BRICS

NATIONAL SYSTEMS OF INNOVATION

The Role of the State

EDITORS
Mario Scerri | Helena M. M. Lastres

ROUTLEDGE

The Role of the State

BRICS ■ National Systems of Innovation

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Editors

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List of Abbreviations

ANC	African National Congress
APL	Local Productive Arrangements (Arranjos Produtivos Locais)
AsgiSA	Accelerated and Shared Growth Initiative for South Africa
BASIC	Brazil, South Africa, India, and China
BIPP	Biotechnology Industry Partnership Programme
BNDES	National Bank of Economic and Social Development (Banco Nacional de Desenvolvimento Econômico e Social)
Bolsa Familia	Poor Family Support Pension
BPC/LOAS	Social Benefit/Social Security Act
BRIC	Brazil, Russia, India, and China
BRICS	Brazil, Russia, India, China, and South Africa
CadÚnico	Unified Register of Social Programs
CAE	Chinese Academy of Engineering
CAPES	Coordination of Qualification of Graduate Human Resources (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior)
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CEPAL	The Economic Commission for Latin America and the Caribbean (ECLAC)
CIDE	Tax on Intervention in the Economic Field (Contribuição de Intervenção do Domínio Econômico)
CII	Confederation of Indian Industry
CLTD-2020	Conception of a Long-Term Development of the Russian Federation until 2020
CNI	National Confederation of Industry (Confederação Nacional da Indústria)
CNPq	National Council of Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico)
COSATU	Congress of South African Trade Unions

COMECON	Council for Mutual Economic Assistance
CPC	Communist Party of China
CSIR	Council for Scientific and Industrial Research
CTA	Aerospace Technical Centre (Centro Técnico Aeroespacial)
DACST	Department of Arts, Culture, Science, and Technology
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DHET	Department of Higher Education and Training
DOD	Department of Ocean Development
DoE	Department of Education
DOEn	Department of Environment
DoL	Department of Labour
DoS	Department of Space
DRDO	Defence Research and Development Organisation
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
DTI	Department of Trade and Industry
DTI	Scholarship for Industrial and Technological Development (Desenvolvimento Tecnológico e Industrial)
EMBRAPA	Brazilian Agricultural Research Corporation
ESKOM	Electricity Supply Commission
ESTD	Early Stage Technology Development
EU	European Union
FAIR	Facility for Antiproton Reactor and Ion Research
FAST	Fund for Accelerating Start-ups in Technology
FBA	Federal Budget Allocations on R&D
FDI	Foreign Direct Investment
FERA	Foreign Exchange Regulation Act
FICCI	Federation of Indian Chambers of Commerce and Industry
FINEP	Studies and Projects Funding Agency (Financiadora de Estudos e Projetos)
FNDCT	National Fund of Scientific and Technological Development (Fundo Nacional de Desenvolvimento Científico e Tecnológico)
FPP	Family Pension Programme
FTE	Full-time Equivalent

FUNTEC	Technological Fund
GDP	Gross Domestic Product
GEAR	Growth Employment and Redistribution: A Macroeconomic Strategy
GERD	Gross Expenditure on Research and Development
HEI	Higher Education Institution
HSE	State University, Higher School of Economics (Moscow)
HSRC	Human Sciences Research Council
IBGE	Brazilian Institute of Geography and Statistics
IBSA	India, Brazil and South Africa
ICAR	Indian Council of Agriculture Research
ICICI	Industrial Credit and Investment Corporation of India
ICMR	Indian Council of Medical Research
ICT	Information and Communication Technology
IDC	Industrial Development Corporation
IDRC	International Development Research Centre
IITs	Indian Institutes of Technology
INPE	National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais)
INR	Indian Rupee
INSPIRE	Innovation in Science Pursuit for Inspired Research
IPCA	Inflation Rate
IPEADATA	Database on Brazilian economy
IPRs	Intellectual Property Rights
ISCOM	Iron and Steel Corporation of South Africa
IT-BPO	Information Technology and Business Process Outsourcing
ITER	International Thermonuclear Experimental Reactor
ITIs	Industrial Training Institutes
JIPSA	Joint Initiative on Priority Skills Acquisition
LDB	Law of Fundaments and Guidelines for Education (Lei de diretrizes e Bases da educação)
Lei da Inovação	Law of Innovation
Lei do Bem	Law of the Goods

MCT	Ministry of Science and Technology (Ministério da Ciência e Tecnologia)
MDIC	Ministry of Development, Industry and Foreign Trade (Ministério do Desenvolvimento, Indústria e Comércio Exterior)
MEC	Ministry of Education (Ministério da Educação)
MIIT	Ministry of Industry and Information Technology
MIT	Ministry of Information Technology
MNES	Ministry of Non-conventional Energy Sources
MOE	Ministry of Education
MS&T	Ministry of Science and Technology
MRTP	Monopolies and Restrictive Trade Practices
MS	Ministry of Health (Ministério da Saúde)
MSE	Micro and Small Enterprise
MTE	Ministries of Labour and Employment (Ministério do Trabalho a Emprego)
NACI	National Advisory Council on Innovation
NASSCOM	National Association of Software and Service Companies
NCR (Delhi)	National Capital Region (Delhi)
NCST	National Council of Science and Technology
NDRC	National Development and Reform Committee
NEPAD	New Partnership for African Development
NGP	New Growth Path
NIS	National Innovation System
NMITLI	New Millennium Indian Technology Leadership Initiative
NNSF	National Natural Science Foundation
NRDC	National Research Development Corporation
NRDS	National Research and Development Strategy
NRF	National Research Foundation
NRGES	National Rural Employment Guarantee Scheme
NRH	National Rural Health Mission
NSERB	National Science and Engineering Research Board
NSI	National System of Innovation
OBMEP	Brazilian Mathematics Olympiad of Public Schools
OECD	Organisation for Economic Cooperation and Development
PAC	Programme for the Acceleration of Growth (Programa de Aceleração do Crescimento)

PACTI	Action Plan for Science, Technology and Innovation
PDE	Plan for Development of Education
PDP	Policy for Production Development
PDTA	Programme for Agricultural Technological Development
PDTI	Programme for Industry Technological Development
Petrobras	Brazilian Energy Company
PINTEC	Brazilian Survey on Technological Innovation
PISA	Programme for International Students Assessment
PITCE	Industrial, Technological and Foreign Trade Policy (Política Industrial, Tecnológica e de Comércio Exterior)
PMO	Prime Minister's Office
PNCTI	National Policy of Science, Technology and Innovation
PPP	Public–private partnership
PRDSF	Pharmaceutical R&D Support Programme
PRO-AERO-NÁUTICA	Programme for Financing to Enterprises from the Brazilian Aeronautical Production Chain
PROFARMA	Programme of Support to the Development of the Health Industrial Complex
PROSET	Stimulus to Retention of Human Resources of Interest to Sectoral Funds
PROSOFT	Development of Software Industry and Services Information Technology
PROTVD	Programme of Support to Implementation of the Brazilian System of Terrestrial Digital TV
PRS	Public Research System
PURSE	Promotion of University Research and Science Excellence
R&D	Research and Development
RDP	Reconstruction and Development Programme
Real Plan	Plan for Economic Stabilisation (Plano Real)
RedeSist	Research Network on Local Innovative Production Arrangements and Systems
RGPS	General Regime of Social Security
RHAE-Inovação	Human Resources for Strategic Activities-Innovation

RISDP	Regional Indicative Strategic Development Plan
RMV	Life Monthly Pension (Renda Mensal Vitalícia)
Rosnano	Russian Corporation for Nanotechnology
Rosstat	Russian State Statistical Service
RSA	Republic of South Africa
RVC	Russian Venture Company
SADC	South African Development Community
S&T	Science and Technology
SAEB	The System for Assessment of Basic Education (Sistema de Avaliação da Educação Básica)
SARChI	South African Research Chairs Initiative
SCI	Science Citation Index
SETEC	Secretariat of Technological Development and Innovation
SMEs	Small- and Medium-scale Enterprises
SPR	Scientific Policy Resolution
SPREAD	Sponsored Research and Development
SPRU	Science Policy Research Unit
SSI	Sectoral System of Innovation
STIs	Scientific and Technological Institutions
STPs	Software Technology Parks
STPIs	Software Technology Parks of India
TDDP	Technology Development Demonstration Programme
TELECE-NTROS	Community centres for Internet access
TePP	Techno-Entrepreneur Promotion Programme
TIA	Technology Innovation Agency
TIFAC	Technology Information Forecasting and Assessment Council
TNCs	Transnational Corporations
TV–PROTVD	Brazilian System of Terrestrial Digital
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USSR	Union of Soviet Social Republics
USTP	University Science and Technology Park
VA	Value-added
VAT	Value-added tax
VTC	Vocational Technical Centres (Centros Vocacionais Tecnológicos)
WTO	World Trade Organization

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Foreword

If there are any reservations about the importance of intensified cooperation between Brazil, Russia, India, China, and South Africa, this book will speedily dispel them. The usual reservations are based on doubts about economic complementarities and fears that all developing countries rely mainly on natural resource endowments and are therefore unable to trade with each other. This book shows that there is ample scope for comparative studies and hence cooperation in science and technology, and hence innovation for the mutual benefit of each.

The book also shows beyond any doubt that the state has a crucial role in sponsoring innovation, directly and indirectly, thereby leading a process that is often well-supported by the private sector. An essential foundation for innovation is obviously strong mathematics and science in schools and universities. However, state institutions are also vital for providing leadership, setting the pace, providing incentives, and in many other ways.

The history of state leadership is particularly striking in post-independence India when Nehru insisted on a modernisation programme which has been built on by succeeding leaders, not least of whom the current Prime Minister. Indeed, the chapter on India is an inspiring story of the deliberate actions by a government in an underdeveloped country striking out to develop science and technology to break through the legacy of backwardness. Would that other countries were equally determined and decisive!

The contrast, the chapter on China, is surprising. China's industrialisation path was initially based on natural resource endowments and has only recently pressed forward with innovation seriously. This may be because the Asian Tigers initially adopted the policy of last-stage assembly in factories introduced from developed countries. This meant that the relevant research and development was denied them for a long time. It seems that China and others first concentrated on the introduction of technology and equipment with short-term efficiency objectives. However, it is obvious that they have caught up and are now capable of designing their own

innovation systems which are clearly essential to sustain their high growth rates.

The case of Brazil is of great interest. In recent decades the state has resorted to a variety of institutions to boost science and technological development. Each step reflected a realisation that Brazil ought not to depend on the importation of US capabilities. The establishment of the National Bank for Social and Economic Development (BNDES) is an outstanding example of a country seeking an original approach to the harnessing of capital for industrial investment. The results are astounding and the impact on GDP growth very significant.

The story from Russia is less inspiring, though there too big advances are underway. The South African case is perhaps the least encouraging, though there has been a significant advance in spending on R&D recently. The problems here are very fundamental, starting in the schooling system, and the lack of drive at the universities to promote mathematical sciences. The efforts of the innovative African Institute of Mathematical Sciences are embryonic but influential because its teaching is based on problem solving, and thereby shows what can be done.

The challenge in South Africa is all the greater for the recent revelation by Citigroup Global Markets that it has over US$ 2.5 trillion of non-energy monetary reserves making it the richest nation when assessed by the in situ value of its natural resources. South Africa is in the top 15 countries with gold, iron ore, nickel, and platinum group metal reserves. This poses an enormous challenge for innovative work to ensure that beneficiation follows on exploration, leading to fabrication.

Fundamental to all this is the financial contribution of the state. As we have now learnt with respect to the international financial crisis, the market alone cannot fix a country's inadequacies. According to Ha-Joon Chang, 40 to 60 per cent of R&D in the United States is provided by the state. It is well-known that their university research benefits enormously from their military budget even if the grants are often disguised. However, it is not only the state that has a responsibility. We are informed that in India gross expenditure on research and development is 68 per cent from government sources and 30 per cent from the business enterprise sector. Surely others can learn from this example.

This book raises the platform of discourse on development to a higher level. It escapes from the narrow confines of trade and investment policy, and reaches out to the more remote spaces of scientific innovation. It is an exciting journey.

Ben Turok

Member of Parliament
African National Congress
South Africa
May 2010


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Preface

This book is the result of a collaborative effort of several people and institutions. The contributions presented here consolidate the findings of the project 'Comparative Study of the National Innovation Systems of BRICS' sponsored by the International Development Research Centre (IDRC). The project is rooted in a larger research effort on BRICS national innovation systems being developed in the sphere of the Global Research Network for Learning, Innovation and Competence Building Systems — Globelics. The Globelics initiative on BRICS economies brings together universities and other research institutions from Brazil, Russia, India, China, and South Africa. The aim is to strengthen an original and less dependent thought, more appropriate to understanding development processes in less developed countries.

First and foremost, we would like to thank Professor Bengt-Ake Lundvall, the coordinator of Globelics, who supported and promoted the BRICS project from the outset in 2003 and organised the First International Workshop of the BRICS Project in Aalborg, Denmark, in 2006. Without his leadership and enthusiasm the project could not have taken off.

We owe special thanks to project researchers and coordinators for their engagement in project activities and accessibility to overcome difficulties that naturally emerge from the geographical and cultural diversity of BRICS. We are also very grateful to those who provided the necessary administrative and secretarial support that resulted in the good performance of this project, especially Luiza Martins, Fabiane da Costa Morais, Tatiane da Costa Morais, and Eliane Alves who helped in editing activities and whose support was crucial for formatting the manuscript and organising the tables and figures. Max dos Santos provided the technical IT support for the research network.

The core ideas analysed in this book were discussed at international seminars organised in Brazil (2007), South Africa (2008), India (2009), and again in Brazil (2009) under the auspices of the BRICS Project, gathering scholars, academics, policy makers, businessmen,

and civil society representatives. Our understanding of this complex theme has evolved considerably thanks to the seminar participants' constructive criticism. We are grateful to them as well as to all the other people not named here who also helped in the implementation of the project.

None of this work would have been possible without financial support. The support given by the IDRC was essential for the completion of this project. We are very obliged to IDRC and their staff for their support. We would especially like to thank Richards Isnar, Federico Buroni, Gustavo Crespi, Veena Ravichandran, Isabel Bortagaray, and Clara Saavedra. We are also grateful to Bill Carman and Michelle Hibber, then IDRC Publishers, for the technical assistance provided in the preparatory work that led to this publication.

Supplementary grants were received from various agencies of the Brazilian Ministry of Science and Technology, especially FINEP, the Brazilian Innovation Agency and CNPq, the National Council for Scientific and Technological Development. In particular, we would like to thank the general secretary of the Ministry of Science and Technology, Dr Luiz Antonio Elias, and the president of FINEP, Luis Fernandes, who have given enthusiastic support to the BRICS project since its inception.

Introduction

BRICS National Systems of Innovation

José E. Cassiolato and *Maria Clara Couto Soares*

Preamble

The world is experiencing significant transformations in its geopolitical and economic constitution. The processes of transformation have accelerated over the last decades. A significant part of the growth potential of the world economy nowadays and for the coming decades resides in some fast-developing countries. Brazil, Russia, India, China, and South Africa (BRICS) have displayed such potential for dynamic change. In a historic rupture with past patterns of development, the BRICS countries are now playing a major role in alleviating the current global crisis whilst revealing new and alternative progressive paradigms.

Much beyond the emphasis given by international agencies to the identification of investment possibilities in the BRICS production structures or to the prospects presented by their consumer markets, our perspective in analysing the BRICS countries is inspired by their significant development opportunities, as well as their several common characteristics and challenges, and the learning potential they offer for other developing countries. Identifying and analysing these opportunities and challenges will help to uncover alternative pathways towards fulfilling their socio-political-economic development potential within the constraints of sustainability.

The central focus of this book series is the National System of Innovation (NSI) of the five BRICS countries. Each book deals with a key component of the innovation system, providing the reader with access to analyses on the role played by the state, the financing, direct investment and the small and medium enterprises, besides approaching a particularly relevant — though still not extensively studied — aspect of the BRICS economies: the challenge of inequality and its interrelations with the NSIs of these countries.

The research endeavour that generated the publication of this book series has gathered universities and research centres from all the BRICS countries, as well as policy makers invited to discuss the outcomes. The research development and the comparative analysis of its results are intended to bring to light the challenges and opportunities of the BRICS countries' national innovation systems from the points of view of these same countries. Part of the effort undertaken was addressed to the construction of a shared methodology aimed at advancing the comprehension of the specificities of innovation systems in each country. This was done in view of the need for improvements in the analytical framework used for the analysis of the national innovation systems located in countries outside the restricted sphere of developed countries. Special attention was paid to the political implications. However, instead of searching for generalisable policy recommendations, it was sought to identify and analyse bottlenecks that are common to the BRICS economies, their complementarities and competition areas, as well as other aspects of major importance for supporting decision makers and that are able to incite reflection about the subject of innovation and development in other less developed countries.

It is worth mentioning that the research consolidated in this publication is rooted in a larger research effort on BRICS national innovation systems being developed in the spheres of Globelics (www.globelics.org, accessed 3 December 2011) and RedeSist (the Research Network on Local Production and Innovation Systems) at the Economic Institute of the Federal University of Rio de Janeiro (www.redesist.ie.ufrj.br, accessed 3 December 2011). Globelics is an international academic network which uses the concept of innovation systems (IS) as an analytical tool aimed at the comprehension of the driving forces that push economic development. It aims to advance the use of the IS perspective on a world basis. Established in 2002 and inspired by renowned scholars from the field of economics of innovation such as Christopher Freeman (1987) and Bengt-Äke Lundvall (1992), the Globelics network has, among others, the purpose of encouraging knowledge exchange between less developed countries, thus fostering mutual learning across innovation research groups in Latin America, Africa and Asia. With this, it is sought to strengthen an original and more autonomous approach to understanding the development processes in developing countries. On the other hand, the focus put by the Globelics network on the

study of innovation systems of BRICS results from the recognition that understanding the particular dynamics which connects the knowledge base with innovation and economic performance in each of the five BRICS countries is, today, a precondition for better appreciating the direction that the world economy will be following (Lundvall 2009). It is within such analytical field that the contribution offered by this book series is inserted.

In the following sections we (*a*) present the broad conceptual approach of NSI used as the guiding analytical framework for the research gathered under this book series; (*b*) characterize the increasing importance of the BRICS countries in the global scenario; and (*c*) introduce the five-book collection on NSIs in the BRICS countries.

NSI and Development — A Broad Perspective

One of the most fruitful ways of thinking developed in advanced countries in the last 30 years came from a resurrection and updating of earlier thinking that emphasised the role of innovation as an engine of economic growth and the long-run cyclical character of technical change. A seminal paper by Christopher Freeman (1982) pointed out the importance that Smith, Marx and Schumpeter attached to innovation (ibid.: 1) and accentuated its systemic and national character (ibid.: 18). Freeman also stressed the crucial role of government policies to cope with the uncertainties associated with the upsurge of a new techno-economic paradigm and the very limited circumstances under which free trade could promote economic development. Since it was formulated in the 1980s, the system of innovation (SI) approach has been increasingly used in different parts of the world to analyse processes of acquisition, use and diffusion of innovations, and to guide policy recommendations.[1]

Particularly relevant in the SI perspective is that since the beginning of the 1970s, the innovation concept has been widened to be understood as a systemic, non-linear process rather than an isolated fact. Emphasis was given to its interactive character and to the importance of (and complementarities between) incremental and radical, technical and organisational innovations and their different and simultaneous sources. A corollary of this argument is the context-

specific and localised character of innovation and knowledge. This understanding of innovation as a socially determined process is in opposition to the idea of a supposed techno-globalism and implies, for instance, that acquisition of technology abroad is not a substitute for local efforts. On the contrary, one needs a lot of knowledge to be able to interpret information, select, buy (or copy), transform, and internalise technology.

Systems of innovation, defined as a set of different institutions that contribute to the development of the innovation and learning capacity of a country, region, economic sector, or locality, comprise a series of elements and relations that relate production, assimilation, use, and diffusion of knowledge. In other words, innovative performance depends not only on firms and R&D organisations' performance but also on how they interact, among themselves and with other agents, as well as all the other forms by which they acquire, use and diffuse knowledge. Innovation capacity derives, therefore, from the confluence of social, political, institutional, and culture-specific factors and from the environment in which economic agents operate. Different development trajectories contribute to shape systems of innovation with quite diverse characteristics requiring specific policy support.

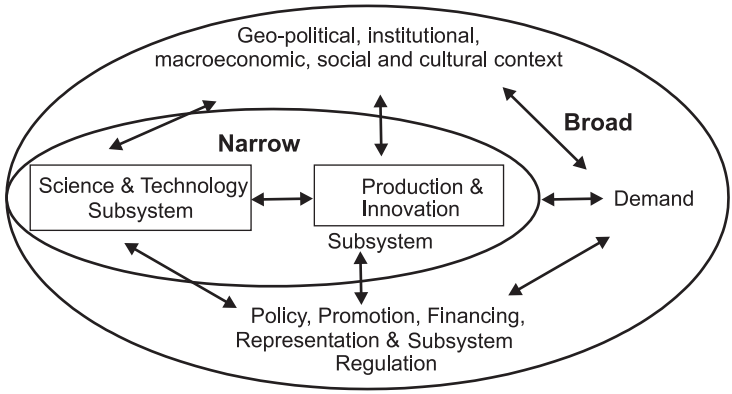
It is this understanding of the systemic nature of innovation that allows for two crucial dimensions of the SI approach to be explicitly discussed: the emphasis on historical and national trajectories and the importance of taking into account the productive, financial, social, institutional, and political contexts, as well as micro, meso and macro spheres (Freeman 2003; Lastres et al. 2003). Although all of these contexts are relevant for a discussion about development, two in particular should be singled out that are pertinent to this study. One is the financial context, recognised by Schumpeter (1982 [1912]) in his *The Theory of Economic Development*. For him, entrepreneurs, to become the driving force in a process of innovation, must be able to convince banks to provide the credit to finance innovation. In this sense, any discussion about innovation systems has to include the financial dimension.[2] The other is the idea that space matters, that the analysis of systems of innovation should be done at the national (Freeman 1982; Lundvall 1988) and local levels (Cassiolato et al. 2003).

The national character of SI was introduced by Christopher Freeman (1982, 1987) and Bengt-Äke Lundvall (1988) and has been

widely used as an analytical tool and as a framework for policy analysis in both developed and underdeveloped countries. As a result, research and policy activities explicitly focusing on SI can be found in most countries and a rapidly growing number of studies of specific NSIs have been produced. Although some authors tend to focus on the NSI in a narrow sense, with an emphasis on research and development efforts and science and technology organisations, a broader understanding of NSI (Freeman 1987; Lundvall 1988) is more appropriate. This approach takes into account not only the role of firms, education and research organisations and science and technology institution (STI) policies, but includes government policies as a whole, financing organisations, and other actors and elements that influence the acquisition, use and diffusion of innovations. In this case emphasis is also put on the role of historical processes — which account for differences in socio-economic capabilities and for different development trajectories and institutional evolution — creating SI with very specific local features and dynamics. As a result, a national character of SI is justified.

Figure 1 is an attempt to show both the narrow and the broad perspectives on NSI. The broad perspective includes different, connecting sub-systems that are influenced by various contexts: geopolitical, institutional, macroeconomic, social, cultural, and so on. First, there is a production and innovation sub-system which contemplates the structure of economic activities, their sectoral distribution, degree of informality and spatial and size distribution, the level and quality of employment, the type and quality of innovative effort. Second, there is a sub-system of science and technology which includes education (basic, technical, undergraduate, and postgraduate), research, training, and other elements of the scientific and technological infrastructure such as information, metrology, consulting, and intellectual property. Third, there is a policy, promotion, financing, representation, and regulation sub-system that encompasses the different forms of public and private policies both explicitly geared towards innovation or implicitly, that is, those that although not necessarily geared towards it, affect strategies for innovation. Finally, there is the role of demand, which most of the time is surprisingly absent from most analyses of SI. This dimension includes patterns of income distribution, structure of consumption, social organisation and social demand (basic infrastructure, health, education).

Figure 1: *The Narrow and Broad Perspectives on NSI*



Source: Adapted from Cassiolato and Lastres (2008).

This portrayal of the national innovation system framework is a corollary of an understanding that

- innovation capacity derives from the confluence of economic, social, political, institutional, and culture-specific factors and from the environment in which they operate, implying the need for an analytical framework broader than that offered by traditional economics (Freeman 1982, 1987; Lundvall 1988);
- the number of firms or organisations such as teaching, training and research institutes is far less important than the habits and practices of such actors with respect to learning, linkage formation and investment. These shape the nature and extensiveness of their interactions and their propensity to innovate (Mytelka 2000; Johnson and Lundvall 2003);
- main elements of knowledge are embodied in minds and bodies of agents or embedded in routines of firms and in relationships between firms and organisations. Therefore, they are localised and not easily transferred from one place/context to another, for knowledge is something more than information and includes tacit elements (Lundvall 1988);
- the focus on interactive learning and on the localised nature of the generation, assimilation and diffusion of innovation implies that the acquisition of foreign technology abroad is not a substitute for local efforts (Cassiolato and Lastres 1999);
- national framework matters, as development trajectories contribute to shape specific systems of innovation. The diversity of NSIs is a product of different combinations of

their main features that characterise their micro, meso and macroeconomic levels, as well as the articulations among these levels (Freeman 1987; Lastres 1994).

From the specific point of view of less developed countries (LDCs) the usefulness of the SI approach resides precisely in the facts that (*a*) its central building blocks allow for their socio-economic and political specificities to be taken into account and (*b*) it does not ignore the power relations in discussing innovation and knowledge accumulation. As this book argues, these features are particularly relevant in the analysis of the BRICS countries' innovation systems. As the analysis of economic phenomena also takes into consideration their social, political and historical complexity, policy prescriptions are based on the assumption that the process of development is influenced by and reflects the particular environment of each country, rather than on recommendations derived from the reality of advanced countries. A number of development studies followed these ideas, arguing that technical change plays a central role in explaining the evolution of capitalism and in determining the historical process through which hierarchies of regions and countries are formed. Furtado (1961), for instance, established an express relation between economic development and technological change pointing out that the growth of an economy was based on the accumulation of knowledge, and understood development within a systemic, historically determined, view. Although original, these contributions have a close correspondence with Myrdal's (1968) proposition that: (*a*) contexts and institutions matter; (*b*) positive and negative feedbacks have cumulative causation; (*c*) cycles may be virtuous or vicious, and with Hirschman's (1958) point that interdependencies among different activities are important.

The need to address paradigmatic changes and the problems and options deriving from the upsurge of information technologies led to the outbreak in Latin America in the 1980s of a series of interconnected work from the innovation perspective. Building on Furtado's work on changes associated with the industrial revolution, authors like Herrera (1975) and Perez (1983) analysed the opportunities and challenges associated with the introduction of these radical changes in the region. It was only then that the innovation and development literature started to integrate the empirically validated knowledge about learning inside firms with the contributions stemming from the work of Freeman, Perez, Herrera, and others on new technologies,

changes of techno-economic paradigms and systems of innovation. What gave special impetus to this direction was the empirical work focusing on technological capability building as part of a broader national innovation system. The role of government policies in orienting the speed and direction of technological changes was also highlighted (Freeman and Perez 1988).

Development processes are characterised by deep changes in the economic and social structure taking place from (technological and/or productive) discontinuities that cause and are caused by the productive, social, political, and institutional structure of each nation. Development is also seen as a systemic process, given the unequal capitalism development in the world. The recognition of national specificities of these processes is also fundamental. We found the same stress on the national character of development processes in List's work (1841), and on the NSI idea of Freeman (1982) and Lundvall (1988) in Furtado's (1961) discussion about the transformation of national economies where their structural complexity is manifested in a diversity of social and economic forms. For Furtado, it is in this transformation that the essence of development resides: structural changes 'in the internal relations of the economic and social system' (ibid.: 103) that are triggered by capital accumulation and technological innovations. The emphasis on diversity, and the recognition that: (*a*) both theory and policy recommendations are highly context dependent, (*b*) the economy is firmly embedded in society, and (*c*) knowledge and technology are context-specific, conform some general identities.

Furtado (1961) established a direct relation between economic development and technological innovation pointing out that the growth of an advanced economy was based on the accumulation of new scientific knowledge and on the application of such knowledge to solve practical problems. The Industrial Revolution set into motion a process of radical changes based on technical progress that has lasted till now and that is at the root of how the world economy is conformed. In essence, those changes: (*a*) rendered endogenous the causal factors related to growth into the economic system; (*b*) made possible a closer articulation between capital formation and experimental science. Such articulation has become one of the most fundamental characteristics of modern civilisation. As pointed out by Furtado (ibid.), the beginning of such a process took place in the countries that were able to industrialise and create technical

progress first, and the quick accumulation made possible in the development of this process became the basic engine of the capitalist system. For this reason, there is a close interdependency between the evolution of the technology in the industrialised countries and the historical conditions on the basis of which such development was made possible. As the behaviour of the economic variables relies on parameters that are defined and evolve into a specific historical context, it is quite difficult to isolate the study of economic phenomena from its historical frame of reference (Furtado 2002). This assertion is more significant when analysing economic, social and technological systems that are different from each other, as in the underdeveloped economies. In this context, underdevelopment may not, and should not, be considered as an anomaly or simply a backward state. Underdevelopment may be identified as a functioning pattern and specific evolution of some economies. Social and economical peripheral structure determines a specific manner under which structural change occurs (industrialisation during the 1950s and 1960s) and technical progress is introduced. Hence different outcomes from those in developed countries are to be expected (Furtado 1961; Rodriguez 2001).

The neo-Schumpeterian perspective also argues that economic development is considered a systemic phenomenon, generated and sustained not only by inter-firm relations, but most significantly by a complex inter-institutional network of relations. Innovation is eminently a social process. Therefore, development — resulting from the introduction and diffusion of new technologies — may be considered as the outcome of cumulative trajectories historically built up according to institutional specificities and specialisation patterns inherent to a determined country, region or sector. Each country follows its own development trajectory according to its specificities and possibilities, depending fundamentally on their hierarchical and power position in the world capitalist system. The more distant underdeveloped countries are from the technological frontier, the larger will be the barriers to an innovative insertion in the new technological paradigm. More serious than technological asymmetries are knowledge and learning asymmetries, with the implication that access, understanding, absorption, domination, use and diffusion of knowledge become impossible. However, even when the access to new technologies becomes possible, most of the time they are not adequate for the reality of underdeveloped

countries and/or these countries do not have a pool of sufficient knowledge to make an adequate use of them. This occurs because the learning process depends on the existence of innovative and productive capabilities that are not always available. On this aspect, Arocena and Sutz (2003) argue that there are clearly learning divides between North and South that are perhaps the main problem of underdevelopment nowadays.

The Increasing Relevance of the BRICS Countries

The BRICS denomination was originally used to connect the dynamic emerging economies of Brazil, Russia, India, China, and South Africa as continental countries bearing a strategic position in the continents of the Americas, Europe, Asia, and Africa. The BRICS are also joined by their large geographical and demographic dimensions. Collectively, they were home to 42.2 per cent of the world population as of 2010 representing nothing less than 2.9 billion people. In addition, the five countries account for approximately 30 per cent of the earth's surface, holding significant reserves of natural resources such as energy and mineral resources, water and fertile lands. As well, BRICS countries have 24.3 per cent of world biodiversity; Brazil alone embracing 9.3 per cent of the total (GEF 2008).

Moreover, it is the recent performance of these economies and their macroeconomic indicators that make them more and more the focus of surveillance and analysis. In fact, the BRICS countries display a growing economic importance. In 2000, the five countries accounted for 17.1 per cent of the world GDP in public–private partnership (PPP). Their share increased to 25.7 per cent in 2010, with China and India accounting for 13.6 per cent and 5.5 per cent respectively, followed by Russia (3 per cent), Brazil (2.9 per cent) and South Africa (0.7 per cent) (IMF 2011).

The participation of the BRICS countries in world GDP is expected to rise sharply in the years to come. The impact of the financial crisis and global recession on developed world economy over the last three years has only lent support to this expectation, beyond attracting attention to the BRICS economies' capacity to remain immune or quickly recover from the crisis. Large domestic markets, pro-active investment policies, monetary and tax policies with anti-cyclic

capacity, presence of major public banks, and high level of reserves are elements increasingly recognised as having helped at least some BRICS economies to be less affected by the crisis.

While growth slowed in all major regions, China and India continued to grow rapidly in 2009 and 2010 (Table 1). In other BRICS countries the crisis rebounded fast. In Brazil, the GDP fell 0.2 per cent in 2009, but the economy surpassed pre-crisis growth rates in 2010 (7.5 per cent). South Africa showed a GDP decrease by 1.8 per cent in 2009 and had a 2.8 per cent increase in 2010. In Russia, heavily dependent on commodities like oil and gas, the economy has been hit more severely by the global crisis. It experienced shrinking of almost 8 per cent in 2009 but the GDP growth recovered to 3.7 per cent in 2010, beating the developed economies' growth rates. Prospects for 2015 show the five economies representing 29.5 per cent of the world economy.

The economic performance of the BRICS countries has, however, varied widely during the last decades as shown in Table 1. China has maintained its position as the fastest growing economy worldwide. India has also grown significantly and regularly. Brazil has had an irregular performance, well below its potential, but showed an enhancement in the second half of the 2000s. Russia, after the severe 1990s crisis that resulted in a decline of 40 per cent in its real GDP, has recovered and South Africa has had a small improvement in its economic performance that remains below its potential.

These different performances were accompanied by significant changes in the productive structure of the five countries, which reflect dissimilar development strategies.

The competitiveness of China's industrial sector is the main source of the country's impressive economic growth. The share of industry in the composition of China's GDP is unusual and growing: it was around 40 per cent in 1990 and reached 48 per cent in 2009. In contrast, in 2008, 56.1 per cent of the Chinese labour force still remained in rural areas. The relative share of the agricultural sector, which accounted for 30.2 per cent in 1980, is constantly falling, to 11 per cent of GDP in 2009. The share of services grew from 21.6 per cent in 1980 to 41 per cent in 2009.

Really impressive is the mounting share of China's manufacturing sector in world manufacturing GDP (Figure 2). In 1990, it represented 3.1 per cent of global manufacturing GDP, achieving 21.2 per cent in 2009.

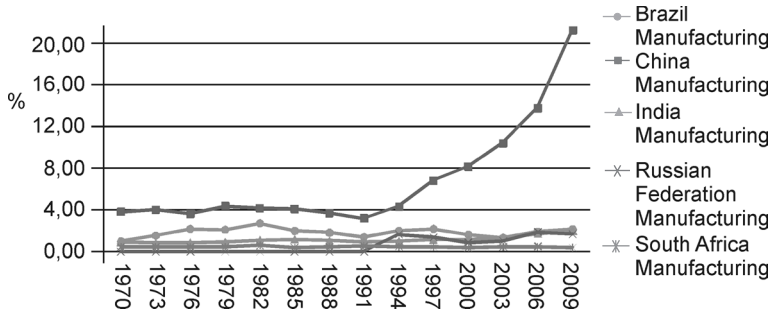
Table 1: *BRICS: Average Rates of Growth of Real GDP, 1980–2015 (percentage)*

	1980–1990	*1990–2000*	*2001–2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2015**
Brazil	2.8	2.9	2.8	3.7	5.7	5.1	-0.2	7.5	4.1
Russia	-	-4.7	6.2	7.4	8.1	5.6	-7.9	3.7	5.0
India	5.8	6.0	6.9	9.8	9.3	7.3	6.5	9.7	8.1
China	10.3	10.4	9.6	11.6	13.0	9.0	8.7	10.3	9.5
South Africa	1.6	2.1	4.0	5.4	5.1	3.1	-1.8	2.8	2.8
Developed Countries	3.1	2.8	1.9	2.8	2.5	0.8	-3.2	3.0	2.3

Source: UNCTAD (2010) for the period 1980–2008 and IMF (2011) for 2009–2015 data. See http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx (accessed 15 March 2011).

Note: * Estimate.

Figure 2: *Manufacturing Sector: BRICS' Share in World GDP, 1970–2009*



Source: UNCTAD (2009). See http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx (accessed 15 March 2011).

China has diversified its industrial system to a significant degree during the last 25 years and the share of technologically intensive sectors in industrial output in 2009 reached 42 per cent of the total value added by the manufacturing sector. In the other four countries this share is around 15 per cent.[3] In addition, some major differences in the characteristics of the BRICS countries' manufacturing sectors should be noticed.

Brazil has gone through a structural transformation since the late 1980s, with a significant reduction of the share of industry in total GDP (declining from 41.7 per cent in 1980 to 25.4 per cent in 2009) and a high growth of services (from 50 per cent to 68.5 per cent in the same period). It is worth emphasising that agricultural goods that have had an important role in the country's trade surplus were responsible for only 6.1 per cent of GDP in 2009, showing a fall from 9.0 per cent in 1980. In Brazil, as in Russia and South Africa, the products based on natural resources and commodities have a relatively greater share of national GDP than in China and India.

Russia's economic development is heavily dependent on energy and raw material resources. As in Brazil, the contribution of manufacturing sector to GDP in Russia has declined since the 1980s, decreasing from 44.6 per cent in 1983 to 32.9 per cent in 2009. The share of defence-related industrial complex in manufacturing is significant, together with the strong production base in non-electric machines and equipment. The oil and gas industry alone accounts for more than 10 per cent of the gross value added. The share of services in total GDP has grown in the last two decades achieving

62.4 per cent in 2009 while agriculture has decreased its participation accounting for only 4.7 per cent in 2009.

The Indian economy is essentially service-led. Skills in the manufacturing sector are relatively modest and concentrated in non-durable consumer goods and in the chemical-pharmaceutical complex. However, some manufacturing segments in the automobile complex and in certain basic industries have been developing rapidly in recent years. Since the mid-1980s, the contribution of industry to India's GDP has been almost constant and around 26 per cent, but from 2004 to 2009 it increased to 28.3 per cent. India's capacity in the area of services is significant, particularly those linked to information and communication technology (ICT). The share of services in GDP has grown from 39 per cent in 1980 to 54.6 per cent in 2009. Although the agricultural sector is declining in India's GDP, it still represented 17.1 per cent in 2009 (compared to 36.8 per cent in 1980) and constitutes an important determinant of the overall economic growth.

The services sector has also been playing a more important role in the South African economy. The share of this sector in GDP was 45.4 per cent in 1980 and increased to 65.8 per cent in 2009. The development of the financial sector and the growth of tourism have contributed to this growth. Finance, real estate and business services are expanding their share with regard to government services. South Africa's industrial sector is heavily based on natural resources, mainly steel and non-ferrous metals, with some increases in capacity occurring in non-durable consumer goods and the automobile sector. The share of industry-added value in total GDP value decreased from 48.4 per cent in 1980 to 31.4 per cent in 2009. The metal and engineering sectors dominate the manufacturing sector. Although agriculture is responsible for a small share of South Africa's GDP (3 per cent in 2009), it still represents an important source of employment. The minerals and mining sector remains important also with respect to both employment and foreign trade.

The changes observed in the participation of BRICS countries in international trade were even more significant (Table 2). Their share in merchandise trade value more than doubled in the short period of 2000–2010, exports rising from 7.5 to 16.4 per cent and imports from 6.2 to 14.9 per cent. However, the contribution of the five countries varied significantly. The most notable fact is the well-known growth of China in the merchandise trade value: its exports mounted from

3.9 per cent to 10.4 per cent of world exports reaching US$ 1.58 trillion in 2010, and imports increased from 3.4 per cent to 9.1 per cent in the same period.

Table 2: *BRICS: Merchandise Trade Value (in billion of current US$) and Share in World Total, 2000–2010 (percentage)*

	2000		*2005*		*2010*	
Exports	*Value*	*%*	*Value*	*%*	*Value*	*%*
World	6,448.57	100.00	10,495.70	100.00	15,174.44	100.00
Brazil	55.12	0.85	118.53	1.13	201.915	1.33
China	249.20	3.86	761.95	7.26	1,578.270	10.40
India	42.38	0.66	99.62	0.95	221.406	1.46
Russia	105.57	1.64	243.80	2.32	400.424	2.64
South Africa	31.95	0.50	56.26	0.54	85.700	0.56
	2000		*2005*		*2010*	
Imports	*Value*	*%*	*Value*	*%*	*Value*	*%*
World	6,662.89	100.00	10,800.15	100.00	15,353.26	100.00
Brazil	58.64	0.88	77.63	0.72	191.46	1.25
China	225.02	3.38	660.21	6.11	1,396.20	9.09
India	51.52	0.77	142.84	1.32	328.36	2.14
Russia	49.13	0.74	137.98	1.28	273.61	1.78
South Africa	30.22	0.45	64.19	0.59	96.25	0.63

Source: UNCTAD (2010).

India also experienced a sharp increase of exports, reaching 1.46 per cent of the world total in 2010. Fostered by Chinese growth and commodities boom, the share of Brazil and Russia in world exports grew rapidly from 2000 to 2010, increasing almost four times. South Africa is the only BRICS country that still shows less than 1 per cent of world exports. On the import side, India and Russia increased their share in world imports more than fivefold. Except India and South Africa, the other BRICS countries managed to keep a surplus in their merchandise trade in 2010. In India inflows on account of invisibles have been helpful in financing the growing deficit in merchandise trade.

The BRICS economies have significantly increased their openness to international trade in the last decades. They have raised their exports and imports both in volume terms as a share of GDP, but the level of trade openness has varied quite a lot (Table 3). The greater changes occurred in China and India, particularly since the 1990s when they speeded up their international trade flows. Currently, China, South Africa and Russia are the BRICS economies with the higher levels of openness. The Brazilian economy, despite the liberalisation process in the 1990s, remains the most closed amongst the BRICS countries.

Table 3: *BRICS: Foreign Trade (in million of current US$) and Share of GDP (percentage)*

	Exports + Imports				
Countries	*1970*	*1980*	*1990*	*2000*	*2010*
Brazil	8,719	25,412	61,212	113,762	393,379
China	4,833	38,919	114,71	474,227	2.972.960
India	4,792	28,839	51,144	93,941	540,489
Russia	–	–	349,249	136,973	627,323
South Africa	8,352	50,411	48,6	56,782	161,953
	(Exports + Imports) GDP				
Countries	*1970*	*1980*	*1990*	*2000*	*2010*
Brazil	13.0%	10.3%	14.0%	17.6%	18.8%
China	5.3%	12.9%	29.9%	39.6%	50.6
India	7.9%	15.7%	15.8%	20.4	31.3
Russia	-	-	36.1%	52.7	42.4
South Africa	45.7%	61.2%	43.4%	42.7	44.5

Source: United Nations (2010); World Bank (2011).

The bilateral trade flows between BRICS countries have been relatively restricted. However, since the first half of the 2000s there was a widespread increase of exports and imports flows between the five economies, but particularly a stronger presence of China as an important trade pole for the other four countries (Baumann 2009). In 2009, China surpassed the US as the main trade partner of Brazil and also emerged as the second main trade partner of India and Russia.