# Sustainability-oriented Innovation Systems in China and India

Edited by
Tilman Altenburg

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# Sustainability-oriented Innovation Systems in China and India

Global economic growth, recently fuelled by Asia's emerging economies, has greatly accelerated the accumulation of greenhouse gases in the atmosphere and boosted demand for scarce natural resources, including energy, food and mineral raw materials. These developments are pushing the planet close to its ecological boundaries.

Transforming the world economy towards sustainability, while ensuring decent levels of resource use for all global citizens, is the greatest challenge of our time. This book explores how innovation systems need to be adapted to successfully confront these challenges. The first chapter introduces the concept of sustainability-oriented innovation systems which highlights the systematic differences between systems that have developed along current resource-intensive technological trajectories and those that address the impending environmental mega-problems. The subsequent articles present case studies of sustainability-oriented innovations in a number of policy areas, including energy efficiency, electric mobility and generation of renewable energy, in China and India. These case studies confirm the specificities of innovation systems geared towards a green techno-economic paradigm.

This book was originally published as a special issue of *Innovation and Development*.

**Tilman Altenburg** is an economic geographer and Head of the Sustainable Economic and Social Development Department at the German Development Institute, Germany. Since 1986 he has carried out empirical research and published books and journal articles on issues of competitiveness, industrial and innovation policy, SME promotion and value chain development.

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# Notes on Contributors

**Tilman Altenburg** is an economic geographer and Head of the Sustainable Economic and Social Development Department at the German Development Institute, Germany. Since 1986 he has carried out empirical research and published books and journal articles on issues of competitiveness, industrial and innovation policy, SME promotion and value chain development.

**Shikha Bhasin** is a Researcher in the Energy research Centre of the Netherlands (ECN).

**Ankur Chaudhary** is based in the Indian Institute of Technology, New Delhi, India.

**Doris Fischer** is Professor and Chair of the Department of Chinese Studies at Würzberg University, Germany. She was previously based at the German Development Institute, Bonn, Germany.

**Adrian Lema** is based in the Danish Ministry of Climate, Energy and Building.

**Rasmus Lema** is an Associate Professor in the Department of Business Studies at Aalborg University, Denmark.

**Ajay Mathur** is based in the Bureau of Energy Efficiency for the Indian Government.

**Johan Nordensvärd** is a Lecturer in Social Policy at the University of Southampton, UK. He was previously based at the London School of Economics, UK.

**Jonathan Nowak Delgado** works for Next Century Strategy + Innovation (UG).

**Anna Pegels** is an economist based in the Sustainable Economic and Social Development Department at the German Development Institute, Germany.

**Ambuj Sagar** is based in the Indian Institute of Technology, New Delhi, India.

**Frauke Urban** works as a Senior Lecturer in Environment and Development at the Centre for Development, Environment and Policy, SOAS, London, UK.

**Rainer Walz** is based in Competence Center Sustainability and Infrastructure Systems, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany.

**Yuan Zhou** is an Assistant Professor in the School of Public Policy and Management at Tsinghua University, Beijing, China.

# Preface

The chapters of this book are articles that originally appeared in one of the special issues of *Innovation and Development*, an inter-disciplinary international journal from Globelics network, published by Taylor & Francis. http://www.tandf.co.uk/journals/RIAD

*Innovation and Development* is a relatively young journal born at a particular juncture in the discourse on development. The closing decades of the last century witnessed unprecedented changes in different spheres of economies and societies. This was induced by, among others, technological innovations led mainly by information communication technology and institutional innovations, resulting in increased integration between countries under globalization. In the emerging context of heightened competition, international competitiveness became the only means of survival. With the expanding global production networks and global innovation networks, different sectors across countries got themselves located appropriately in the global value chains. Instances of high rates growth sustained even for decades tended to suggest that achieving faster economic growth is within the reach of developing world. Unfortunately, however, the episodes of high growth induced by innovation at different levels turned out to be not inclusive and sustainable. The challenge, therefore, is to accomplish development that is sustainable and inclusive.

The mandate of *Innovation and Development* has its roots in this new millennium challenge. Since the role of innovation in development is increasingly being recognized in both the developed and the developing world, an enhancement of our understanding on the interface between innovation and development might help to find ways of addressing many of the developmental issues and of making growth process inclusive and sustainable. Hence, understanding the link between innovation, capacity building and development has emerged as a critical issue of concern for the academia, practitioners and policy makers, including international organizations such the World Bank or United Nations.

But our understanding of the links between innovation and development remains at best rudimentary, notwithstanding an unprecedented increase in studies on development and innovation on the one hand and a heightened interest in development practice on the other. While the two disciplines (development studies and innovation studies) have been growing in parallel, as they are traditionally separated with limited linkages, in recent years there has been an upsurge of interest in innovation issues in development studies. At the same time, with an increasing engagement of civil society organizations in developmental issues, innovative development practices are becoming more visible and their impact felt more than ever before.

By adopting a broader approach to innovation (to include technological, institutional, organizational and others) the journal and this book series aims at providing a forum for discussion of various issues pertaining to innovation, development and their interaction, both in the developed and developing world, for achieving sustainable and inclusive growth.

It is matter of great satisfaction that *Innovation and Development* has been able to lay the strong foundations for integrating innovation studies and development studies through the high

quality articles contributed by scholars across the world. These articles dealt with issues pertaining to diverse contexts ranging from primary agriculture to high-end services and from low technology sectors to high technology sectors operating in both the developing and developed world. In tune with the Globelics research agenda, *Innovation and Development* has also been promoting research and discourse on innovation at the national, regional, sectoral and societal level to facilitate building up of systems for learning, innovation and competence building. A unique feature of Innovation Developments is its supplementary sections that publish Ph D abstracts, web resources for research and innovations in practice.

The editorial board of *Innovation and Development* also takes pride in highlighting the significant contribution of this journal during the last five years of its existence through its special issues that focused on subjects of much relevance for theory and policy. The special issues brought out by the journal dealt with issues that include;

a) Sustainability–oriented innovation systems in China and India, guest editor Tilman Altenburg
b) Capability building and global innovation networks, guest editors Glenda Kruss and Michael Gastrow
c) Innovation and global competitiveness: case of India's manufacturing sector, guest editors N. S. Sidharthan and K. Narayanan;
d) Innovation for inclusive development, guest editor Fernando Santiago, and
e) New models of inclusive innovation for development, guest editors Richard Heeks, Christopher Foster and Yanuar Nugroho

We place on record our appreciation for all our guest editors for joining hands with us in our endeavor to take forward the agenda of *Innovation and Development*. We also take this occasion to acknowledge the liberal support that we received from the Editorial Advisory Board and the Scientific Committee. Our special appreciation for Taylor & Francis for bringing out this book series from the special issues of *Innovation and Development* and Ms Emily Ross for taking this project to its local conclusion.

It is our hope that this book series will be found useful by the academia at large, innovation scholars in particular and the policy makers concerned.

K. J. Joseph (Editor in Chief),
Cristina Chaminade, Susan Cozzens, Gabriela Dutrénit,
Mammo Muchie, Judith Sutz and Tim Turpin

***Editors, Innovation and Development***

# Contents

## Introduction

Global economic growth, recently fuelled by Asia's emerging economies, has greatly accelerated the accumulation of greenhouse gases in the atmosphere and boosted demand for scarce natural resources, including energy, food and mineral raw materials. These developments are pushing the planet close to its ecological boundaries. Transforming the world economy towards sustainability, while ensuring decent levels of resource use for all global citizens, is the greatest challenge of our time. This year, the Rio + 20 United Nations Conference on Sustainable Development marks a renewed effort to embark on ways of 'greening' the global economy in the context of sustainable development and poverty eradication. Greening the economy entails a techno-economic paradigm shift that needs to be:

- *radical*, as unsustainable technological trajectories need to be disrupted and replaced by new generations of technologies in order to decouple economic development from resource consumption and carbon emissions;
- *rapid*, because this decoupling has to take place within the next decade or two – a failure to take immediate action will overstrain the carrying capacity of critical global ecosystems and lead to much higher costs in the future; and
- *systemic*, as it implies changing technological regimes and combining industrial and institutional sub-systems in innovative ways.

This Special Issue explores how innovation systems need to be adapted to successfully confront these challenges. The first article introduces the concept of Sustainability-oriented Innovation Systems (SoIS) which highlights systematic differences between systems that have developed along current resource-intensive technological trajectories and those that address the impending environmental mega-problems. The subsequent articles present case studies of sustainability-oriented innovations in a number of policy areas, including energy efficiency, electric mobility and generation of renewable energy, in China and India.

The concept of SoIS is presented by Altenburg and Pegels. In trying to accelerate the development and deployment of environmentally sustainable technologies, SoIS are confronted with all-pervasive market failures that place high demands on governance. Governments need to find ways to internalise environmental costs, using a range of innovative policy instruments, such as cap-and-trade systems, feed-in tariffs for renewable energy, or environmental standards and labels that make markets more transparent. Also, they need to discourage the use of less sustainable alternatives and encourage promising 'clean' technologies, in some cases for decades before they emerge as cost-competitive under free market conditions. Which technological alternatives deserve support is often politically contested, as ongoing heated debates on biofuels, nuclear energy, or carbon capture and storage exemplify. Thus, governmental agencies need to establish a political consensus over technological roadmaps; and they need to be able to mobilise and eventually withdraw subsidies for selective technologies in ways that minimise misallocation and political capture. At the same time, the fact that roadmaps are highly policy-driven and

dependent on societal preferences and political settlements suggests a considerable divergence of national technological trajectories.

The following case studies explore how China and India deal with these challenges of 'transitioning' towards developing into sustainable economies. Given the size and sustained growth of these two economies, their efforts to decouple economic development from carbon emissions and resource consumption are crucial to avoid overstretching of the global ecosystems' carrying capacities. Both countries have recently adopted ambitious plans to curb carbon emissions and advance sustainability-oriented innovations. China and India are latecomers to industrial development, with innovation systems heavily reliant on foreign companies, joint ventures and technology licensing; but in recent years have also managed to spawn industrial champions that are amongst the world leaders in low carbon technologies. China is the largest manufacturer of wind turbines, photovoltaic cells and electric two-wheelers and among the world's leaders in battery technology for cars. India is lagging behind China in most technologies and has more budget constraints, but has nevertheless been able to bring forth successful companies including one of the world's leading wind turbine manufacturers and one of the first exporters of electric cars. Given their differences in initial economic and environmental conditions, policy objectives and patterns of economic governance, both countries offer interesting comparisons.

Lema and Lema explore the relevance of different international transfer channels for low carbon technology acquisition in China and India. Looking at wind and solar power as well as electric and hybrid vehicle technologies, the authors find that conventional technology transfer mechanisms such as foreign direct investments, joint ventures and licensing were important for industry formation and take-off. However, over the last 10 years, China and India's cross-border technology relations have evolved significantly and unconventional mechanisms for technology acquisition, such as investment in international R&D collaboration and acquisition of foreign firms, are today very important in defining their technological trajectories.

Chaudhary, Sagar and Mathur focus on energy-efficiency programmes in India. The authors start from the key challenge of SoIS – that environmental public goods are typically under-provided by ordinary market activities and require a coordinating organisation that is able to identify innovation gaps and design programmes to address them. They analyse four programmes run by the Bureau of Energy Efficiency, including a standards and labelling programme to provide the consumer an informed choice about the energy saving potential of household equipment; a programme to accelerate the dissemination of compact fluorescent lamps; the introduction of the Energy Conservation Building Code; and a market-based mechanism to enhance energy efficiency in the industrial sector. The case studies reflect how large-scale deployment needs to draw on a combination of policy measures (including information campaigns, standards and labels, demonstration projects), economic incentives and a mix of voluntary and mandatory regulations. The combination of such elements depends on the specificities of each technology. The authors also highlight the importance of a commercial orientation in the programmes for technology dissemination.

Altenburg, Bhasin and Fischer have applied the SoIS concept to electromobility in China, France, Germany and India. They highlight the transition to e-mobility as a multidimensional challenge implying severe coordination failure. For example, mass production of electric vehicles is hampered by the lack of public infrastructure for recharging batteries, which in turn only attracts investments if a considerable fleet of electric vehicles ensures demand for charging services. Likewise, simultaneous investments need to be made in interdependent technologies, such as batteries, light materials and power trains. Policymakers therefore need to provide upfront incentives and ensure synchronisation of R&D and investments activities to mobilise the entire sector. Incentive packages depend on the underlying objectives of e-mobility promotion, e.g. whether only renewable energy sources are eligible or not, and on the interest of the incumbent automotive industry.

The authors show that all four countries adopt very different policy packages, and trace differences back to initial industry characteristics, specific political priorities and patterns of economic governance.

Two papers analyse the emergence of the wind turbine industry. Walz and Nowak Delgado show how China and India have successfully developed indigenous wind turbine industries. In both countries, leading domestic players started by obtaining production licenses, moved on to form joint ventures, and finally started to produce their own designs and in some cases took over their foreign joint venture partners. At the same time, both countries' technology acquisition strategies differ markedly. India pursues a private sector-led approach, with fairly open trade regimes and an open door policy for foreign investors. Technology has mainly been acquired through international R&D collaboration and firm acquisitions. China, on the other hand, has followed a more policy-driven strategy, with state-owned enterprises playing a prominent role. The Chinese government strongly fosters capability building and supported the emergence of big national wind turbine manufacturers.

Urban, Nordensvärd and Zhou complement this research by analysing the motives that have been driving wind turbine industry growth in China. They argue that specific configurations of interest groups influence the direction, speed, development and implementation of wind energy policies and technological trajectories. Having analysed the interests of national and provincial government authorities, state-owned-, private-, and foreign firms, as well as research institutions and NGOs, the authors find that the primary motives driving wind energy innovation in China seem to be related to energy security and competitiveness, despite a growing climate change discourse. Wind turbine manufacturing is seen as an opportunity for Chinese firms to build cutting-edge capabilities and compete with international players. While in the beginning the domestic wind turbine industry was built on technology transfer from foreign investors and local content requirements, reliance on both factors has recently decreased and a large number of domestic firms have emerged under strong state leadership and state financing.

Finally, Fischer discusses the deployment of solar energy technologies in China. Due to its competitive advantages in manufacturing, China has become the largest producer of solar photovoltaic (PV) cells and modules in the world. Production, until recently was almost completely export oriented since the government was not willing to provide the necessary subsidies for promoting PV deployment in its home market: firstly, to keep energy prices low, and secondly, to avoid dependency on imported purified silicon. However, in 2009 this situation changed and the local market for PV installations is now growing rapidly. The author argues that this change was not mainly driven by climate change concerns. Instead, the fear that export markets would plummet due to the economic crisis in industrialised countries and China's own increased ability to produce purified silicon and therefore become technologically self-reliant, were decisive factors for embarking on an ambitious solar energy deployment programme.

In sum, the case studies confirm the specificities of innovation systems geared towards a green techno-economic paradigm. The Governments in China and India have taken a pro-active role in incentivising and coordinating sustainability innovations, and are experimenting with a range of innovative policy approaches. The approaches taken by the two governments to tackle the problem of multiple market failures and balance economic and environmental policy objectives differ considerably. While the development of low carbon technologies is in most cases still at an early stage, different patterns of competitive specialisation are already becoming evident.

Most papers in this Special Issue have been developed under a collaborative research project on 'Technological trajectories for climate change mitigation in China, Europe and India'. The researchers involved in this network are grateful for funding from a consortium of three European

research foundations: The Swedish Riksbankens Jubileumsfond, the German Volkswagen Foundation and the Italian Compagnia di San Paolo. Furthermore, the Altenburg/Pegels and Lema/Lema papers benefited from generous funding from the German Federal Ministry for Economic Cooperation and Development (BMZ), and the Lema/Lema and Fischer papers from the European Commission's CO-REACH programme.

Tilman Altenburg
*German Development Institute*

# Sustainability-oriented innovation systems – managing the green transformation

Tilman Altenburg and Anna Pegels

*German Development Institute / Deutsches Institut für Entwicklungspolitik, Bonn, Germany*

Global warming and other impending environmental mega-problems call for a new technological paradigm. The urgency of the development and deployment of technological solutions is such that governments will need to make widespread use of 'carrots and sticks' to ensure that next-generation technologies are developed and deployed, more demanding standards and regulations are applied and stricter enforcement is guaranteed. To capture the main elements of this paradigm shift, we introduce the concept of Sustainability-oriented Innovation Systems (SoIS). SoIS make particularly high demands on governance, because governments need to disrupt unsustainable technological pathways and encourage alternative technologies long before they reach the stage of commercial viability. This implies picking winners in situations of technological uncertainty and highly disparate stakeholder preferences. SoIS also build on new types of policies that help to internalise environmental costs. The policy-driven nature of technological development may possibly result in a wide divergence of national technological trajectories.

## Introduction: a new approach to innovation systems research

In the past, economic growth has been achieved at the expense of natural resource depletion, without stocks being allowed to regenerate. Ecosystems have been widely degraded and biodiversity has been lost at an unprecedented pace (Millennium Ecosystem Assessment, 2005). If current resource-intensity continues, environmental tipping points may create ecosystem disequilibria that will threaten human livelihoods.[1] While climate change is the most pressing challenge, many other environmental imbalances are expected to become unsustainable in the near future. A group of Resilience Alliance researchers has identified nine 'planetary boundaries' that must not be crossed if major risks to humanity are to be avoided. They include limits to freshwater use, ocean acidification, loss of biodiversity and chemical pollution (Rockström et al., 2009).

At the same time, the global economy is experiencing a phase of unprecedented growth which is putting an enormous strain on global and local ecosystems. Humankind is approaching the planetary boundaries at high speed.

Changing to sustainable patterns of development while ensuring decent levels of resource access for all the world's citizens is the greatest challenge of our time. It calls for what Freeman (1992) termed a *green techno-economic paradigm shift*: while the need for new generations of resource-efficient technologies is undisputed, a paradigm shift will also entail a change in societal norms and values, motivating new life styles, different ways of accounting for

development and economic incentive schemes that systematically internalise environmental costs. In the same vein, the German Advisory Council on Global Change (WBGU) calls for a 'new global social contract for a low carbon and sustainable global economic system' to achieve a transformation similar in scope to the Neolithic and industrial revolutions (WBGU, 2011, p.1).

This paper sets out to develop a conceptual framework for the analysis of the innovation efforts required to embark on such a sustainable development path. Building on groundwork done by Stamm et al. (2009), we develop the conceptual foundations for Sustainability-oriented Innovation Systems (SoIS). This concept is based on evolutionary innovation systems research, but places far greater emphasis on governance and introduces relevant additional dimensions.

The starting point is the need to accelerate the development and deployment of environmentally sustainable technologies. In pursuing this objective, SoIS are confronted with particularly serious market failures. Innovation systems research traditionally concentrates on the market failure of non-appropriability: as the social benefits of science, technology and innovation tend to exceed privately appropriable benefits, the services concerned are frequently undersupplied. While this also applies to SoIS, the current rules of market economies are even less effective when new generations of environmentally sustainable technologies are to be developed: firstly, because they allow economic agents to externalise many environmental costs, which then have to be borne by society as a whole now and in the future. Secondly, SoIS need to disrupt unsustainable technological trajectories and foster the development of sustainable substitutes, some of which may require more than a decade or two to become competitive. Supporting these clean technologies of the future is fraught with coordination and information failures.

This has important ramifications for policy and future technological trajectories. As will be shown later, the multiple market failure calls for governments to play a more active guiding role and for a very distinctive range of policy instruments and may result in diverging national technological trajectories, reflecting specific societal preferences, power constellations and policy frameworks.

This paper is divided into three sections. Section 1 stresses the urgency of changing innovation efforts to the search for environmentally sustainable solutions and considers the extent to which innovation systems research has already taken up the challenge. Section 2 advances the existing literature further by developing the concept of SoIS. It highlights important differences between 'business as usual' innovation systems and those aimed at disrupting unsustainable trajectories and accelerating the development and deployment of 'clean' technologies. The three sub-sections of Section 2 are devoted to these differences: increasing demands on governance; different sets of policies; and potentially diverging technological trajectories. Section 3 concludes by identifying relevant topics for future research.

## 1. Innovations for environmental sustainability: relevance and conceptual debates

### 1.1 *An evolutionary perspective on innovation*

The concept of innovation systems (Freeman, 1995; Lundvall, 1992) seeks to explain the systemic nature of innovation. More specifically, it helps us to understand how technologies, industries and institutions co-evolve and shows how technological paradigms are created and how they give rise to specific technological trajectories. Thus the concept provides in principle a suitable analytical framework for understanding the implications of a paradigm change from a fossil fuel-based economic system to one of resource-efficient sustainable production.

The core principle of the innovation systems approach is that innovation is a relational, interactive and cumulative process that occurs between producers and users of goods and services,

including private industries, universities, providers of knowledge-intensive business services, trade organisations and public support institutions. This relational nature means that technological knowledge cannot be fully codified and traded like any other good. Innovation is described as a process whereby institutions and technologies co-evolve in particular ways (Nelson, 1994): as initial institutional conditions differ – in terms of how markets operate or of societal values and product preferences, for example – different technologies necessarily evolve differently, which in turn leads to particular adaptations of the institutional framework.

Central to this evolutionary understanding of innovation are the notions of technological paradigms and technological trajectories. According to Dosi (1982), a technological paradigm is a kind of directed research programme aimed at discovering solutions to a specific set of perceived problems. Importantly, a paradigm implies 'strong prescriptions on the directions of technical change to pursue and those to neglect' (Dosi, 1982, p. 152). Once a technological paradigm has gained hegemony, the development of new technologies follows a certain direction of advance within its boundaries: a *technological trajectory*. As progress on a technological trajectory is cumulative, the search for new technologies reinforces its initial direction. As we argue later, this in-built path-dependency and inertia of technological trajectories constitutes the main challenge for sustainability-oriented innovation systems that try to disrupt firmly established, but environmentally unsustainable trajectories.

Traditionally, policy frameworks for technological innovation have been defined mainly at the level of nation states. This has given rise to the notion of *national* innovation systems. While these are mostly understood as a 'permeable territorial formation, the borders of which are crossed by numerous linkages within global-local production networks' (Coe et al., 2004), the focus on national systems and country-specific patterns of technological specialisation nevertheless means that home-country determinants, such as linkages between national firms and research institutions, are deemed more important than cross-border linkages. The popular debate on the 'competitiveness of nations' (for example, Porter, 1990) builds on the same premises.

With increasing globalisation, however, the number of international regulations has proliferated. Global and regional bodies have gained considerably in importance as sources of norms and standards to which national actors must adhere. Similarly, international sources of knowledge and transfer mechanisms are becoming increasingly important for technological learning. Among these new international conduits of technology acquisition are the integration of firms into global value chains, joint ventures, mergers and acquisitions, the formation of international research networks in both the public and the private sphere and international labour migration (Altenburg et al., 2008; see also Lema and Lema in this volume).

Innovation systems are therefore characterised by increasingly complex forms of multi-level governance. Nation states still have an important role to play in setting regulatory frameworks, defining national research priorities and promoting networks among national firms and supporting organisations. However, a growing body of rules and regulations is negotiated at international level and then further specified at lower levels – regional, national and sub-national. As we will show in Section 2, multi-level governance is particularly challenging when it comes to innovations in the field of global public goods.

### 1.2 *The need for a paradigm change towards environmental sustainability*

For more than two decades, the global economy has experienced a phase of unprecedented growth, fuelled mainly by the dynamism of Asia's emerging economies. Since the 1990s, the annual growth rate of the global economy has averaged about 3% (World Bank, 2011). This growth has led to rising demand for scarce natural resources, including food, energy and mineral raw materials, which has in turn contributed to accelerated growth in regions that are