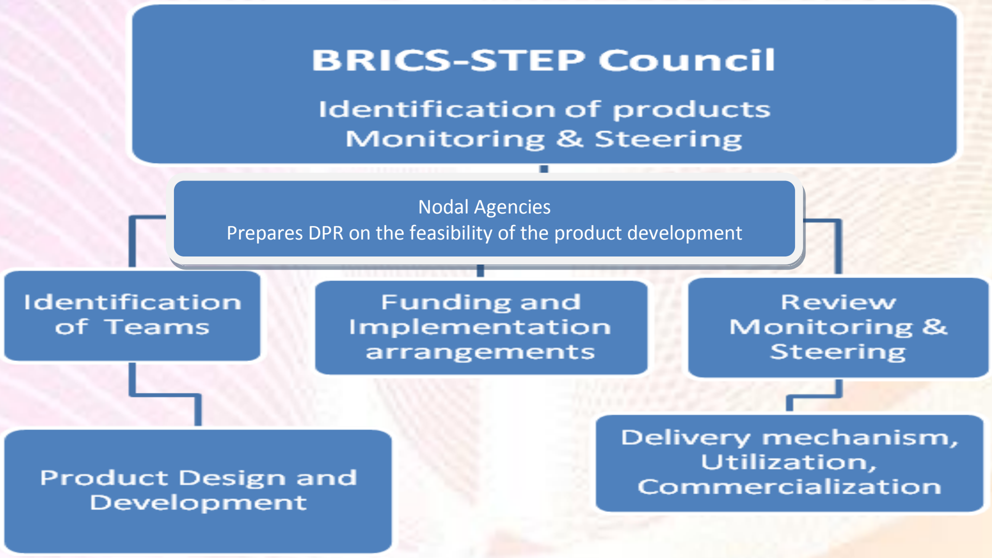
BRICS
INDIA 2016

BRICS-STEP at a Glance

BRICS has been quite successful in enhancing scientific collaborations among the member nations, as evidenced by scientometric analyzes. However, there is potential in BRICS to provide a platform for shaping the economic, social and political contours for a better world, accelerating transformation through Bold, Responsive, Inclusive and Cohesive Solutions. In spite of their inevitable developmental path dependencies, the commonalities of concerns and aspirations far outweigh differences: harnessing potential synergies, BRICS can address current regional and global concerns.

The proposed BRICS S&T Enterprise Partnership (BRICS-STEP) will engage BRICSs' scientists in an enterprise mode that would be driven by S&T challenges, thus creating a new identity for BRICS. The BRICS-STEP programmes will be sustained based on compelling commonalities where synergetic partnership can significantly add value to national aspirations and provide global leadership. BRICS-STEP will complement traditional discipline-driven collaboration with product-oriented programmes in priority and challenging areas, through sustained, critical effort and delivery mechanisms aimed at high impact.

For implementation, BRICS-STEP should be created with an action-oriented structure. The management structure of BRICS-STEP should be designed to allow integration of thoughts and inputs from all the three tiers: policy makers, experts, and young scientists, who should be involved in the industry from the inception. These inputs will be used to design and drive the BRICS-STEP implementation, like choices and prioritization of projects. A project team will be created for each identified project through pooling of required resources from the participating members, ensuring end-to-end product and utilization. The entire process can be overseen by a BRICS-STEP Council.



With the strong and growing evidence of scientific collaboration among its scientists and enthusiastic and energetic support of young researchers, BRICS can realize its potential with bold, responsive, inclusive and cohesive initiatives through an S&T Enterprise Partnership (STEP). In the process, BRICS can develop new ways to relate to the world, creating a model for other societies.





Prologue: BRICS and World Order

P Goswami and Baldev Raj

The emergence of BRICS has added new opportunities and dimensions for shaping the economic, social and political future of the BRICS nations and the world. The opportunities emerging are clear from the fact that the share of the world Gross Domestic Product of these five countries is almost steadily increasing. However, it is also an opportunity to look beyond; BRICS can now position itself to play a major role in alleviating the current global concerns through novel paradigms through Science, Technology and Innovation. However, major challenges remain.

In spite of their growth stories, the BRICS nations still recorded poor Human Development Index in 2014, with Russia at 50, Brazil at 75, China at 90, South Africa at 116 and India at 130. The GDP of the BRICS nations as a percentage of world GDP also showed a wide diversity in 2014 with Russia, Brazil, China, South Africa and India accounting for 3.1%, 2.6%, 17.4%, 0.6% and 7.2% of world GDP respectively. Similarly, GDP per capita in 2014 for Brazil, Russia, India, China and South Africa stood at 5.0, 25.2, 6.6, 15.1 and 13.2 respectively. Given this diversity, a natural question would be whether BRICS could provide a cohesive, effective and sustainable platform.

Yet there is convergence, hope and great potential residing in the opportunities offered by synergetic science and technology. Although the BRICS countries have unique histories and thus natural developmental path dependencies, the commonalities in their development challenges and aspirations far overweigh their diversities. Many of these common aspirations, like meeting the challenges of climate change through Intended Nationally Determined Contributions or achieving the goals of sustainable developments, require strong and sustained S&T solutions.

It is clear that any effective, synergetic and sustained efforts must be based on strong principles of commonality; it is equally important that the efforts go beyond discipline-driven, isolated activities. What is urgently needed is joint development of S&T solutions using their commonalities and greater flow of technology and knowledge. High level of scientific and technological research and innovation among BRICS can effectively contribute to the design and achieve sustainable development goals. However, this calls for a systematic and sustained effort.

There is a close proximity between science and technology. While science remains an autonomous line of human excellence and many areas of contemporary science like cosmology and unified field theory are far removed from immediate technological concerns, there is a need to consider an enterprise for BRICS that involves both science and technology. The concept of a BRICS S&T Enterprise (BRICS-STEP) is founded on this premise.

In practical terms, the capacities and the inclinations in the BRICS nations are diverse, but they can be complementary, like China's global manufacturing capacity and India's leading supply of services. Similar complementariness exists in many areas; this makes the concept of a BRICS-STEP credible.

BRICS-STEP will have certain clear advantages. BRICS, for example, have a better grasp on frugal innovation, informal innovation and of socio-economics of "bottom of pyramid" market. BRICS-STEP can thus aim at dynamic new markets disrupting global corporate and locational hierarchies of innovation. Through BRICS-STEP, the BRICS platform could be given a new identity and a bigger responsibility.

Underlying any science there exists a worldview, like reductionism. A worldview, and the science based on it, naturally encourages certain lines of investigation and interpretation and discourages or even shuns others. BRICS-STEP cannot only enrich the dominant worldview but can also add new dimensions of the investigation leading to transformative science.

Multilateral cooperation can provide the BRICS countries with opportunities to address the perceived failures of their national innovation systems – through using cumulative expertise and resources, sharing best practices and coordinating their actions. Here BRICS-STEP can bring the desired change and therefore give BRICS a new identity. In particular, BRICS-STEP could revisit aspects of the nature of scientific activity and knowledge (constitutive aspects internal to science), social contexts of scientific activity and societal implications of scientific activity and accomplishments.

The success of an S&T Enterprise, however, need careful detailing and integrated planning. This document attempts to highlight the major aspects of a proposed BRICS-STEP. However, the thoughts and the structure presented here are only indicative, aimed at fostering more in-depth discussions.

The results of this initial attempt are, however, very encouraging. From the intense participation of the young scientists to the deep deliberations of the thought leaders and policy makers, BRICS-STEP emerges as not only viable but highly desirable.

BRICS: Emerging Reality

S Relia, A Kumar, K Mandal and S Chandran

Key Points

- BRICS as a part of emerging global reality
- Role of BRICS in regional and global economic scenario
- Global perspective on BRICS as a scientific and technology enterprise

The term "BRIC" was coined in 2001 by then-chairman of Goldman Sachs Asset Management, Jim O'Neill, in his publication *Building Better Global Economic BRICs*. The foreign ministers of the initial four BRIC states (Brazil, Russia, India, and China) met in New York City in September 2006 at the margins of the General Debate of the UN General Assembly, beginning a series of high-level meetings. A full-scale diplomatic meeting was held in Yekaterinburg, Russia, on 16 June 2009.

BRICS is increasingly being recognized as a major scientific and economic block. OECD for example, in its report “Innovation and growth rationale for an innovation strategy” (2007) has called BRICS as the foremost significant economies. China being a key driver of this rise but the other BRICS countries are also playing a key role. The emerging and growth-leading economies (EAGLEs) include Brazil, Russia, India and China as members, along with South Africa, are members of EAGLE’s NEST a second set of countries.

After the Yekaterinburg Summit, seven annual summits were held. India is hosting the eighth BRICS Summit during its Chairmanship which is scheduled to take place on 15-16 October 2016 in Goa. The theme of India’s BRICS Chairmanship is building **B**old, **R**esponsive, **I**nclusive and **C**ollective **S**olutions. The leaders of the member countries have been holding at least one annual meeting. In Durban Summit, the first cycle of summits was completed, each member country having hosted a meeting of leaders. In this period, BRICS has evolved in an incremental manner, in areas of consensus amongst its members, strengthening its two main pillars: (i) coordination in multilateral fora, with a focus on economic and political governance; and (ii) cooperation between members.

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Regarding the first pillar, efforts towards reforming the structures of global governance, especially in the economic and financial fields – Financial G-20, International Monetary Fund, World Bank– received a special emphasis, as well as the reform of political institutions, such as the United Nations. Intra-BRICS cooperation has also been gaining intensity: a broad agenda has been developed, comprising of areas such as finance, agriculture, economy and trade, combating transnational crime, science and technology, health, education, corporate and academic dialogue and security. The financial sector receives a special focus as a new front of BRICS cooperation. At its 6th Summit, the BRICS established the New Development Bank, aimed at financing infrastructure and sustainable development projects in the BRICS and other developing countries. BRICS has also agreed to create the Contingent Reserves Arrangement (CRA), a fund with an initial sum of US $100 billion, which the BRICS countries will be able to use to forestall short-term liquidity pressures. The establishment of the Bank and the CRA conveyed a strong message on the willingness of BRICS members to deepen and consolidate their partnership.

The Fortaleza Summit launched a new cycle for the BRICS with Brazil aiming at incrementally increasing existing cooperation. The meeting's particular focus on social inclusion and sustainable development gave visibility to policies implemented by member countries, and to the contribution of the BRICSs' economic growth to poverty reduction. The theme "inclusive growth, sustainable solutions" is not only in line with the member countries' social policies, but also highlights the need to tackle challenges in the social, economic and environmental fields, and creates new opportunities for the BRICS countries in different areas, including the negotiations on the post-2015 development agenda.

BRICS as a scientific enterprise is catching attention of various international organizations such as UN, OECD, G-20, EU to name a few.

The BRICS members are all leading, developing or newly industrialized countries, but they are distinguished by their large, sometimes fast-growing economies and significant influence on regional affairs; all five are G-20 members. However, BRICS countries have significantly slowed down with South Africa only growing at 1% in 2015 similar to the 1.6% a year from 1994 to 2009. The five nations have a combined nominal GDP of US $16.039 trillion, equivalent to approximately 20% of the gross world product, and an estimated US $4 trillion in combined foreign reserves. However, meeting the economic challenges and achieving the goals may critically depend on innovative and collective S&T initiatives.

BRICS as a scientific enterprise is catching the attention of various international organizations such as UN, OECD, G-20, EU to name a few. This document on BRICS – STEP gives an account of the existing state of S&T partnerships and defines a realm of BRICS S&T in times to come. It also offers a new insight on the scope of BRICS Scientific Enterprise with directions for thematic collaborations that are relevant to and can impact society to accelerated change.

BRICS: Common Aspirations, Common Challenges

P Goswami and Baldev Raj

Key Points

- BRICS Nations have common aspirations, common challenges that need S&T solutions
- BRICS growth strategies may not be sustainable unless supported by innovation
- BRICS-STEP can provide a cohesive and sustained framework for effective solutions

BRICS countries have made significant progress in science, technology, innovation and industrial performance. However, their growth strategies may not be sustainable unless they address common problems in moving to innovation-based development. These include lagging infrastructures and health care systems, inequalities in access to education and income distribution. Furthermore, the emerging economies need to adapt and coordinate their policy agenda. Policies are required to reflect changes in patterns of innovation, such as the growing importance of non-technological innovation, the pervasiveness of open innovation, and increasing multidisciplinary and allied technology convergence. Innovation-based growth is increasingly considered as a response to economic, social and environmental pressures. Strengthening cooperation among the BRICS countries is, therefore, crucial. BRICS summits since 2009 have formulated a policy framework for cooperation in science, technology and innovation, but it has been limited to meetings, conferences and publications; an enterprise approach is required for effective results.

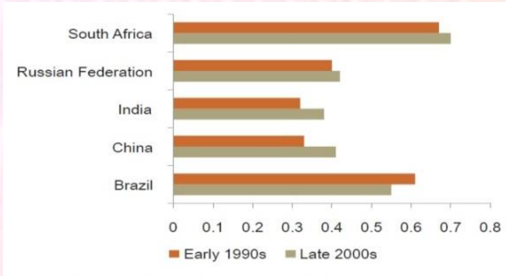

Figure 1: Inequality levels (Gini coefficient of household income) BRICS, early 1990s and late 2000s

The announcement of priorities in 2011 was a step forward. It included joint activities in microelectronics, bio- and nanotechnologies, energy efficiency and renewable energy, food, sustainable agriculture and the use of natural resources. It emphasized the responsibility to make these technologies available to developing countries, integrate traditional knowledge and advanced technologies, increase the food productivity of smallholders and improve socio-economic development conditions in rural areas.

BRICS countries have their unique histories and thus developmental path dependencies. However, while the diversities may differentiate us, common challenges unite us. BRICS-STEP is envisioned as an effective platform to meet these common challenges and common aspirations.

Despite their overall positive evolution in science, technology and innovation, the BRICS countries still lag behind developed economies. Shared, common challenges include low levels of business engagement in innovation, inadequate commercialization of research and development (R&D), weak links within national innovation systems, insufficient

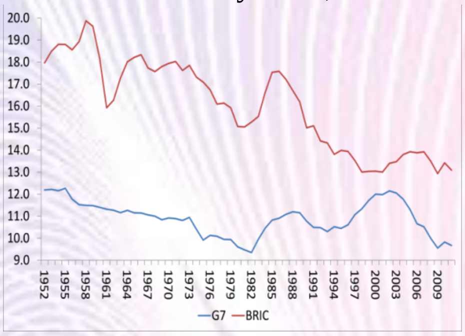

Figure 2: The rate of profit in G7 economics and BRICs (%)

demand for innovation, sectoral imbalances, and inefficient use of natural resources, socio-economic cleavages and uneven involvement of population. These structural disproportions lead to an unsustainable model of BRICS integration into the global economy, as suggested by five indicators identified by the OECD and the Royal Society. In societal terms, like inequality levels (Gini coefficient of household income), the BRICS countries score between 0.3 (Russia, India, China) to 0.7 (S. Africa & Brazil); there has been only incremental improvement between 1990 and 2000 (Figure 1).

In terms of an S&T enterprise, there remain several challenges. The impact of scientific publications and the extent of international scientific collaboration within BRICS is below average. Another challenge for BRICS-STEP would be that although the BRICS contribution to the global scientific literature has been rising rapidly, the number of articles published in top-quartile journals remains below average. However, in terms of total publications, independent of quality, China holds the second position after the US. In terms of patents, despite an increase in the number of triadic patent families (the same invention was disclosed and patented by an inventor in Europe, the US and Japan), the BRICS share is almost 10 times smaller than that of the European Union, Japan and the US. In addition, the brain drain of qualified human resources remains a common problem. For instance, 70 percent of the Chinese people who studied abroad between 1978 and 2006 did not return to China.

Although the profit (Figure 2) by the BRICS was much higher than the corresponding profit by the G7 countries until about 2000, the gap has reduced in the recent years. BRICS- STEP with a vigorous innovation engine could be the solution to maintain the BRICS edge. For this to be realized a careful characterization of BRICS-STEP is required based on the well-articulated characterization.

The common challenges and the common aspirations far outweigh the diversities among the BRICS nations. A sustained collaborative effort through BRICS-STEP can provide transformative values to all the member nations; it will also highlight the unique socio-cultural dimensions of BRIC.

Brave New World: Sociocultural and Philosophical Dimensions of the BRICS-STEP

S Sarukkai and A Sinha

Key Points

- BRICS-STEP can provide alternate cultures and philosophies
- BRICS-STEP can provide more meaningful collaborations between different societies
- Initiative like BRICS-STEP can lead to different paradigms of science and technology

The BRICS-STEP initiative is extremely important for reasons that go beyond the economic, political and the pragmatic. Perhaps most significantly, it is an assertion of new ways of understanding the world and the role of the human in it. In other words, while there are various practical benefits of this initiative, one of the most significant ones is to globally make visible the alternate cultures and philosophies of the BRICS nations and their people.

The history of modernity has created an imbalance of influence of cultures. For various reasons, our modern sensibilities seem to be dominated by the worldviews, ambitions and purpose of a few dominant societies across Europe and North America. This singular approach to the world, and our place in it becomes homogenised and is accepted as part of the necessary ways of living today. One of the most important engines that drive this phenomenon is the belief in the ahistoricity and aculturality of science and technology.

In contrast to what could be called the dominant European imagination, the multiple imaginations of societies and cultures in Asia, Africa and South America. India and China are striking examples of intellectual traditions that created powerful traditions in philosophy, arts, science and technology. Their approach to these activities, however, has been quite different from the way these developed in Europe. Brazil and South Africa may have had relatively longer

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histories of European influence but these societies too are repositories of deep and important intellectual local traditions. Finally, Russia can justifiably lay claim to a dominant part of the European imagination, and as a giant straddling two continents has had a long history of pioneering work in the social sciences, technology and the arts.

BRICS places these alternate frameworks and cultures in the foreground of contemporary practice in S&T. Thus, it not only challenges the current understanding of the world but also offers important alternatives to contemporary living. It serves as a model of ways to integrate other cultural views in developing a global outlook towards a common human civilisation and articulating meaningful futures that will ensure the coexistence of societies in a peaceful and dignified world.

Science and technology offer the possibility of multiplicity of perspectives through their essential relation to human practice. In earlier periods of global connectivity in S&T, the partnership was skewed dominantly towards a few countries and their scientific communities. Now, especially in the digital era, the very contours of the global partnership have been drastically altered. There is now a greater possibility of more meaningful collaborations between various societies. It is in this sense that a new global practice of S&T is emerging.

A partnership between the BRICS countries can contribute immensely to new ways of understanding collaborative initiatives between different scientific communities across the world. Innovative S&T is often driven by local problems; even major theories in science have occasionally arisen as a response to the social experiences of a community. However, the traditional collaboration of science did not allow and even actively suppressed the participation of the local, non-dominant communities. With an initiative like BRICS-STEP, a completely different paradigm can emerge where local concerns can drive S&T, leading not only to new science and novel ideas but also to alternative, innovative, ways of relating to the world.

The BRICS initiative should go beyond the economic and political in visualising a new world of S&T, which would absorb and incorporate the cultural, humanistic and philosophical values of multiple societies, enabling the development of a more universal outlook towards a common human civilisation.

Such new world of S&T, which absorbs and incorporates the epistemological, humanistic and cultural values of multiple societies is destined to form an integral part of global mainstream science. If and when this happens, it will revolutionise how science will be practiced and technology is developed in the years to come. It will also drastically change the way we understand the relationship between science and society, but perhaps, more importantly, between science and the human.

The consideration of the socio-cultural dimensions of the BRICS enterprise may have direct implications for the socio-economic landscape of the BRICS nations, particularly in terms of certain parameters such as pricing strategies or demand and product profiles. These aspects could potentially be considered integral to BRICS–STEP policy planning, its characterization and structure.

BRICS-STEP: Characterization and Structure

K Mandal and P Goswami

Key Points

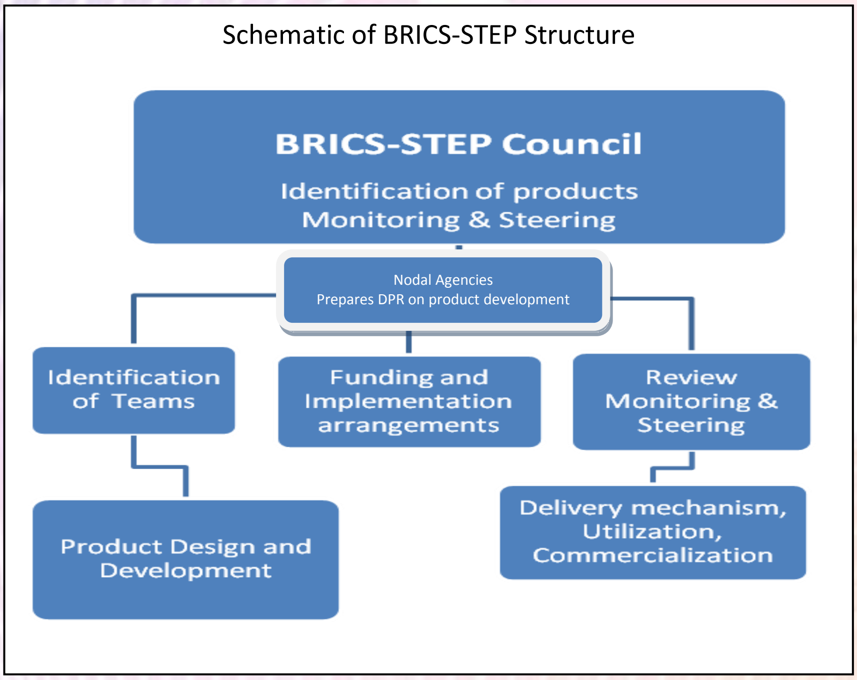
- BRICS-STEP needs careful and well-articulated characterization
- BRICS growth strategies may not be sustainable unless supported by innovation
- BRICS-STEP with enterprise characteristics can provide an effective platform

BRICS-STEP should have the ability to conduct scientific research on an extended basis, involving multiple researchers over an extended time. Generally, the research is funded not only for the science itself but for some application which shows promise for the enterprise. But the researchers, if left to their own choices, will tend to follow their research interest, which is essential for the long-term health of their chosen field. Note that a successful scientific enterprise is not equivalent to a successful high-tech enterprise or to a successful business enterprise, but that they form an ecology. Science as an enterprise has individual, social, and institutional dimensions.

For a successful enterprise partnership, certain unique and defining characteristics are required. Foremost among these is the commonality of the interests of the members in the enterprise programmes, with emphasis on the intersection of interests and challenges to complement or add value to national initiatives. Secondly, the enterprise programmes should have a clear and compelling partnership and effective synergy. The emphasis should be on integration, leading to an end-to-end value added product/service, in place of independent verticals. The enterprise products/services should have global relevance, with an emphasis on frontier research areas that can lead to market/development leadership. Finally, sustainability and growth should be ensured through product planning and positioning based on careful techno-socio-economic analyses, resource mapping and Human Resource Development policies for continuity.

BRICS-STEP should encourage the exploitation of synergies. Policies aimed at building collective capacity in science, technology and innovation will contribute to move up the global value chain. Areas of excellence should be identified, taking into account national technological specializations. BRICS-STEP should be characterized by a clear identification of resource mapping, like the China's global manufacturing capacity and India's leading supply of services.

Stimulating R&D collaboration and commercialization will require mechanisms for cost-sharing and co-investment for joint initiatives in basic and pre-competitive research, as well as funding schemes for joint programmes. It is necessary to build such mechanisms into BRICS-STEP inherently.



BRICS-STEP should have provision for improving infrastructure to facilitate knowledge exchange and technology transfer, develop facilities for mutually beneficial R&D, and promote links between R&D, education and industry.

The management structure of BRICS-STEP should allow integration of thoughts and inputs from all the three tiers: policy makers, experts, and young scientists, with the involvement of industry from the inception. These inputs will be used to design and drive the BRICS-STEP implementation, like choices and prioritization of projects. A project team will be created for each identified project through pooling of required resources from the participating members, ensuring end-to-end product and utilization. The entire process can be overseen by a BRICS-STEP council.

A regulatory framework that fosters labour mobility can characterize BRICS-STEP, involving visa policies, scholarships, research and travel grants, internship programmes and academic exchanges. Finally, evidence-based innovation policies should be supported, with joint data collection on indicators, international collaboration and BRICS macroeconomic performance. Regulation of science, technology and innovation should be performance-oriented, with results-based budgeting, established quantitative and qualitative programme indicators, regular monitoring and performance evaluation.

A successful S&T enterprise also needs a business and an operational model. In case of BRICS-STEP, its operational model should closely reflect its socio-cultural dimensions and its characterization as an enterprise. While such an operational model has to evolve through in-depth engagements of all the BRICS nations, an outline is provided next to initiate such engagements.

BRICS-STEP: An Operational Model

S P Bhuvaneshwaran, S Bhattacharya, T Jamal, S Pohit, K Mandal and P Goswami

Key Points

- BRICS-STEP should have in-built invention-development-production integration
- BRICS-STEP should have a mechanism for sustained operation without breaks
- BRICS-STEP should have an operational model for eventual financial self-reliance

As an S&T enterprise, BRICS-STEP must have an operational and a business model, based on the principles of common aspirations and strengths. There are various options possible, which need to be deliberated among the partners based on careful analyses. The options discussed in the following para are therefore merely indicative.

In terms of Business model, BRICS-STEP could be designed as an independent, not for profit enterprise which should provide innovative solutions to the common problem of BRICS countries. Thus, the output of the enterprise could be products or services. The financing of work on suo moto basis or on innovative solutions can be done by cross-subsidization from revenue generated from contract research.

In terms of an operational model, the model code of work can be on suomotu basis or could be contract research depending on client’s request. The enterprise should also be a storehouse of knowledge generation and should work towards improving harmonizing knowledge standards across BRICS countries[1]. Ideally, enterprise should be a vertically integrated organization for efficient working so that in-house skills can provide solutions for most problems and out-sourcing model of work should not be the dominant mode of work.

BRICS nations have developed innovation capacity in many areas of developmental challenges and have provided new pathways to solve these challenges. Generic drugs that help in removing the cost barrier and thus giving access to critical drugs, exploiting traditional knowledge for cure and prevention of diseases, successful bio fuel innovation and commercialization are some of the examples of BRICS countries innovation that have a far reaching socio-economic impact in developing economies. These strengths and achievements now need to be integrated into a functional business model.

As a scientific enterprise, it calls for enhanced interaction with the invention-development-production components of the innovation cycle, the undermining of specialized disciplinary silos, and a transition from supply pushed innovation system to a demand pulled funding process. Incubation of promising technologies and business accelerator

[1]Currently, degrees across BRICS members are not mutually recognized

needs to be created to support BRICS-STEP.

The BRICS-STEP can be visualized as a cabinet or body framed to foster interdisciplinary research involving the different stakeholders across the research and innovation value chain in the BRICS countries. Key targets would be to develop lab scale outcomes having economical values to upscale profitable commercial outcome. Commercialization's activities can be performed by providing a license to the manufacturer, which in turn would benefit R&D centers for further socio-economic development of the BRICS countries.

BRICS-STEP could include an action plan with objectives, implementation mechanisms, institutional arrangements and specific programmes. It would involve joint strategic intelligence exercises to map R&D needs and assess strengths and weaknesses. Complementarities should be a priority. The overall policies should encourage demand for innovation in all sectors, and stimulate new sectors and non-technological innovations. And the plan should foster innovation-based, inclusive growth. A common agenda should be integrated into BRICS countries' national and international strategies to address socioeconomic inequalities and environmental challenges.

Funding must be diversified, with increased corporate involvement and the creation of venture capital institutions. Technology transfer and the development of knowledge markets must be stimulated, removing barriers to trade and investment, promoting technology alliances and encouraging technology commercialization and transfer. A framework for public-private partnerships should be established to exploit R&D results and technology transfer.

As for any enterprise, however, the success of BRICS-STEP would strongly depend on its strategies. Once again, such strategies should be rooted on the basic characteristics of BRICS-STEP and its value system. It is shown that such formation of strategies is possible.

BRICS-STEP: Strategy and Positioning

S Pohit, K Mandal and P Goswami

Key Points

- BRICS-STEP should be a self-sustaining, competitive and leadership enterprise
- BRICS-STEP programmes should be based on careful techno-economic analyses
- BRICS-STEP should share complementary expertise, capabilities and resources

Strategies of BRICS-STEP should be planned and implemented at all relevant fronts: product, R&D planning, financial and procedural. BRICS-STEP needs to be positioned as a self-sustaining, competitive and leadership enterprise, significantly adding value to the aspirations and the development goals of the member nations.

In addition to the R&D and product planning, BRICS-STEP should have effective customs and tax policies on scientific materials and instruments, promote international networking among R&D institutions and universities, and ensure effective mechanisms for information exchange.

An important part of these strategies would be analysis of BRICS-country-wise preferred trends in choosing countries, regional or global entities for collaboration. Such analyses should also provide information on coverage desired on specific information on successful collaborations**,** recounting key people and their scientific careers. Identification of challenges and bottlenecks in BRICS-wide collaboration should be integrated into the strategy.

Implementation of the strategy should encourage integration for impact through multilateral collaborations, consortia and talent transfer initiatives targeting each section of the stakeholders. Mobility programmes for Bachelor's, Master's and Doctoral students among BRICS nations should be integrated for continuous flow of young talents.

Sharing of complementary expertise and capabilities through technical services and training to MNCs and SMEs can be built into BRICS-STEP for its positioning. Similarly, industry engagement through partnerships, collaborations and technology transfer would give BRICS-STEP a unique strategic identity. "Technology incubation" for the development of proof-of-concept (POC) or a prototype for commercial adoption.

> *The concept (BRICS) also took on a meaning of what the BRICS were not: they were not the Northern developed nations, who were seen in some circles as a forced designed to limit the BRICS growth. In this conception, the North (e.g., the United States and Europe) …, but were now working to either consciously or on a de-facto basis to limit the growth of the BRICS. This conspiratorial theory was always just that, but it did lead BRICS to focus on blaming outside forces for their inability to develop quickly, rather than take the tough reforms they needed to take to grow and innovate.*
>
> Robert Atkinson, President, IITF

Similarly, flexible funding schemes to translate the IP created into market-ready technologies for commercial use can help making BRICS-STEP self-reliant and profit-making.

It is equally important to provide funding Support for Start-ups to attract, develop and nurture outstanding research talent. International talent adds diversity and robustness to the talent pool. BRICS members can facilitate access to science and technology infrastructure amongst BRICS through initiatives like BRICS-STEP joint Research and Innovation Networking Platform.

> *To be successful, it will be important for the STEP initiative to be grounded in the right principles. The first is that to succeed in the innovation economy, nations need to embrace innovation in all sectors, not simply seek to promote a few narrow high-tech sectors. ……Sharing best practices in how each nation is doing this can help the BRICS nations as a group move forward.*
>
> Robert Atkinson, President, IITF

Another area where BRICS-STEP can play a critical role is engagement with various multilateral bodies like IPCC, WTO on issues that are S&T centric. It would be of particular interest to form expert forums where BRICS countries can deliberate on contentious issues and propose a common framework to the multilateral bodies.

Among other key issues which BRICS-STEP strategies should address is the problem of brain drain, more specifically Internal Brain Drain', leading a country to wastefully build up high-level capital and human resources with little impact on local economic systems. For example, skilled manpower may not be available for meeting the demands of domestic industry, while large capacities are created in areas with little demand. BRICS can provide the opportunity of proper utilization of such capacity leading to the collective strengthening of socio-economics across BRICS countries.

Doctoral Students Workshops on an annual basis is a desirable mechanism to listen to the experiences and add value to their suggestions for a pan BRICS young scientist action plan. The success of an initiative like BRICS-STEP, however, would strongly depend on participation by young minds; fortunately, there is enough enthusiasm among the young scientists of India; it is to be hoped that this interest will be amplified and shared during the Conclave.

8 Young Speak on BRICS-STEP

Key Points

- Intense engagement of young scientists from India for developing BRICS-STEP
- Well-articulated ideas on potential collaborations in frontier areas
- Identification of potential collaborators in BRICS countries

It has been emphasized and reemphasized that the success of initiatives like BRICS-STEP will critically depend on the active participation of young minds. The BRICS Young Scientists Conclave provides a great opportunity for engaging young scientists. As a preparatory exercise, meetings with young scientists from India were organized, and their views were integrated into this document; the conclave will provide an excellent opportunity for discussing these and additional items involving young scientists of the other countries, exploring bold, and exciting ideas.

A special meeting of a number of young scientists from academia, R & D institutions and industry was organized to develop exciting and cohesive ideas for BRICS-STEP through interactive discussions. This section provides glimpses of discussions on three focal areas: Computational Intelligence, Energy and Healthcare; additional material is provided in the Appendix.

The scientists were also requested to identify existing and potential participants from the other BRICS countries; the list that emerged from this essentially extemporary effort was quite encouraging (Appendix B).

It needs hardly any emphasis that with a framework for a sustained and enabling framework a lot of young energy can be infused into BRICS-STEP.

Computational Intelligence

N Agrawal, S Saikia, J Chintalapati, S Mohanty and Y Suman

Current trends show that the usage of Machine Learning (ML) and Artificial Intelligence (AI) have many applications, especially in healthcare and energy. Development of products with computer intelligence requires multi-disciplinary expertise and is a good candidate for BRICS-STEP.

Big Data and Analytics with their aids have tremendously changed the healthcare experience for patients and doctors alike. They have been instrumental in implementing ***Precision medicines*** and in making genetic diagnosis possible through learning about new disease genes. The inclusion of AI in healthcare is generating the potential for gaining significant medical insights by translating observations into insights, insights into products and services, thereby increasing the efficacy and efficiency of healthcare. A successful formation of this "BRICS VDP" will help in the following areas:

Proactive Healthcare: By cutting out risky habits in people's lifestyles, preventable diseases will reduce. This could lead to extended life spans, and even set us on the path to escaping death for good.

Predictive and Preventive Healthcare: Real-time prediction and diagnosis of pandemics could now be achieved through the proposed "BRICS VDP"**.**

Telemedicine: Most of the population in BRICS Countries resides in remote areas having little or no access to doctors. Electronic consultations through this platform can provide real-time interactions between patient and healthcare professional.

Energy: Cheap and efficient materials that can store energy such as super-capacitor, capturing of solar energy, material for hydrogen storage, etc.

Transportation: Light, strong and corrosion free material for automobile parts, as well as high-temperature resistant material for engine and other parts of automobile.

Healthcare: Biomaterials for implants such as joints, bone plates etc., medical devices such as artificial heart, pacemaker etc.

Electronics: Efficient material for sensors, magnetic and optical storage devices, integrated circuits etc.

Development of enterprise solutions in computer intelligence will also require large computing capabilities. The emerging paradigm of cloud computing can be harnessed for such requirements.

Energy

M Bhati, S Arunachalam, A Dhar, S PBhuvaneshwaran, K Biswas, S Pohit, Nagaraja Bhat Y V and Sujoy K Guha

Key Points

- Developing wind generated hydrogen as clean and green fuel for transport sector
- Hydrothermal gasification, thermoelectric materials for waste to electricity
- Utilization of renewable energy to reduce air pollution

In December 2015, COP21 **BRICS countries had reiterated their support for plans to develop a UN-led global warming deal.** The targets, although difficult, can be achieved by concerted and committed cooperation among BRICS countries. The BRICS New Development Bank (NDB) has approved its first package of loans worth 811 million dollars for four renewable energy projects in Brazil, China, South Africa and India to be used in the area of green and renewable energy projects. On completion of these projects, they will help to reduce a number of harmful emissions by 4 million tonnes annually.

However, there is significant scope and potential for developing products that can help energy solutions. Some suggested enterprise projects for BRICS-STEP on energy are outlined:

1. **Wind generated hydrogen as clean and green fuel for transport sector:** The local wind potential available at a given site, can be converted into electricity using wind turbines, and this electricity will be further used for the electrolysis of water whereby water is split into hydrogen and oxygen; the wind-generated hydrogen is subsequently compressed, stored, and can be later used in transport sector.

2. **Hydrothermal gasification (HTG)** is the magical key that has the potential to deal with both, the waste and energy monster. The beauty of Hydrothermal Gasification is that it utilizes the water present in the feed, thus eliminating the need forenergy-intensive drying process. It is important to note that all the BRICS nations are stressed with handling MSW, which has moisture content more than 50%.

3. **Thermoelectric materials**/devices can directly and reversibly convert waste heat into electrical energy, and will play a significant role in the future energy management. Different sectors of application include automobiles (car/bikes), heavy trucks and vehicles, petroleum refineries, thermal power plant, nuclear reactor facilities and waste heat recovery from burner/generator in the day to day life.

Development of implementable, cost-effective, maintenance-friendly renewable energy solutions for sectors like agriculture can facilitate rapid and inclusive economic development; here an enterprise approach through BRICS-STEP can play a crucial role.

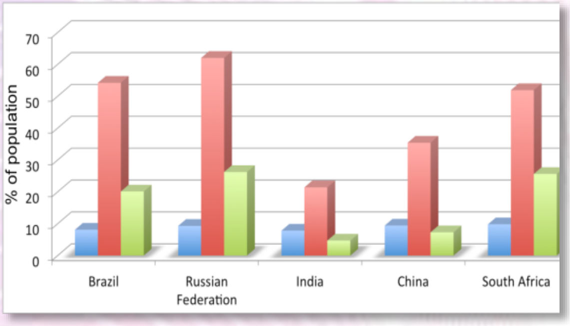
Healthcare

S Anand, N Tarannum, S Ray and A Vaid

Key Points

- Healthcare for the aged population through smart appliances
- Affordable diagnostic/therapeutic methods for non-communicable diseases
- Neo-natal care
- Design of BRICS-specific pre/probiotics
- Integrated holistic healthcare through integration of traditional knowledge

Despite significant differences in geographic locations and living culture of BRICS nations, they face similar health issues calling for increased medical attention. Coordination between research groups across BRICS countries with complementary skills can help to accelerate development and standardization of novel treatment methods.



Percentage of individuals with non - communicable diseases (2016, WHO report)

Lifespan research: The increased life expectancy in all the BRICS countries has created a "new age of the old" which now requires planning, logistics and training for caregivers.

Neonatal care: *A major challenge in BRICS is to reduce neonatal* and *infant mortality rates* by improving the *care* for the mother during pregnancy, childbirth and of Low Birth Weight infants.

Detoxification therapy: BRICS nations can collaborate on traditional systems (e.g. Ayurveda, yoga, unani, siddha and naturopathy, Chinese system, etc.) of medicine have included techniques of detoxification as part of their preventive and therapeutic approaches to overcome diseases.

Mental health: The primary challenge is to identify precursors to mental illness for early diagnosis and to explore new diagnostic technologies for mental illness. BRICS-STEP can adopt a multilateral approach to look for new drug sources in traditional medicine for mental health and well-being.

Clearly, these are only some of the healthcare issues, and there is great potential for developing enterprise solutions for healthcare through an integration of smart healthcare, traditional knowledge and digital database.

BRICS STEP: IPR Policy and Financial System

S Bhattacharya, S Pohit and P Goswami

Key Points

- BRICS Nations have common aspirations, common challenges
- BRICS growth strategies may not be sustainable unless supported by innovation

BRICS-STEP should create and follow a well-designed IPR policy and financial system, keeping in view the regional and the global context.

TRIPS (Trade Related Aspects of Intellectual Property Rights) agreement has forced different countries to modify their IPR to harmonize with its provisions. TRIPS has far reaching implications as it is intertwined with international trade and also changes the context in which technologies are developed nationally. Thus adoption of TRIPS framework has been a contentious issue as it had a major impact on technology development, technology transfer and research, among others. The impact has been more severe for developing and emerging economies as technology development was largely through exploitation of 'Knowhow' (mastering a given technology and running it) and 'know why' (modify and improve upon a technology mainly through reverse engineering).

Coordinated efforts by developing/ emerging countries have contributed to raising concerns and modifications in the TRIPS agreement. BRICS countries in many occasions have joined together to highlight various issues such as compulsory licensing of drugs during health emergencies and high costs, data exclusivity and ever-greening of patents and parallel imports.

A critical introspection of the IPR system and international negotiation forums highlights the strategic understanding and cooperation among developed economies.

> *The BRICS-STEP initiative offers the BRICS nations a chance to focus on their core strengths and in so doing make important contributions to the global economy. It would be a mistake for the STEP initiative to work to try to replicate the technology strengths of the existing technology leaders….. Rather, there is a real opportunity to focus on the unique capabilities the nations share. For example, India has had success with what is known as "frugal innovation" –….. In many cases, nations can build off the success of frugal innovation to move up the value chain to gain competitive advantage in developed nations.*
>
> *Robert Atkinson, President, IITF*

The process of negotiation for a common cause requires strategic cooperation among developing economies which has not been to that extent as desired. An effective, institutionalized mechanism is required through which BRICS countries can raise their concerns in a coordinated manner.

Another important area of cooperation would be designing the IPR systems in each of the BRICS countries through learning of each other's practices. There have been issues within the domestic system between monopoly and competition resulting in anti-trust instruments being applied to curb monopolistic tendencies. However, it has been observed that IPR holders have been stifled by the competition laws. Standards in patents are another area that requires critical understanding. The best practices for intellectual property sharing between academia-industry, technology transfer, trade etc. requires disruptive thinking and new innovation models. BRICS countries are designing their IPR policies to address these challenges. The close reading of these policies exhibits many commonalities as well as new approaches. BRICS can adopt an institutionalized forum for policy making that can benefit individual nations and promote intellectual sharing contributing to developing new technologies and trade.

To make the vision of becoming a leading Global S&T Enterprise the capability to attract, generate and feed outstanding research talent is critical. In order to meet these needs, collaborative R&D among BRICS countries is essential. Collaborative research will aid highly knowledgeable researchers with international talent to get high-class research infrastructure, global international networks and financial resources. STEP should play important role in development of industry relevant R&D based intellectual skills and establishment for possible outcomes for the interchange of talent between the public and private research sectors among BRICS countries.

BRICS-STEP can plan to establish innovation as a commercial application by engaging industries at different stages of research and commercialization range to facilitate knowledge and technology transfer. It should also ensure better alignment between upstream research and downstream commercialization efforts. Sincere search institutes collaborate with various industries STEP has to establish Intellectual Property Rights (IPR) for the mutual benefit of researchers and industrial collaborators. IPR sector will provide technology intelligence and competitive intelligence to facilitate the translation process of technologies generated from STEP and implement new initiatives to encourage innovators. A multi-agency IP mediator can be envisioned to expand the innovation capacities of local enterprises through enabling and optimizing their businesses, products and services.

There is strong, existing S&T collaborations among the BRICS nations. The urgent requirements are to transform these strengths into an S&T enterprise like STEP Building on experiences and competencies.

BRICS-STEP: Building on Experiences and Competencies

BRICS Collaborations: Rising Scientometric Evidence

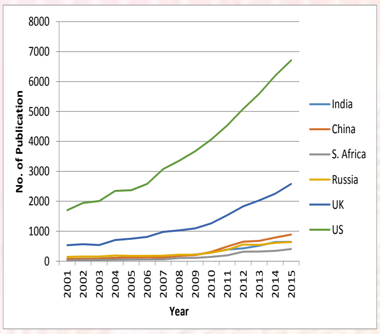
N Kumar, S Bhattacharya, TA Abhinandan, S Arunachalam, M Bhati and AK Das

Key Points

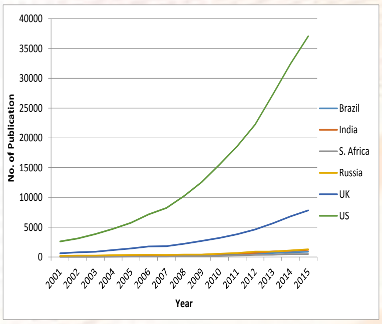
- Scientometeric analyses & patent mapping show rising BRICS collaborations
- Second-moment (h-index) analyses showing growing BRICS competency
- BRICS patents capture 37% & 36 % of the total world patents in energy & health care

Scientometric, as well as patent landscaping, show that formation of BRICS has led to a rise in scientific collaboration as well as patenting activity. These analyses provide evidence for the feasibility of BRICS-STEP. The emergence of international collaboration as an important component of global research has a strong rationale. Research is increasingly becoming highly capital intensive, highly interdisciplinary requiring varied complementary skills and becoming a major driver for new technologies. Knowledge production is thus taking the characteristic of an enterprise leading to strategic linkages for knowledge production and exploitation. International collaboration among countries is happening with governments creating frameworks to develop partnerships that can enable the participating countries to overcome their research gaps and develop mechanisms that can lead to useful knowledge that is jointly produced. The emergence of BRICS is thus an important development that can help countries in this group to *produce and exploit knowledge*, this can also be called as science, technology and innovation (STI) that can help to address developmental challenges and create new products for the global economy.

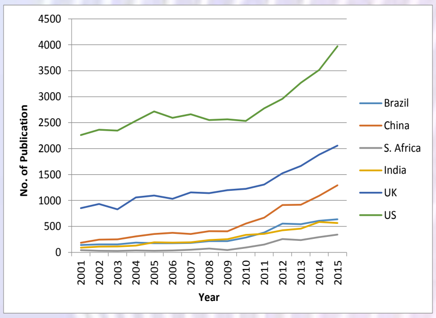
Figure (a-e): Collaboration of BRICS nations with other Countries (2005-2015)



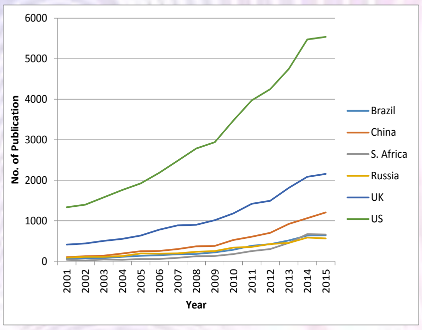
(a) Brazil



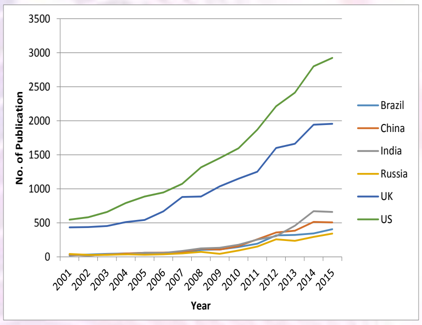
(b) China



(c)South Africa



(d) India



(e) Russia

Since major emphasis of the policy makers of these countries is to develop a culture of S&T enterprises, it is imperative to visualize the S&T activities in these countries. Evidently, scientific publication and patents are considered one of the key indicators of science and technology development. It also reflects the degree of scientific activities, which directs the future research agenda of a country. The issue is complicated by the fact that a country's scientific capability plays a key role in its economic progress that fosters advancements in the scientific and technological (S&T) research. It was observed that the European Union (EU) and the United States published a larger share of the world's total scientific publication, which indicates disparities in the publication output between developing and developed countries. Further, the scientific publication output in Latin America, South East Asia, North Africa, Eastern Europe and Sub-Saharan Africa has shown an increasing trend but Russian publication output share indicates a slight decline in the world publication output during 2009. This attracted the attention of scholars and policymakers' to analyze publication growth in Russia and more particularly in emerging economies like Brazil, Russia, India and China commonly known as BRICS region. There is a major concern for BRICS countries because the share of research publications is comparatively low except China. Further, BRICS nations are projected to be the emerging economies in the coming years and expected to play an important role among the developing countries. This is reflected on many fronts i.e. economic, military, political, scientific and S&T.

Based on recent literature in this area, it was seen that there is a paradigm shift in the Scientific of Collaboration in BRICS countries since the year 2005. All the BRICS countries have registered growing trends with joint publications and emerging trends of collaboration in paper publications is presented in Figures (a-e). Data analyses carried out based on the Web of Science has also strengthened these observations.

Second-moment (h-index) Analyses

K Mandal and P Goswami

Digital, online databases now offer new and exciting opportunities for profiling and monitoring scientific performance. **h-index** as an alternative to other bibliometric indicators is now well established as it reflects both the number of publications and the number of citations per publication. It is increasingly being considered useful for comparing different researchers in similar fields as it endorses that if the h-index is similar for the two researchers, their overall influence in the scientific field is similar, independent of the number of papers written or the number of overall citations. Web of Science and Scopus collect and organize citation counts to calculate an individual's h-index. Google Scholar does it via Google Scholar Citations. However, each source may determine a different value of the h-index for each individual. The main advantage of h-index over other bibliometric indicators, such as total number of papers or total number of citations is that it measures the both quality and quantity of scientific output simultaneously. It provides a robust measure of sustained and durable performance. Also, the h-index does not have an artificially fixed time horizon.

Indexes in scientometrics are based on citations. However, in contrast to the journal impact factor, which gives only the ranking of the scientific journals, ordered by impact factor, indexes in scientometrics are suitable for ranking of countries. Hence it becomes imperative to analyze the h-index of BRICS countries which give a lead to BRICS-STEP initiative.

Scimagojr data reveals that among the BRICS countries, China leads in terms of h-index with 26% of total h-index over the years 1996-2015, with others as Brazil (19%), India (19%), Russian Federation (19%) and South Africa (15%). Even in the three sectors namely computer, energy and health, China continues to hold the top rank among BRICS countries.

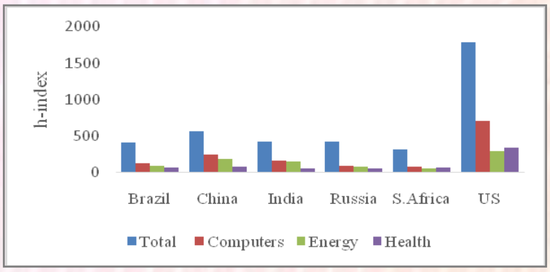


Figure: h-index for BRICS countries and US

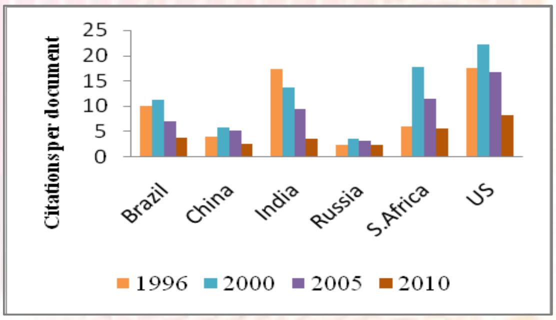


Figure: Fifteen years trend of citations per document for BRICS countries and US

Roadmap for future

The publication, patent activities and OA may be the core dimension to address the efficiency of S&T activities among BRICS countries to analyze the trends/strength of scientific development through the application of some Scientific Indices. This would enable identification of strengths of different subject areas by different BRICS countries and to develop joint programs.

Patent landscaping of Energy, Healthcare and Computational Intelligence Sectors in BRICS

H Purushotham and S Majumdar

The patterns of patenting activity in the above-mentioned specific technology domains for the years 2001 to 2015 pertaining to BRICS countries (Brazil, Russia, India, China, and South Africa), US and European regions. The patent search is carried out using the commercial patent database. The search strategy to extract the data includes using specific code of *Cooperative Patent Classification* and 'patents granted' between years 2001 to 2015.

In general, if the number of granted patents in BRICS countries are taken together and compared with the number of granted patents in the US and European regions, it was found that the total number of granted patents in BRICS Countries is greater than the number of granted patents in the US and European region in the energy sector. And in the healthcare and computational intelligence sectors, number of granted patents in the US is higher, followed by BRICS and European region.

The ratio of total BRICS patents to total global patents in energy, healthcare and computer intelligence during 2001-2015 are 0.37, 0.36 and 0.16 respectively with the largest share from China.

Figures show granted patents in selected technology domains of Energy, Healthcare and Computational Intelligence sectors in BRICS countries

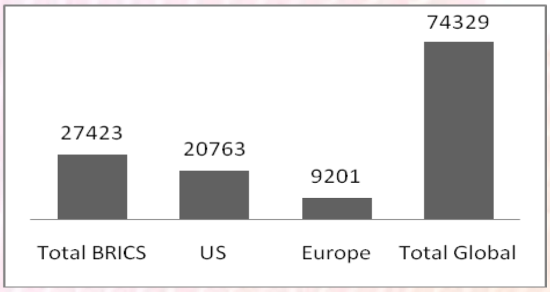


Figure. 1: Energy

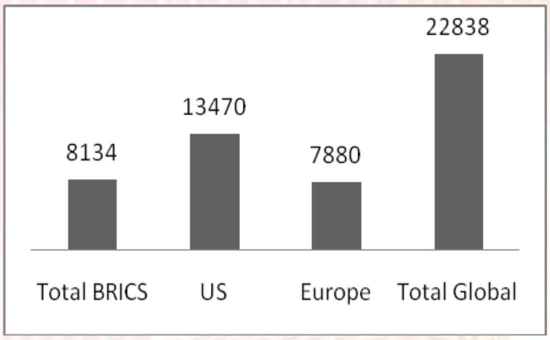


Figure 2: Healthcare

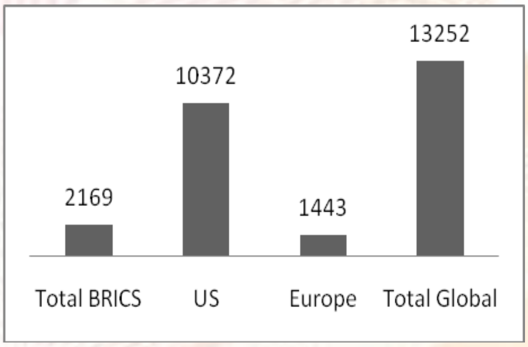


Figure 3: Computational Intelligence

Epilogue/Outlook

P Goswami and Baldev Raj

The world growth trajectory in the next few decades will be almost certainly driven by science, technology and innovation; the BRICS growth trajectory has to be aligned and above it. With its large talent pool and growing economies, this is an opportunity that BRICS should not miss; while BRICS has the advantage, the world has other options.

With BRICS-STEP as the stepping stone, it is necessary to look beyond with a cohesive growth trajectory, accelerated by momentum for innovation, realized through connecting of young minds. There are many areas where BRICS can create disruptive innovations, leading to accelerated growth and global leadership; naturally, strategies will play a key role in its success.

BRICS-STEP should take advantage of emerging paradigms like cloud computing. Growth in the cloud computing market will also be driven by growing adoption of technology among small and medium enterprises (SMEs). A BRICS Cloud Computing Platform (BCCP) can be envisioned to provide end-to-end cloud-computing solutions with complete functionalities ranging from integration of internal and external clouds, automation of business critical tasks, and streamlining of business processes.

Another area where BRICS-STEP can play a leadership role is healthcare. Essentially all the BRICS nations today face a spectrum of healthcare challenges, from increasing life spans to neo-natal care to mental health; most of these challenges are also global in nature. Meeting these challenges requires new paradigms of healthcare. A BRICS Integrated Smart Healthcare (BISH) initiative can be designed to engage in developing relevant and competitive healthcare solutions by integrating traditional knowledge with digital database and modern healthcare appliances with computer intelligence.

An area of immediate relevance to BRICS is sustainable habitat. Sustainable habitats require cooperative and complementary actions among all stakeholders. The question of sustainable and adequate habitat is a challenging issue for all the BRICS nations with low per capita land. A BRICS Habitat Research Initiative (BHRI) can address challenges and seek implementable S&T solutions in all aspects of habitat, integrating unique socio-economic factors of BRICS.

With the strong and growing evidence of scientific collaboration among its scientists, BRICS can realize its potential with bold, responsive, inclusive and cohesive initiatives through an S&T Enterprise Partnership (STEP), creating hope for other developing economies.

Appendix A: Inputs from Young Scientists on BRICS-STEP Collaborations

Scientometric Analysis

A large body of literature applying scientometric analysis has shown BRICS countries emergence as a major player in global research. Their share of new contributions to the universe of scientific knowledge has been growing faster than the world average; more importantly, the share of their contributions involving (bilateral and multilateral) collaborations has been growing even faster. Some new research hot spots can be observed in BRICS countries. International collaboration's pattern is changing with emerging countries exhibiting increasing collaboration among themselves; collaboration among BRICS countries act as a major factor for this new trend. BRICS acts as one family and tries to provide the fruits of STI and to share the scientific solutions for the betterment of all the people of BRICS countries is the underlying goodwill of all the Presidents and Prime Ministers of BRICS countries who have frequently expressed this through several declarations. Thus the need for importance of scientific collaborations between BRICS cannot be overemphasized.

Publication trends and emerging S&T areas among BRICS countries

Available statistics show that scientific output in BRICS countries are not comparable as in the developed countries, except China, which has shown a fast increase in its publication output over a couple of years. A comparative status of scientific output and estimation of S&T publication of BRICS countries provides a useful starting point for strengthening research collaboration among BRICS countries. A few indications (as in Table 1) from scientometric analysis of BRICS research output is given to illustrate the huge potentiality that exists for research collaboration amongst themselves. To make a future strategy and compete with the developed countries in the area of S&T, it is required to analyze the Scientometrics indicators among BRICS countries. It would help in providing innovative, viable solutions to common problems to the BRICS in the area of S&T. In order, the scientific collaboration to be efficient, it is necessary to quantitatively measure and analyze the scientific contributions among BRICS. This is primarily due to the substantial heterogeneity prevailing among BRICS in terms of resources, expertise, technology, facilities, geography, demography, economy etc. One of the ways to address the efficiency of scientific collaboration among BRICS is to identify and select proper scientific index as applicable to BRICS. Apart from traditional indicators, there is a need to create hybrid indicators that include socio-economic indicators also. In other words, a composite indicator that captures research in a more comprehensive manner.

Open Science and Altmetrics in BRICS Countries

Open Science, that promotes proliferation of open access (OA), may be considered an important dimension to analyze S&T activities among BRICS countries. Directory of Open Access Journals (DOAJ) data shows that 1498 OA journals are published from BRICS nations, having 16.16% of global coverage (as on 25 August 2016). Open DOAR (Directory of Open Access Repositories) data shows that 260 OA repositories are in operation from BRICS nations, having 8.17% of global coverage (as on 25 August 2016). It was observed that Brazil and India are most supportive of Open Science causes, while other countries are catching up.

Altmetrics or article level metrics has gained importance in the scholarly world in recent time. The earlier indicator of productivity of scientific publications, i.e., citations count, has several limitations, while Altmetrics captures various parts of impact a paper or work can have, viz., number of times one paper is viewed, discussed, saved, cited and recommended. The OA journals in BRICS countries have not yet started using Altmetrics tools for generating Altmetric score. Therefore, publication, patent activities and OA may be the core dimension to address the efficiency of S&T activities among BRICS countries to analyze the trends/strength of scientific development through the application of some Scientific Indices. This would enable identification of strengths of different subject areas by different BRICS countries and attribute to develop joint programs.

Table-1: Number of Papers in Top Five Areas in BRICS*

	Brazil	Russia	India	China	S. Africa
Brazil		Physics Particles Fields (275); Astronomy Astrophysics (151); Physics Nuclear (87); Physics Multidisciplinary (59); Oncology (35)	Physics Particles Fields (158); Astronomy Astrophysics (93); Physics Nuclear (66); Materials Science Multidisciplinary (29); Physics Multidisciplinary (29)	Physics Particles Fields (268); Astronomy Astrophysics (155); Physics Nuclear (84); Physics Multidisciplinary (52); Oncology (42)	Physics Particles Fields (121); Astronomy Astrophysics (67); Infectious Diseases (28); Physics Nuclear (27); Immunology (20)
Russia	Physics Particles Fields (275); Astronomy Astrophysics (151); Physics Nuclear (87); Physics Multidisciplinary(59); Oncology (35)		Physics Particles Fields (200); Astronomy Astrophysics (156); Physics Nuclear (73); Physics Multidisciplinary (52); Materials Science Multidisciplinary (22)	Physics Particles Fields (321); Astronomy Astrophysics (219); Physics Nuclear (101); Materials Science Multidisciplinary (94); Physics Multidisciplinary (93)	Physics Particles Fields (122); Astronomy Astrophysics (89); Physics Nuclear (30); Physics Multidisciplinary (21); Zoology (15)
India	Physics Particles Fields (158); Astronomy Astrophysics (93); Physics Nuclear (66); Materials Science Multidisciplinary (29); Physics Multidisciplinary (29)	Physics Particles Fields (200); Astronomy Astrophysics (156); Physics Nuclear (73); Physics Multidisciplinary (52); Materials Science Multidisciplinary (22)		Physics Particles Fields (179); Astronomy Astrophysics (132); Physics Nuclear (69); Materials Science Multidisciplinary (61); Chemistry Physical (50)	Physics Particles Fields (77); Astronomy Astrophysics (74); Chemistry Physical (42); Chemistry Multidisciplinary (37); Materials Science Multidisciplinary (31)
China	Physics Particles Fields (268); Astronomy Astrophysics (155); Physics Nuclear (84); Physics Multidisciplinary (52); Oncology (42)	Physics Particles Fields (321); Astronomy Astrophysics (219); Physics Nuclear (101); Materials Science Multidisciplinary(94); Physics Multidisciplinary (93)	Physics Particles Fields (179); Astronomy Astrophysics (132); Physics Nuclear (69); Materials Science Multidisciplinary (61); Chemistry Physical (50)		Physics Particles Fields (120); Astronomy Astrophysics (71); Physics Nuclear (32); Multidisciplinary Sciences (28); Physics Multidisciplinary (20)
S. Africa	Physics particles fields (121); Astronomy astrophysics (67); Infectious diseases (28); Physics nuclear (27); Immunology(20)	Physics particles fields (122); Astronomy astrophysics (89); Physics nuclear (30); Physics multidisciplinary (21); Zoology (15)	Physics particles fields (77); Astronomy astrophysics (74); Chemistry physical (42); Chemistry multidisciplinary (37); Materials science multidisciplinary (31)	Physics particles fields (120); Astronomy astrophysics (71); Physics nuclear (32); Multidisciplinary sciences (28); Physics multidisciplinary (20)	

**Figures in brackets represent number of papers*

BRICS-STEP: Patent Landscaping

Among the few available indicators of technology output, patent indicators are probably the most frequently used as patents are a key measure of innovation output. Patents reflect the inventive performance of countries, regions, firms, etc. BRICS countries showed their visibility individually by positioning themselves in top 30 countries in terms of patent counts (USPTO). After merging the patent counts contributed by all BRICS nations, BRICS is strengthening their position to 8 places and contribute 3% of total patent counts (Figure1).

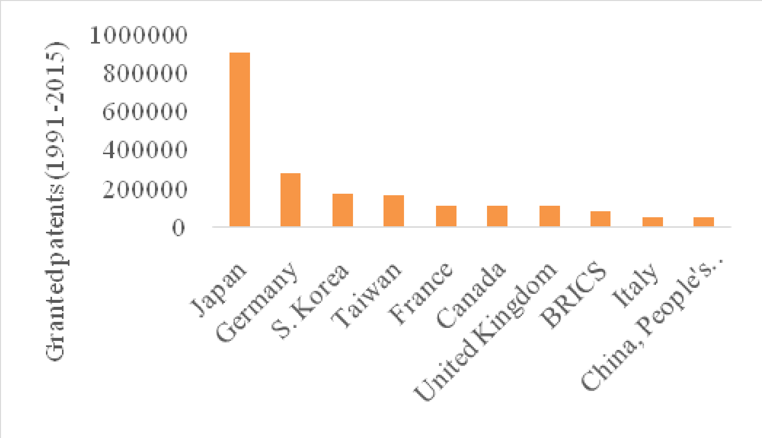
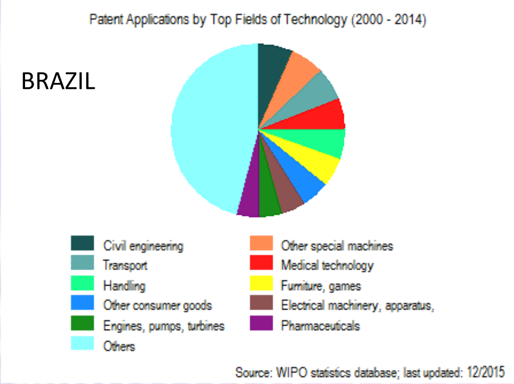
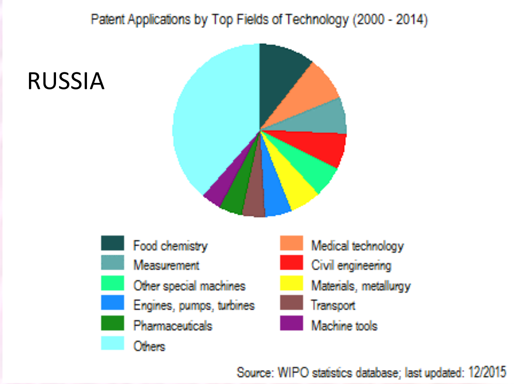
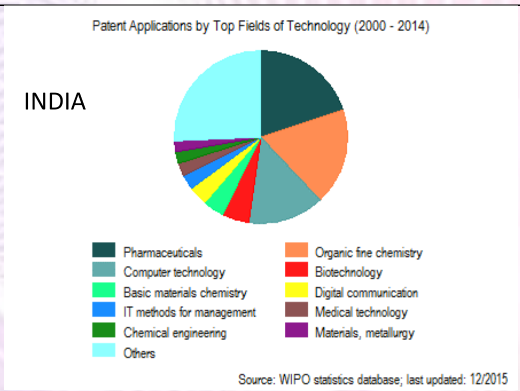


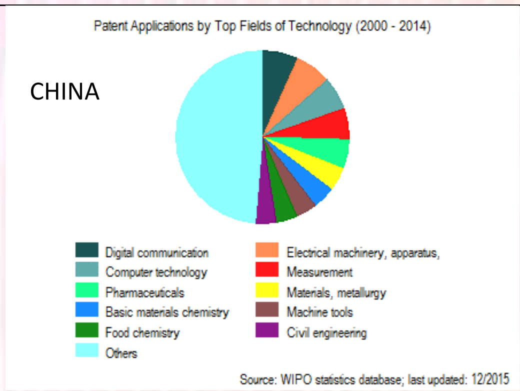
Figure 1: Patents Granted by Country of Origin

Further analysis (Figure 2) shows that all the BRICS nations are actively involved in IP protection and therefore the trend of their patent applications has been over several sectors. It was observed that Brazil leads in civil engineering technologies, Russia in food technology, India in pharmaceuticals, China in digital communications and South Africa in civil engineering. This analysis gives a fair idea of the expertise available in respective countries and could be helpful in decision making while conceiving joint programs.









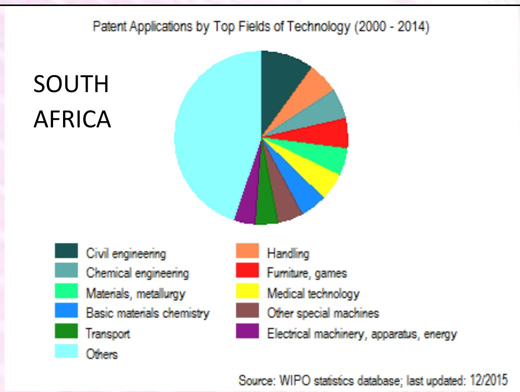


Figure 2: Patenting activity in BRICS countries in top field of technology from WIPO report *(Source: WIPO statistics database)*

Role of Computational Intelligence in tackling healthcare challenges in BRICS countries - A case of Virtual Data Platform

To address the various healthcare challenges using ML & AI, there is a need of huge amount of diverse healthcare data from all BRICS nations in order to predict and diagnose better. This data will come from several disparate sources in large volumes and processing it efficiently is a challenge; fusing the data to form a central knowledge-base is also a known research problem which has to be solved for valuable information extraction. Therefore, the next big challenge is to develop a system that can be applied to the entire data available from different sources, automatically detect problems, provide analysis and a set of solutions for the problems. From these solutions, the doctors can choose the best one and discover new techniques for patient care. Such a system requires large data handling which requires huge computational capabilities. BRICS countries have made quite significant developments in the area of IT infrastructure but recent challenges have made it pertinent for them to enhance their computational capabilities through sharing mode. A virtual data platform can be extremely helpful in synthesizing their individual computational capabilities towards achieving a level where they can't reach individually. Hence we propose to build a joint **Virtual Data Platform** (VDP) by all BRICS nations, where a variety of healthcare data will be hosted/ uploaded by BRICS nations. Data that can be collected from various Government labs, Regulatory agencies, Diagnostic centers and other relevant sources for developing ***Precision medicine***.

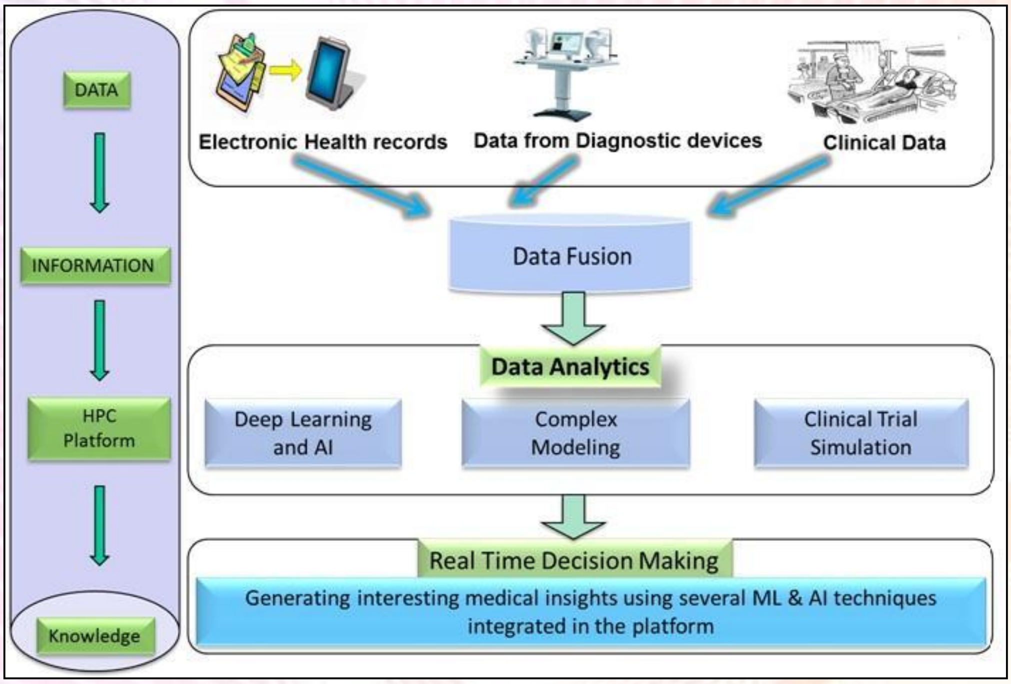


Figure: Virtual Data Platform Architecture

Though the value-addition by integrating the above-listed data is huge, there are two major challenges that need to be addressed for VDP establishment and they are:

1. **Lack of standardization in healthcare data format:** Lack of standardization in health related data is another prevalent problem in most of the BRICS countries, this virtual data platform can help in bringing uniformity in this data. This will help in achieving interoperability between systems; and meaningful statistical analysis; reduction in duplication of effort and redundancies. Standardization might

include Classification of Diseases, Systematized Nomenclature of Medicine, Digital Imaging and Communications in medicine etc. [5].

2. **Huge computing resources required for complex models execution:** Pharmaceutical researchers in today's time use high-quality 3D molecular dynamics models to design targeted drug treatments. This may require millions of calculations per second.
   Both of these challenges can only be solved by considering huge computing capability in VDP and availability of complex models using ML & AI for data crunching and analysis.

- **The role of High-Performance Computing (HPC)** can play a big role in the VDP by solving scientific complex problems quickly, leading to fast analysis and decision making. Here research work focuses on reducing the ETA (Estimated Turnaround Time) of complex models processing through parallel processing using a VDP which incorporates high computing capabilities.
- **Data Fusion and Deep Learning:** The VDP will result in the collection of a mountain of unstructured and largely inaccessible information gathered in different medical archives, public and private sector hospitals, government databases, etc. This data is rich, and we need the right tools to mine it. It can be studied and analyzed to extract patterns and behaviors, exceptions that exist in it, which can guide in drawing useful insights which otherwise were unknown and hidden in data, making decisions for effective diagnosis thereby helping to build better diagnostic machines. Unfortunately, much of this data is not being used to improve the diagnosis and treatments of patients.

The proposed "**BRICS VDP**" with HPC capabilities can help for processing of disparate and incongruous data sources in real-time. The harmonized data can then be used for generating interesting medical insights using several AI techniques integrated into the platform. ***Deep learning (DL)*** techniques can be applied for handling voluminous big data. Until recently, a set of rules were created to manually select a tiny subset of the massive amount of information available, which resulted in softwares which were only as powerful, comprehensive, and flexible as this set of rules. In contrast, ***DL*** automatically examines all the available information to automatically discover, without human intervention, which parts are informative for the task at hand which enables it to handle a broad spectrum of diseases. With such useful insights, better tools can be designed which will augment doctors, clinical technicians, healthcare community workers and make it possible to enforce actionable diagnostic insights in real time from millions of prior patient cases and other medical data. Such tools can increase what each individual doctor can achieve by multiplying their effectiveness.

Computational Intelligence for discovery of new materials:

In the meeting of S&T ministers of BRICS countries held in February 2014 at Kleinmond, South Africa, it was agreed to intensify cooperation in science, technology, and innovation, for equitable growth and sustainable development. While China would lead the new and renewable energy, and energy efficiency program, India, and South Africa would lead the Biotechnology program [6]. Much of these innovations rely on discovery of new materials, which directly or indirectly help in research. The world is now moving towards data-intensive innovation and discovery, where new discovery can be made from the information stored in large databases using Computational Intelligence (CI). The existing databasesdoes not include all the materials that have been discovered and still the material that remain undiscovered is quite large. Some researchers have opined that the way human genomic studies have paved a new way for treatment of diseases, the "material genome" could help discover new materials for application in various sectors, twice as fast and at a fraction of the cost [7]. The phrase "material genome" has been invented and copyrighted by Zi-Kui Liu of Pennsylvania State University [8]. Just like biological information is encoded in DNA base pairs, in the same way, may be the material properties are encoded in the atoms, electrons and the crystal structure of the material, which they term as "materials genome". The proposed ***"VDP"*** can store the properties of different materials obtained from experiment, theory as well as computation, and ML algorithms can be developed that could extract the properties of a new material from its genomic information. The US government has already taken initiative with itsprogram on "Material Genome Initiative" [9] and so has the European Commission with a project on "The Materials Genome in Action" [10]. Thus collaboration between BRICS countries is essential.

Conclusion

Joint "**BRICS VDP**" will bring in collaboration among BRICS nations. It will bring subject matter expertise of various countries together to form cost effective solutions. Benefits of this proposal may be:

- Shared investment to setup and maintain the lab which requires frequent advancement of computing technologies (like GPGPU, FPGA, Storage, Networks etc.)
- Research collaboration among BRICS nations is the key to this initiative as most of the problems are common.
- For designing/optimizing complex ML algorithms we need to have a system as well as a domain expert. It is difficult to get a knowledge area experts who are a good blend of both system and domain knowledge. There is a need to create a pool of resources jointly among BRICS nations who can solve complex problems which will facilitate faster and effective resolution.

The successful formation of this "BRICS VDP" will help in the following areas:

- **Proactive Healthcare** By cutting out risky habits in people's lifestyles, he says preventable diseases will reduce. This could lead to extended life spans, and even set us on the path to escaping death for good.
- **Predictive and Preventive Healthcare:** Real-time prediction and diagnosis of pandemics could now be achieved through the proposed "BRICS VDP"**.**
- **Telemedicine:** Most of the population in BRICS Countries resides in remote areas having little or no access to doctors. Electronic consultations through this platform can provide real-time interactions between patient and health professional.
- **Energy:** Cheap and efficient materials that can store energy such as super-capacitor, capturing of solar energy, material for hydrogen storage, etc.
- **Transportation:** Light, strong and corrosion free material for automobile parts, as well high-temperature resistant material for engine and other parts of automobile.
- **Healthcare:** Biomaterials for implants such as joints, bone plates etc., medical devices such artificial heart, pacemaker etc.
- **Electronics:** Efficient material for sensors, magnetic and optical storage devices, integrated circuits etc.

Energy

1. **Application of wind-generated hydrogen as a green fuel for use in the transport sector.**

It is realizable. The Wind-to-hydrogen (Wind2H2) project carried out by U.S. National Renewable Energy laboratory (NREL, US) along with Xcel Energy in the year 2009 can be regarded as the pioneering work which demonstrated that hydrogen can be economically produced from natural wind power for transportation fuel purpose.

Any success story in India? Yes. In a recent study, Shrinet and Govindan (2013) from Energy Research Development Association (ERADA), Vadodara, have demonstrated that wind-generated hydrogen can be used as a medium of energy storage and designed a workable model for generating hydrogen from renewable wind using wind turbines and water electrolysis process. The model was designed for application in rural areas with poor grid connectivity, to meet the energy needs of cooking. While this is a significant achievement, in small-scale, up-scaling of application for the use of hydrogen as a fuel to transport sector poses greater scientific, technical and financial challenges. In the year of 2015-2016, Prof Sujoy K Guha from IIT Kharagpur proposed an innovation which was appreciated by the government for clean energy in the world. The proposed innovation was “Fuel conservation together with vehicular pollution minimization” (Patent pending). The innovation introduced the concept to reduce the pollution during traffic through electricity driven transport for the vehicles which reduces the consumption of fuels and in turn reduces vehicular pollution.

What is the need and advantage by resorting to BRICS Collaboration? The work by ERADA, Vadodara has demonstrated the validity of wind-generated hydrogen as a viable and useful concept at laboratory level; it'supscaling to meet real-world requirements is really complex. Considering both scientific and technological challenges, and noting that the problem being common to all BRICS, it is but prudential to share the available knowledge, expertise, technology, research and manufacturing facilities etc. to enhance mutual scientific collaboration among BRICS countries.

Currently,USA is the only country who has initiated and pioneered in this technology in the world. However, BRICS countries can take a leading scientific - collaborative role in this direction since sub-topics of this major problem can be more effectively solved by combined concerted scientific efforts.

2. **Development of humanoid (robot) to work in hazardous environment**

Humanoid is a robot which is designed in a way that it has similar body features like a human being and thinks like a human. At present few humanoids have been developed in the few countries worldwide but they are designed to perform very simple tasks like playing games, singing, dancing etc. To prevent an accidental situation like in the nuclear reactor which creates a very harsh environment in the nearby places like radiation, high temperature, the presence of hazardous gasses which causes a threat to the working crew of the reactor and people living in close proximity to the reactor location. Considering this, designing a human type robot which can perform similar works like a human being is very useful. This robot can be used in the normal working conditions which are unsafe for human interaction. This kind of humanoid robot also can be effectively designed for the robotic surgery. Hence for BRICS STEP, this program suits since it interconnects the present BRICS theme of computational intelligence, energy, and health care.

3. **Cellulosic biomass-based interior coating for industrial furnace exhaust to reduce the air pollution for renewable multipurpose applications**

Exposure to particulate contaminants along with heavy metals from industrial smokes is the major cause of environment pollution globally. The process of collection and utilization of these contaminants of smoke along with contaminants will be cost effective than the process of removal. This idea focuses on utilization of these pollutants for construction, and bio fuel generation purposes. From ancient days, cattle dung, charcoal were acting as insulating material in an eco-friendly house constructions. They have excellent insulating properties, improving air quality, being able to soak up moisture and protect from radiation. Rice husk dust is also used as an insulating agent by preparing false ceiling. When all these compounds are combined together in particular proportions, they may act as efficient insulating agent in household constructions. By focusing this as a primary objective, a prototype model of interior coating for industrial furnace exhaust made up of rice husk dust and cattle dung mixed in particular proportion was made in our laboratory. This cattle dung coating can be used in large scale industries to prevent the smoke pollution from industries. This coating was subjected to the insulation property test. A significant amount of temperature reduction was observed by using cattle dung coating as an insulating agent. Further, this coating material can also be used as a source material for biogas production. Cattle dung, agricultural residues, etc. were used as a cellulosic source for biogas production. Biogas technology offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. This cattle dung and rice husk coating with carbon deposition can be added directly to cement which will be suitable for construction. This prototype model can be subjected for multipurpose applications. However, the concentration of heavy metals and charcoal deposited has to be evaluated in each batch in different industries for commercializing this prototype model. This technology will be cost effective, affordable, scalable and in interest of BRICS Nations.

4. Hydrothermal gasification

Hydrothermal gasification (HTG) has the potential to not only manage the waste in a cleaner and safer manner but can also generate energy out of it. Hydrothermal treatments like hydrothermal carbonization, supercritical water oxidation, hydrothermal liquefaction, hydrothermal gasification etc. have been known for quite sometime and are practiced at the laboratory and industrial scale for various purposes. The beauty of Hydrothermal Gasification is that it utilizes the water present in the feed, thus eliminating the need forenergy-intensive drying process. It is important to note that all the BRICS nations are stressed with handling MSW, which has moisture content more than 50%.

5. Generate electricity: Thermoelectric materials

In the BRICS courtiers, a major fraction of the energy is being consumed in terms of the use of coal, petroleum, and natural gas. After the use of an enormous amount of energy in the form of electricity or combustion of petroleum, ~65% of the utilized energy being lost as waste heat. Thermoelectric materials/devices can directly and reversibly convert waste heat into electrical energy, and will play a significant role in the future energy management. Different sectors of application include automobiles (car/bikes), heavy trucks and vehicles, petroleum refineries, thermal power plant, nuclear reactor facilities and waste heat recovery from burner/generator in the day to day life. Anything that uses an internal combustion engine (moving or stationary) can use thermoelectric materials to convert waste heat to electrical energy conversion for enhanced energy-efficiency. New inorganic materials with high thermoelectric efficiency due to the ultra-low thermal conductivity. These materials can easily convert any kind of "waste heat" to electricity.

Healthcare

BRICS today has steadily rising, population of newborns, as well as an enormous proportion of aging population, presenting distinct challenges to the health care systems. Although mortality rates all across BRICS have fallen but morbidities have risen calling for health transitions which can provide preventive, proactive, self-preserving, caring and cost-effective health systems and health services.

Except for the high-level meetings of the BRICS health ministers, there is no joint statement on common initiative on specific health issues by the BRICS nations. One example of collective initiative is the Global Polio Eradication Initiative (GPEI) which is truly a multilateral enterprise. To improve the partnership and engage individually in bi, tri, and multilateral health initiatives BRICS need to explore the newer health knowledge domains. Areas of strengths from the traditional systems of health care from India and China can play a bigger role in providing solutions to the common health problems in BRICS nations. We have identified four common areas of concern which can provide grounds for BRICS health initiatives.

1. Life Span Research

Life expectancy is increasing today. It is known that rapid aging of the population is driven by two different phenomena: the progressive improvement of life expectancy and a remarkable decline in fertility. Total aging population (60 and over) in the BRICS countries is estimated to be about 328 million in 2010, 340 million in 2011 and 355 million in 2012, accounting for 11.3%, 11.6% and 11.2% of the BRICS total population as per BRICS Joint Statistical 2013 published by the National Bureau of Statistics of China (NBSC). Besides tremendous advances in health care today, many elderly people have chronic, incurable progressive diseases and need assistance with the activities of daily living. Thus, challenges ahead are the prevention of physical disability and the extension of "active life expectancy." The increase in aged population affects the demand for health services, social security and care for the elderly. It is important for BRICS countries to exchange views on challenges related to aged population and development issues. The increased life expectancy in BRICS countries has thus created a “new age of the old” which now requires planning, logistics, and training for caregivers. Increased life span means a longer period of life as a retiree. Thus, if people want to preserve their standard of living, they need a larger initial “stock of capital” in order to keep the same monthly pension for the longer period of retirement. This will create imbalances in the pension systems and need careful planning in future. BRICS countries need to work together towards new pension systems for the betterment of aged population. Here, we propose how BRICS countries can accept this challenge and focus on the possibilities of achievable healthy ("successful") aging. The approach will be towards proactive healthcare so as to prevent aging, ensuring wellness. That is, preventive measures if taken at an earlier stage may delay/ arrest aging. Development of nutraceuticals, technologies/ medical appliances for the care of aged population may provide a better health management.

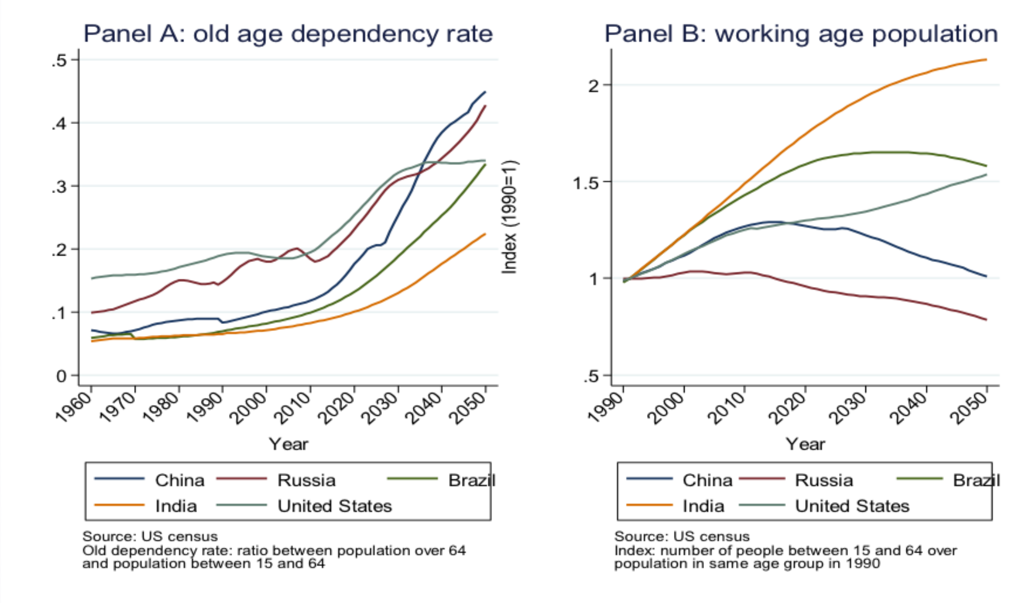


Figure 1. Aging in BRICS and US.

2. Neonatal Care

The first 28 days of life i.e. the neonatal period is considered the most vulnerable time for a child's survival. One of the agenda for BRICS countries is early childhood care i.e. to ensure both women empowerment and child development. High Infant mortality Rate is common to all the BRICS countries (Figure 3). There are various reasons for newborn mortality such as preterm birth, low-birth-weight, suboptimal maternal health (through the lifecycle), intrapartum complications (especially obstructed labour and malpresentation), death of the mother, poverty (by increasing risk factors or reducing access to care), low health care coverage (especially home birth without skilled attendance and delayed or non-referral of sick newborns) etc. It is important to focus on how to reduce neonatal and infant mortality rates by improving the care for the mother during pregnancy and childbirth and of Low Birth Weight infants. Here, we need to take recourse to newer and advanced approaches as well as traditional insights into feeding, temperature maintenance, management of the umbilical cord and placenta, first feeds and herbs, and early detection and treatment of infections and complications including respiratory distress syndrome which can substantially reduce neonatal and infant mortality rates. Earlier innovative policies have been designed and implemented by BRICS countries to reduce neonatal mortality, however, it proved to be difficult to accomplish.

3. Child healthcare

The major complications infants in most BRICS countries arise due to insufficient nutritional availability and disparities in healthcare access. They lead to increased susceptibility in children to infections and thereby, an increase in infant mortality rates. According to UNICEF statistics (depicted in Figure 2), India and South Africa have the high number of children (age <5 years) suffering from stunting and wasting due to under-nutrition, which results from poverty and paucity of nutritious food. Despite registering considerable improvement in the average nutritional status of their populations in the past decade, countries with relatively higher GDPs like China and Brazil still have a considerable percentage of malnourished children in their rural population. Development of novel affordable health care strategies that utilize less painful methods for administration is necessary to ameliorate wasting that occurs in malnutrition affected children.

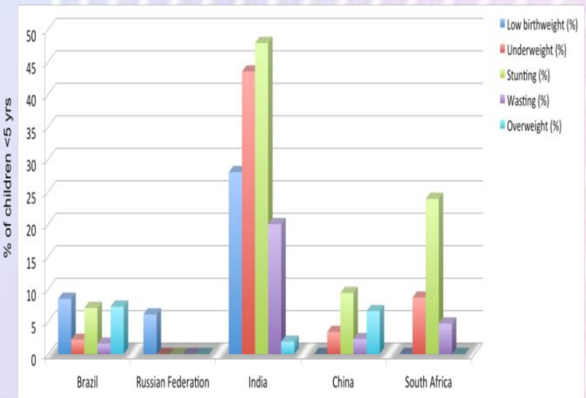


Figure 2: Number of malnourished children in BRICS nations in 2012-13

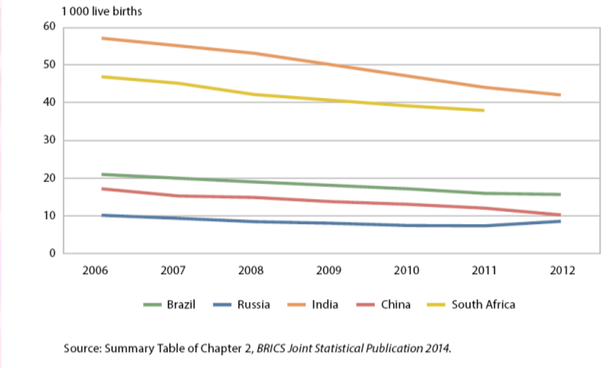


Figure 3: Infant Mortality Rate (2006-2012)

4. Detoxification Therapy

It is well known that toxins (exogenously and endogenously produced substances) if left in the body, may cause harm or promote illness. Hence, regular cleaning systems if adopted may have a great impact in ensuring a good health. Traditional systems (e.g. Ayurveda, yoga, Unani, Siddha, and naturopathy, and Chinese system) of medicine have included techniques of detoxification as part of their preventive and therapeutic approaches to overcome diseases. One of these is Panchakarma therapy which is a set of five therapeutic treatments administered to the patient for the complete detoxification of the body. It removes toxins from the digestive system, bowels, lungs, blood vessels and nervous system, strengthens the muscles and joints, helps in the hormone secretion of all glands and also improves the appetite, sleep quality, sexuality, concentration, and memory. This preventive regimen along with many similar ones can provide a prophylactic approach to enhance immunity of the human body making it less susceptible to death and disease.

5. Mental health

The mental illness today has become a huge burden globally and has to pay a huge cost in terms of not only disability but also economic loss. The impact of mental illness includes family health which gets impaired, access to the job market and job retention is affected, the well-being of future generations becomes insecure, development of human and social capital is affected and thus, economic cost for society and health system. World Alzheimer Report 2012 report says that the increasing cost of healthcare, particularly large out-of-pocket expenses for procuring services, coupled with the increase in the number of people with dementia will place a huge burden on the individual, family, and society, creating a black hole of economic drain and demand. The need of the hour is to identify precursors of mental illness for early diseases diagnosis and also to explore new diagnostic technologies for people affected with mental illness. Modern medicine is now fully short of drugs to treat mental diseases. Development of new drugs can take a long time and huge resources. BRICS should have a multilateral approach to look for new drug sources in Traditional Medicine to address the issues of mental health and well-being.

6. Early diagnosis of Non-Communicable Diseases and design of novel therapeutic strategies

The increasing burden of diseases in developing countries as well as disparities at socio-economic levels call for designing efficient, cost effective and non-invasive methods for early diagnosis as well as treatment of these NCDs highly prevalent in BRICS nations. Thus, the criticality of the development of these treatments suggests a need for sustainable and logistic strategy for the advancement of research collaboration across these nations towards a common goal.

Non-invasive microbiome biomarker-based diagnostics and therapy

Traditional culture-based microbiology techniques utilized to detect disease-causing pathogens are unable to identify unculturable organisms. The recent emergence of metagenomics allows their characterization and understanding their functional potential with respect to human physiology [7]. These techniques enhance the diagnostic process by identification of disease-causing agents at an early stage. Several bacteria thrive in symbiotic association with the human body and are termed as 'human microbiome'. It is well established that human microbiome is affected by dietary patterns, environmental conditions as well as the genetics of an individual [10,11]. This suggests that in order to find bacterial biomarkers for specific diseases with a global impact, samples from different geographies should be analyzed. A number of initiatives like Metahit (http://www.metahit.eu/) and Human Microbiome project [12,13] have attempted to unify experimental advancements in metagenomics across various countries. The limitation of these consortia is that most of them cater to the American and European population. Since the dietary patterns and lifestyle of these nations are very different from BRICS countries; it becomes necessary to develop a **BRICS microbiome consortium.** This repository can be a useful source for data from all these metagenomics studies and needs to be regularly updated for the benefit of scientists working towards diagnostics and therapeutics.

Target specific Molecular Recognition Markers as Prediagnostic kit

The diagnostic kit comprises of molecular recognition markers for the specific disease-causing targets. The organic polymer format may be tailored to mimic biological receptor via molecular imprinting technique to develop cheap and affordable diagnostic kits [14,15] for BRICS nations. The polymerization of monomers in the presence of a target molecule to imprint structural information into resulting network polymer which is complementary in shape and size to that of a targetmolecule. It is called **molecular imprinting technology (MIT).** MIT is a scientific field that is rapidly gaining significance for a wide range of applications in chemistry, biotechnology, pharmaceutical research, and biosensors. Theoretical optimization of the target–monomer binding and other analytical parameters prior to preparation of molecular recognition agent help in cutting down the experimental cost for the diagnostic kit. Due to their analytically useful properties, such as selectivity, shelf stability, robustness in adverse environmental conditions and reusability, MIP offers potential for the synthesis of artificial recognition material for a specific target. MIPs are relatively inexpensive to produce and can be synthesized in favor of analytes for which no natural antibody exists. Furthermore, the technique does not need any cumbersome sample preparation method. Insighting the importance of biomarking the disease-causing target molecule in blood plasma, blood serum, cerebrospinal fluid, an attempt will be made to successfully synthesize and characterize the target specific imprinted polymer for the disease. This tool will be applied to carry out rapid, cost-effective and specific detection of the analyte and shows promising applications as an artificial biomarker in diseases at an early stage.

The bacterial, as well as molecular biomarkers, can vary across different geographies. Thus, collaboration with labs across BRICS countries specializing in these strategies might lead to a fruitful exchange of ideas and strategies in order to design novel therapeutic and diagnostic regimes. Analysis of molecular and bacterial biomarkers from different BRICS countries will lead to:

- Identification of biomarkers, which might be common to all BRICS countries and can be used for diagnostics/therapy across these nations.

- Recognizing biomarkers specific to a country for personalized diagnostic regimes for a specific population.
- Development of affordable and sensitive diagnostic strategies.
- Designing efficient therapeutic supplements or probiotics to ameliorate disease symptoms.

7. Plasma treatment of Skin Diseases

The treatment of skin diseases are highly expensive and require the patients to apply the ointments twice a day after washing the affected area thoroughly with water then allowing it to dry. This entire procedure is cumbersome and needs time and special care even after the application of ointment.

It should be pointed out that earlier applications of plasma in medicine relied mainly on the thermal effect of plasma [17]. Heat and high temperature have been utilized in medicine for a long time for the purpose of tissue removal, sterilization, and cauterization [18,19]. Stoffels*et al*. studied the plasma needle device and demonstrated the promising potential of the cold plasma in biomedical applications [20]. Laroussi and Lu described the operation of a cold plasma plume using helium as the carrier gas [21]. They demonstrated that the plasma plume can be touched by bare hands and can come in contact with skin and dental gums without causing any heating or painful sensation [22]. Fridman*et al*. demonstrated that cold plasmas can promote blood coagulation and tissue sterilization [23].

These results indicate that plasma jets can be used to alleviate painful symptoms of various skin diseases as well as sterilization to prevent further infection. As this technology is in an early developmental phase, its applicability towards ameliorating different diseases needs to be established before using it on different populations. This is not possible without interdisciplinary approach and collaboration in this field. Several groups in BRICS countries are working towards developing this technique and there is a need to bring all research under one platform so that the common solution can be attained.

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Appendix B: List of potential BRICS collaborators

BRICS Nations	Collaborators			
	Thermoelectrics	**Microbiome-based Biomarkers**	**Molecular Recognition Markers**	**Plasma Technology**
BRAZIL		Dr. Victor S Pylro, Biosystems Informatics and Genomics Group, René Rachou Research Center–CPqRR, Av. Augusto de Lima, Belo Horizonte, Minas Gerais, Brazil		Prof. Anelisa Doria Universidade de Vale do Paraiba, Sao Jose dos Campus, Brazil
RUSSIA	Prof. Alexander Burkov a.burkov@mail.ioffe.ru; Ioffe Physical-Technical Institute of the Russian Academy of Sciences	Dr. Alexander V Tkachev, Department of Internal Medicine Propaedeutics, Rostov State Medical University, Suvorova 118/50, Rostov-on-Don, Russia Dr. Vadim M Govorun. Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry of the Russian Academy of Sciences, GSP-7, Miklukho-Maklaya 16/10, Moscow, Russia Institute of Chemical Biology and Fundamental Medicine SB RAS, Novosibirsk, Russia. Novosibirsk State University, Novosibirsk, Russia Biological Faculty, Lomonosov Moscow State University, Leninskie gory, 1/12, Moscow, Russia.		Dr. Victor N. Vasilets Russian Academy of sciences, Chernogolovka, Russia Dr. Elena Sysolyatina Gamaleya Research Institute, Moscow, Russia
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SOUTH AFRICA			Dr. Anwar Jardine, Department of Chemistry, University of Capetown, South Africa	

APPENDIX C

Short Profiles of the Agency Representatives

Prof. Baldev Raj is known for overcoming the barriers of academic research and industry with acumens of leadership and experiences. Prof. Baldev Raj has been honored by all the four academies of Sciences and Engineering in the country, International Nuclear Energy Academy, Institute of Directors, Indian Academy of Social Sciences, Academy of NDT International, American Society of Metals, German Academy of Science, The World Academy of Sciences etc. Amongst several awards he has been honored with the Padma Shri Homi Bhabha Gold Medal, H K Firodia Award, Om Prakash Bhasin Award, Vasvik Award, National Metallurgist Award, Lifetime Achievement Award of Indian Nuclear Society, Distinguished Material Scientist Award, Distinguished Alumni of Indian Institute of Science. Prof. Baldev Raj has a passion for interacting with students and young professionals for mutual inspirations and service to society. Email: baldev.dr@gmail.com

P. Goswami, Director, CSIR-NISTADS. Dr. Goswami received the Shanti Swarup Bhatnagar Prize in earth and planetary sciences in 2001 for his fundamental contributions in atmospheric and climate modeling. He acted as a Lead Author of the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5, Working Group I Dr. Goswami's research is highly multi-disciplinary, with high-impact research publications in several areas; has currently 76 high-impact SCI publications. He has also guided eight Ph.D. students so far from different universities. Email: pgoswami@nistads.res.in

Sadhana Relia has graduated from the Delhi University in 1982 with post-graduation in Biological Sciences. She is presently working in the DST, Ministry of Science and Technology and heading the International Multilateral and Regional Cooperation Division. She has experience of more than 30 years in dealing with India's S&T cooperation related policies, strategies, institutional and financial frameworks and international collaborative programs at bilateral, regional and multilateral levels. Email: srelia@nic.in

H Purushotham is the Chairman and Managing Director, NRDC, Ministry of Science & Technology, Govt. of India. He is M.Tech from IIT Kharagpur, MBA from IGNOU and Ph.D. from Osmania University. He has acquired over 30 years of diverse experience across the innovation value chain by working at different government institutions such as RRL, Jorhat, CRI, New Delhi, CLRI, Chennai, ANIID Ltd, Port Blair, ARCI, Hyderabad, TDB of DST, NISG, DoIT, New Delhi. He is a recipient of "Meritorious Young Consultant Award 1991" Instituted by Consultancy Development Centre, Ministry of Science & Technology. He has authored/ co-authored 65 project reports, 5 book chapters, one book, published/ presented 70 research papers, filed three patents and helped the industry in commercializing more than 50 technologies in different sectors. Email: cmdnrdc@nrdc.in

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Anu Dhar is Senior Process Engineer working with Reliance Industries Limited and her research is on development of product and processes for biofuels. She is a Chemical engineer, with design and research experience in a wide spectrum of industries like Oil & Gas, petrochemicals, refinery, fertilizers, and biofuel industry. She has worked extensively in process design and engineering of various plants on hydrogen, ammonia, methanol, formaldehyde, ammonium thiosulphate, synthetic natural gas, gas hydrotreating and other technologies for refineries and chemical production plants in Russia, Mexico, USA, Indonesia, Korea, Venezuela, Iraq etc. Email: annu.rast@gmail.com

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