PUBLIC POLICY IN (RE)BUILDING NATIONAL INNOVATION CAPABILITIES:
A COMPARISON OF S&T TRANSITIONS IN CHINA AND RUSSIA

A thesis submitted to the University of Manchester for the degree of
PhD Public Policy and Management
in the Faculty of Humanities

2013

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ABSTRACT

China and Russia – two giants in the group of emerging markets – continue to attract wide attention as evolving science and technological superpowers. However, both countries demonstrate mixed success in innovation development and are struggling to overcome the legacies of the former state planning system and accelerate their transition to effective national innovation systems. This study employs a number of theoretical constructs and evidence sources to evaluate the existing path dependencies and compare the achievements of China and Russia in fostering development and effective systems of innovation and governance.

A detailed analysis of the state planning legacies is provided together with a study of innovation system transformation and the role of public policy in (re)building national innovation capabilities in China and Russia. The system-evolutionary approach is applied to provide a detailed assessment of the strategic effort undertaken by the governments of both countries. Several government failures and path dependencies seem to prevent the nations from implementing a more effective reform. Yet, there are a number of complementarities and opportunities for mutual learning where both countries can benefit from closer collaboration. The challenges of turning universities into research institutions, increasing productivity of state-owned enterprises, constructing effective science parks, promoting indigenous innovation, ensuring more even distribution of innovation development across regions, turning ‘brain drain’ into ‘brain gain’, and improving intellectual property rights protection are common in Russia and China.

As a lens through which to identify and assess innovation systems transformation, the thesis examines emerging nanotechnology development in China and Russia. Nanotechnology is a new science and technology area where policies seem to be independent of many system weaknesses and contribute to breaking existing development lock-ins due to its explorative nature and assumed transformative capacity. Yet, a number of path dependencies do exist in this area but seem to play a marginal role in its progression. An early assessment is provided of nanotechnology impacts on broader socioeconomic development of China and Russia in six key areas: institutional development, knowledge flows, and network efficiency; research and education capabilities; industrial and enterprise growth; cluster and network development; regional spread; and product innovation.

The conclusion summarizes the main findings, revisits the major research questions, links the analysis to the conceptual framework, and offers a number of policy recommendations that seem relevant to both Russia and China with a need to increase the transparency of innovation policy, improve the regulation for innovation process, and promote growth of the private sector to ensure effective technology transfer.

Results from this study have been reported in various forms in the author’s articles published in Research Policy, Science and Public Policy, Review of Policy Research, International Journal of Economics and Business Research, and European Journal of Development Research as well as presented at a number of international conferences (see Appendix).
DECLARATION

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ACKNOWLEDGEMENTS

This thesis would not have taken shape without the great learning experience that I have gained through these years at the Manchester Business School and wider University of Manchester. The environment created at the Manchester Institute of Innovation Research, to which I belong, under attentive leadership of Prof Jakob Edler and other directors have promoted my understanding of science, technology and innovation as well as taught me how to succeed in academia and build important relationships with smart professionals working in the Institute and beyond. I am grateful to all my colleagues, both in academia and in administration, for their permanent support and advice as well as friendly discussions outside work, including Philippe Laredo, Dimitri Gagliardi, Ozcan Saritas, Ian Miles, Sally Randles, Abdullah Gök, Ronnie Ramlogan, Jan Youtie, Kate Barker, Debbie Cox, Siobhan Drugan, Wendy Walker, Sanjay Arora, Mohammad Hajhashem, and many others.

Most of all, I wish to express deepest gratitude to Prof. Philip Shapira and Dr. Kieron Flanagan, my responsive supervisors and careful guides in the complex world of academia. Their support and recommendation went far beyond this thesis and enlightened me in many ways. Our discussions of research strategies, methodologies, intricate questions, career and life are most valuable to me. I also appreciate the generous opportunity that Phil gave me in learning from his projects and the Innovation Co-Lab where I gladly participate together with other colleagues at the University of Manchester, Georgia Tech, Beijing Institute of Technology, and Higher School of Economics in Moscow, who also helped me greatly with the field interviews in China and Russia when pursuing this research.

I was very lucky to have two brilliant scholars – Prof. Stan Metcalfe and Prof. Dan Breznitz – to examine my thesis. I am most grateful to them for the time and thought that they spend to review my work and share their valuable ideas and insights into the topics that fascinate me so much.

A big thank you is due to my parents who supported me both morally and financially throughout these difficult three years.

My wife, Alina, deserves a special place in my heart and my life, and I am sure I would never have reached the point where I am now without her kind care and passionate support. I am eternally indebted to her for the patience and kindness, with which she accompanied me in these several years despite all the stress and pressure that I had encountered during my PhD.
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<tr>
<td>211 Project</td>
<td>National Key Universities Project (China)</td>
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<td>863 Program</td>
<td>High Technology R&amp;D Program (China)</td>
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<tr>
<td>973 Program</td>
<td>Key Basic Science R&amp;D Program (China)</td>
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<tr>
<td>BRIC</td>
<td>Brazil, Russia, India, and China</td>
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<tr>
<td>BRICS</td>
<td>Brazil, Russia, India, China, and South Africa</td>
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<tr>
<td>CAS</td>
<td>Chinese Academy of Sciences</td>
</tr>
<tr>
<td>CMEA</td>
<td>Commonwealth for Mutual Economic Assistance</td>
</tr>
<tr>
<td>Concept-2020</td>
<td>Concept for Long-Term Socioeconomic Development of Russia until 2020</td>
</tr>
<tr>
<td>CSC</td>
<td>China Scholarship Council</td>
</tr>
<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency (USA)</td>
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<tr>
<td>EPO</td>
<td>European Patent Office</td>
</tr>
<tr>
<td>FASIE</td>
<td>Foundation for Small Business Support in the Science and Technology Sphere (Russia)</td>
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<tr>
<td>FDI</td>
<td>foreign direct investment</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GNP</td>
<td>Gross National Product</td>
</tr>
<tr>
<td>HSE</td>
<td>National Research University Higher School of Economics (Russia)</td>
</tr>
<tr>
<td>ICT</td>
<td>information and communications technology</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrochemical Commission</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineering</td>
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<tr>
<td>IPR</td>
<td>intellectual property rights</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>IT</td>
<td>information technology</td>
</tr>
<tr>
<td>MDGs</td>
<td>Millinnium Development Goals</td>
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<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>MLP 2020</td>
<td>Long and Medium Term Science and Technology Development Plan Guidelines 2006-2020 (China)</td>
</tr>
<tr>
<td>MOST</td>
<td>Ministry of Science and Technology (China)</td>
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<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
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<tr>
<td>NCNST</td>
<td>National Center for Nanoscience and Technology (China)</td>
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<tr>
<td>NEICON</td>
<td>National Electronic Information Consortium (Russia)</td>
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<tr>
<td>NERCN</td>
<td>National Engineering Research Center for Nanotechnology (China)</td>
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<tr>
<td>NGO</td>
<td>non-governmental organization</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>NNI</td>
<td>US National Nanotechnology Initiative</td>
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<td>NSF</td>
<td>National Science Foundation (USA)</td>
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<tr>
<td>NSFC</td>
<td>National Natural Science Foundation of China</td>
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<tr>
<td>NST</td>
<td>nanoscience and technology</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
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<tr>
<td>PC</td>
<td>personal computer</td>
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<tr>
<td>PPP</td>
<td>purchasing power parity</td>
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<tr>
<td>R&amp;D</td>
<td>research and development</td>
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<tr>
<td>RAAS</td>
<td>Russian Association for the Advancement of Science</td>
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<tr>
<td>RAS</td>
<td>Russian Academy of Sciences</td>
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<td>RFBR</td>
<td>Russian Foundation for Basic Research</td>
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<td>RFH</td>
<td>Russian Foundation for the Humanities</td>
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<td>RFID</td>
<td>radio-frequency identification</td>
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<tr>
<td>ROI</td>
<td>return on investment</td>
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<tr>
<td>Rosstat</td>
<td>Federal Statistical Service of Russia</td>
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<tr>
<td>S&amp;T</td>
<td>science and technology</td>
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<tr>
<td>S.NET</td>
<td>Society for the Study of Nanoscience and Emerging Technologies</td>
</tr>
<tr>
<td>SBIR</td>
<td>Small Business Innovation Research (USA)</td>
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<tr>
<td>SIPO</td>
<td>State Intellectual Property Office (China)</td>
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<tr>
<td>SOE</td>
<td>state-owned enterprise</td>
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<tr>
<td>SSIP</td>
<td>social system of innovation and production</td>
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<tr>
<td>STI</td>
<td>science, technology, and innovation</td>
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<td>STTR</td>
<td>Small Business Technology Transfer (USA)</td>
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<tr>
<td>TRIPS</td>
<td>trade-related aspects of intellectual property rights</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>US GAO</td>
<td>US General Accounting Office</td>
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<tr>
<td>USPTO</td>
<td>US Patent and Trademark Office</td>
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<tr>
<td>USSR</td>
<td>Union of the Soviet Socialist Republics</td>
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<tr>
<td>WAPI</td>
<td>WLAN Authentic and Privacy Infrastructure</td>
</tr>
<tr>
<td>WEF</td>
<td>World Economic Forum</td>
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<td>WTO</td>
<td>World Trade Organization</td>
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Chapter 1. Introduction

Economic development has long been a focus of policymakers, industry, and researchers all over the world. It is common to believe that in different periods some powers appeared to be more successful in their development than the others with Portugal and Spain being the leaders of the 16th century, Britain and Netherlands taking over in the 17th century, Britain and France leading in the 19th century, and Germany, Japan, Soviet Union and the USA re-making the world in the 20th century. In the early 21st century, the United States is considered to be leading, but with China and other economies fast emerging. These developments have raised a number of questions that have become increasingly topical in the recent decades: what are the key determinants of successful development; what are the most efficient ways to catch up with the leaders; what are the main nation-specific factors that make one power achieve rapid success while others continue lagging behind; and why is it so important to be a world leader and could other strategies be better for the population?

In the new era of globalization these questions have become even more important with the new opportunities (as well as new dangers) faced by emerging economies. Both in economics and political science, it was argued that the ongoing growth of global links and fragmentation of production is limiting the power of states in guiding the nations’ economic development and influencing the routes of innovation growth. However, several studies have refuted this argument and proposed that the states are now faced with a much larger set of choices and entry points than ever before and yet play a significant – although transformed – role in leading their nations to the best possible outcomes (cf. Breznitz, 2007).

After the 2008 financial crisis, ongoing political turmoil in the Middle East as well as the rapid surge of China these ideas have become ever more topical with the national governments taking on most responsibility to ensure stable growth and societal well-being amidst the economic and political uncertainty.

In the meantime, the objectives pursued by various countries in their development strategies remain rather diverse. Many developing nations are guided by the UN Millennium Development Goals that set particular targets in the fight against poverty and hunger, access to primary education, healthcare, and gender equality.¹

¹ See more at http://www.un.org/millenniumgoals.
Although similar problems exist in almost every country, a group of more developed countries often referred to as emerging markets are more concerned with technological catch-up and effective industrial growth where they can use their comparative advantages (e.g., in labor or in natural resources) to leapfrog certain stages of economic development and stay on par with the world leaders.

Among these, transition economies present a special group of countries who are making considerable effort to reform their state planning economic systems and transform them into effective market economies. Some of these nations, like Russia, had already built a strong industrial and technological base in the previous period of their development while others, like China, embarked on the route of substantive gradual economic reform about 30-40 years ago.

At the same time the critical role of science, technology and innovation in effective development (either focused on economic catch-up or the resolution of deeper social and economic problems) has not been practically realized until recently.

Technical progress had basically become one of the major drivers of economic growth only in the 19th century following the industrial revolutions in the western world when factories replaced workhouses and craftsmanship and machines offered much improved productivity. It does not mean that technology and innovation did not define the national advances in the previous times (take for example innovative military organization and weaponry of Alexander the Great that allowed him to conquer half of Asia). But it is in the last two centuries that technology has become recognized as an indispensable means of reaching substantial socioeconomic success through large scale production and deep penetration with the social fabric. As a result, List (1841) and Marx (1867) framed innovation as one of the key factors of growth in the complex production systems and technology – as one of the major components of the production relations in society.

Later on, the economists of the 20th century, driven by the rapidly changing reality, continued looking into the particular interrelation between technological change and economic development. Solow (1956) and Denison (1962) included technical progress into their models of economic growth and considered it as a long-term exogenous factor difficult to count in the short- and mid-term perspective. Romer (1986) made a step further and suggested that technical progress is an endogenous factor, which depends on the present levels of education, training, research and development, etc.
Another group of scholars worked in the domain of evolutionary and institutional economics. The evolutionary perspective offered a new vision of technological change that is a process with multiple variables influencing the macroeconomic growth and competition between firms. In this context innovation is seen as a critical factor in the market structure and one of the major driving forces of capitalist development (cf. Schumpeter, 1934; Nelson and Winter, 1982; Dosi et al., 1988; Metcalfe, 1995).

In the meantime, the innovation process remains highly dependent on a variety of soft factors added to the neoclassical set of labor and capital. These include the internal factors of firm behavior and organizational structure but also a number of external settings including institutional and cultural context of a country or region where a firm operates.

This complex view of innovation helped understand how technical progress may be used to ensure fast development and catch-up growth and also how the innovation process should be constructed in the diverse national and local contexts. Gerschenkron (1962) presented a meticulous study of late-development economies where he argued that these nations have particular advantages compared to the leaders as, first, they already know the market routes and can invest in the sectors where biggest returns are expected, and second, they do not have the burden of older industries to care about.

Later, this vision was supplemented by a number of requirements that should be met by developing nations to ensure successful technological catch-up. Abramovitz (1986; 1989) suggested that in order to ensure rapid growth and efficient development a nation should first possess or acquire the necessary social capabilities by training new personnel, supporting science, investing in research and development, etc. Perez and Soete (1988) argued that, while less developed countries do have particular windows of opportunity, the very imitation by the catch-up economies can be quite costly especially if taking into account the underdeveloped infrastructure that is usually taken for granted in industrialized countries. And based on his study of Japan’s economic miracle, Johnson (1995) concluded that three pillars are required to ensure the impressive growth of what he called a capitalist developmental state. These include strong state, effective bureaucracy, and economic nationalism.

In the 1980s and 1990s, another group of scholars continued to offer a framework to see how the innovation process can be managed in the increasingly complex environment where science and technology are no longer contained within the borders of one country or
region and knowledge is freely exchanged across nations and continents (cf. Lundvall 1985, 1992; Freeman 1987, 1995; Nelson, 1993; Edquist, 1997). The so-called systems-of-innovation approach has become the result of this activity and permits to take a comprehensive perspective on the processes of interactive learning and competence-building at the national, regional and sectoral level, and consider the role of various actors in the innovation development. In general, the approach suggests that innovation is a complex, non-linear process, which is produced as a result of constant interactive learning among universities, government agencies, firms, research centers, other research and development (R&D) units, etc.

Many nations pioneered new approaches to innovation policy based on this concept in the early 1990s with major international organizations following suit including the Organization for Economic Co-operation and Development (OECD), the World Bank, the World Economic Forum (WEF) and various agencies of the United Nations (UN) family. So, today it seems unusual if top-rank officials of any given country do not appreciate the critical importance of modernization and innovation development.

Thus, there appears to be a general consensus in the contemporary world that science, technology and innovation (STI) is imperative to ensure successful development and catch-up with the world leaders (and for the latter to sustain their leading positions). An important question remains open: how a nation can use its history, culture and institutional peculiarities (i.e. the same soft factors) to ensure growth and support of indigenous innovation? In other words, does it matter whether a country has a rich tradition of scientific discovery and technological advancement in the past and what is the role of path dependencies produced by these former achievements in creating the conditions for regaining the ‘superpower’ status in the present times?

1.1. Cases

Two countries are at the core of this study, one is a former superpower and the other is an emerging one. Both are former communist nations with strong state planning legacies. Both have a long history of rivalry and competition as well as a rich tradition of mutual learning and strategic collaboration. Today, Russia and China form a promising political and economic alliance in Asia (through the Shanghai Cooperation Organization and also in the major international organizations including the Asia-Pacific Economic Cooperation and the United
Nations) and are also part of the so-called BRICS\textsuperscript{2} countries that are predicted to surpass the world leaders by 2050 (Goldman Sachs, 2001).

In their transition to the market economy, Russia and China strive to adopt and adapt the best practices of public management, which are the result of long-established experiences in the developed countries. As shown above, one of these experiences demonstrates a clear link between science, technology and innovation, on the one hand, and economic growth, on the other. Proceeding from this assumption, both countries make a great effort to promote indigenous innovation and construct effective national innovation systems today.

Yet, they are two very different countries with unique historical, cultural, institutional and political characteristics. And like in Breznitz’s (2007) comparison of IT industries in Israel, Taiwan and Ireland, Russia and China are provided with a plurality of choices in the new global environment where every nation may choose its own way and yet many of them may prove to be successful. The study of these differences and similarities are a challenging research subject that can shed more light on the comparability and compatibility of the development trajectories in various countries as well as proper conceptual and methodological grounds for such large-scale comparison. Moreover, a number of opportunities for mutual learning in policy and system development may emerge and a different understanding of the cases to follow may come up as a new notion of best practices in today’s world. In other words, western experiences may not suit so well to the different environment of post-communist states and other countries as is common to think – on the contrary, these nations may be better off together like a flock of flying geese that has already been a success in the story of the Asian miracle.\textsuperscript{3}

To test this latter assumption I benchmark innovation trajectories and policies of Russia and China with those observed in the United States, a presumed leader of the contemporary world. After the collapse of the Soviet Union, the USA has been an important model to follow

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\textsuperscript{2} The BRICS include Brazil, Russia, India, China, and South Africa (the latter officially joined the group in 2011 for the summit in Sanya, China).

\textsuperscript{3} The flying geese paradigm was developed by Akamatsu (1962) and describes the pattern of longitudinal economic development in less advanced countries through three sequential stages, “from import to domestic production and further to export” (p. 11). This wild-geese-flying pattern is also relevant to the hierarchical structure of the world economy where the advanced countries have diversified production systems while developing nations strive to catch up with them. Akamatsu (1962) suggests there are three groups of countries where the wild-geese-flying pattern dominates the economic relations around the United States, Western Europe, and Japan. It is the latter group that marks the learning process between the Asian nations in the course of moving their economies towards homogeneity.
and imitate as the most developed and successful nation of the world that is comparable with Russia and China by size, geography, and natural riches. However, the last twenty years did not prove that the foreign values and achievements can be easily transferred and rooted in a different institutional and cultural environment. Thus, the question stands whether the US system can still be adapted to the needs of various nations or each of them should follow a unique path with other models to copy across the entire world.

1.2. Objectives

Focused on two large country cases, this work seeks to make several theoretical, methodological and empirical contributions that are guided by the existing gaps in understanding the dynamics of innovation development, the role of history and culture in this important process as well as the mechanisms of successful development and catch-up in the contemporary world:

1. Following initial insights by Nelson (1993), innovation scholars have been trying to integrate and analyze how the processes of globalization are influencing the emergence and development of innovation systems in the contemporary world. Following the classical firm-centered meso perspective, Edquist (1997) and Carlsson (2006) wrote about the internationalization of innovation systems suggesting that the national boundaries have limited effect on the formation of network connections and interactive learning mechanisms between firms in the global market environment. I apply a different approach by looking at the global innovation system as a set of distinct national innovation systems – or social systems of innovation and production using Amable’s (2000) terminology – where boundaries, historical and cultural diversity continue to play significant role in shaping the opportunities for cross-national innovation cooperation and growth. In this, I argue that some countries have particular policy and system complementarities and can learn from each other based on their former experiences and contemporary challenges.

2. Another big theoretical challenge has been to bring together the ‘static’ innovation system analysis and evolutionary ‘dynamics’ to understand the principles of technological change and growth over the years in various countries. By taking a detailed look at historical path dependencies dating back to the beginning of the last century and earlier and combining this

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4 The notion of social systems of innovation and production is discussed in more detail in section 2.2.3.
analysis with the systemic perspective I try to contribute in understanding these links between various ‘static’ and ‘dynamic’ approaches through a large-scale empirical and theoretical study.

3. Since the offset of the national innovation systems approach various scholars have been trying to understand whether these systems are similar across the globe and various innovation practices can be emulated in different countries with same successful effect as in other more developed nations. The reason for doubt was brought by the fact that most early insights on national innovation systems (Lundvall 1985, 1992; Nelson 1993; Freeman 1987, 1995) were based on the empirical evidence from OECD countries. Lundvall (2007) and the Globalics conference have been trying to address these issues by a variety of empirical research and by bringing researchers from developing countries around one table. Metcalfe and Ramlogan (2008) also sought to find ways where the concept can be adaptable to the distinctive context of developing countries. I aim to contribute to this work by merging the knowledge of two schools (Soviet/Russian Studies, on the one hand, and Chinese Studies, on the other) that rarely communicate and have limited knowledge spill-overs between them by raising the very need for conducting this research.

4. Although the BRIC concept was originally coined by Goldman Sachs in 2001 and has become widely used by business, policymakers, and academics in the recent decade, there has been no large-scale research confirming the academic validity of using the concept in theoretical and empirical contexts based on reasonable comparability and similarity between the four countries of the group (plus South Africa since 2011). Few scholars attempted to fill in this gap (cf. Vitorino and Cassiolato, 2009; Laidi, 2012). I follow these earlier attempts and aim to contribute to this debate by providing a detailed comparative study of Russia and China.

5. There have been few attempts to test whether the dramatic transition experience of the former Soviet Union can be transferred to the post-communist Asian countries and vice versa. I am studying these opportunities by taking a detailed look at historical and economic complementarities of Russia and China.

6. Finally, innovation studies have been largely focused on the issues of economic growth and innovation as an end in itself following the models by Solow (1956) and Romer (1986) as well as evolutionary and institutional economics tradition (Nelson and Winter, 1982; Dosi et al., 1988). In the meantime, recently there has been a trend to see innovation as a means to broader development goals with an involvement of wider groups of population and the rise of
discussions on inequality and other issues related to Millennium Development Goals (Cozzens, 2010; Klochikhin, 2012c). Following this trend, I study the relation between innovation and development and contribute by offering a special methodological framework that provides an early assessment of the effects of nanotechnology in six areas of broader socioeconomic development.

7. Empirically, the BRICS countries, particularly Russia and China, remain seriously understudied, especially from the comparative and innovation system perspective. I provide a detailed comparison of the two countries based on their common state planning legacies and policy solutions that they apply to overcome the historical path dependencies, development lock-ins, and emerging challenges. The successes and failures are assessed with regard to their contribution to the economic transition process and catch-up growth.

1.3. Research questions and contributions

Throughout this work I seek to answer four research questions that are linked to the major theoretical and empirical objectives:

- **How can Russia and China exploit their science and technology to promote indigenous innovation development and resolve the weaknesses of the former state planning system?**

  In answering this question, I find that history must be taken into account when seeking to resolve the main system and policy challenges of today since many of them take their roots in the remote past with no effective solution possible without deep knowledge of the problem’s origins. These roots may lie in the economic, cultural, institutional, social or political frameworks and should be studied in all detail largely following the conceptual approaches developed by the students of world-systems analysis and varieties of capitalism. In this context the role of science and technology in resolving these weaknesses coming from the former legacies (including state planning legacies of Russia and China) is critical due to the vital contribution of innovation to socioeconomic progress, as established by wide groups of innovation researchers and development scholars.
• Are there any particular complementarities between the Russian and Chinese innovation that can contribute to their socioeconomic development?

I find there are a number of important complementarities between the Russian and Chinese innovation due to multiple similarities that exist in both countries based on their common state planning legacies. Many of these common system features can be traced back to the main parameters of the state planning S&T system as discussed in Chapter 4.

• What are the current and emerging opportunities for mutual learning between the two countries?

Based on a detailed analysis of S&T and innovation systems in Russia and China and their development over the last century I proceed to evaluate the major policy instruments applied by the governments of both countries to resolve existing weaknesses and reinforce the strengths. In this study, I come up with seven opportunities for mutual policy learning between the two countries based on the analysis of ‘common problems’ that they face in the strategic transformation of their innovation systems today.

• What is the role of leading-edge and novel technologies in this process?⁵

I choose nanotechnology as a prism through which to understand how China’s and Russia’s innovation systems adapt to the new innovation reality that implies more openness and international collaborations. As nanotechnology appears to be an emerging S&T area it allows me to see whether it is possible to construct the national nano policies overcoming many existing path dependencies. In this, I establish that, although the policies may indeed be started from scratch, certain system limitations and lock-ins continue to influence the novel technological areas despite their emerging nature. Among others, Russia continues to focus on physics and materials science in its nano development much like in the Soviet times and China keeps its major nano centers in Beijing and Shanghai that are traditionally strong in S&T activities.

1.4. Synopsis of this study

Chapter 2 of this study dwells on the theoretical aspects of this work and seeks to justify the methodological choices and explain the decisions made throughout this research. It sets

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⁵ These research questions are discussed in more detail in section 2.6 of the literature review where I present the conceptual framework of this study and also seek to describe explicitly the link of the reviewed theoretical and methodological contributions to the objectives of this work.
forth the grounds for a comparative study of institutional and historical frameworks in the area of science, technology, and innovation. It also reviews the latest concepts that hold proper explanatory power to study the particularities of innovation development in Russia and China. In this chapter, I look at the changing nature of innovation that has led to significant shifts in academic thinking recently with new concepts of distributed innovation processes and national innovation systems emerging over the last two decades. Wider social factors have also been argued to have significant impact on the process of innovation development where Putnam et al. (1993) suggested that civil engagement was one of the key factors for the rapid growth in Italy’s northern regions as compared to the rural south and other scholars established a firm link between catch-up growth and technological change in developing countries (including Gerschenkron, 1962; Abramovitz, 1986; and Johnson, 1995).

I further go on to discuss broader socioeconomic and political effects that science and technology can bring to the emerging powers and developing economies beyond mere economic growth as defined by the major statistical indicators. In other words, I argue that the innovation process does not only depend on the soft factors but also produces a number of soft effects that are quite difficult to capture and are often reflected in tacit social and political improvements.

Although these effects may be similar in many countries they happen to be much dependent on the unique social, cultural, economic and political context of particular nations and thus heterogeneous across different locations. All these inputs and outputs of the innovation process as well as the process itself may be seen as the ‘broad’ understanding of the innovation system (see Freeman, 2002), and thus this discussion contributes to the ongoing debate on the adaptability of the systems-of-innovation approach to the needs of developing countries that is caused by the fact that the approach itself was elaborated based on the empirical evidence from the OECD countries (see Lundvall, 2007; Delvenne and Thoreau, 2012).

In the second half of this chapter, I also discuss new approaches to policy analysis and evaluation primarily in the area of science, technology, and innovation. In the recent years there has been a gradual shift from the concept of market failure to the system-failure-driven approaches to innovation policy, especially in Europe (see more in Smits et al., 2010a). This shift has been controversial since many established economies continue to stand by the concept of market failure, which has proven to be quite effective on their territory. Among others, the free
market relations have been working quite well in the United States with a very prominent role of private sector in producing innovative goods and services. Thus, the debate continues on whether the emerging economies should continue following the US liberal model or choose to upgrade their STI policies to the new systemic vision of innovation activity.

The fact is that many transition countries followed to copy the institutional and network structures of the United States as the best available model in the early 1990s but the result differs significantly across nations. Multiple failures of liberalism are known not only in post-communist states (e.g. Russia went through a severe period of ‘wild capitalism’ in the early 1990s when criminal groups were hijacking (‘privatizing’) the previously state-owned property across the entire country) but also in many other countries including Latin America where liberal policies led to the serious debt crisis and economic failure (Kuczynski and Williamson, 2003; Santiso, 2004). These observations demonstrate that the uniqueness of the historical, institutional and cultural frameworks of particular countries is important in choosing the right models to follow and presents the governments with an opportunity to learn from other countries and choose only right practices rather than emulate entire models and policy strategies.

Chapter 3 talks through the main stages of the research process over the last three years that resulted in this study. It also offers a number of insights about the sources of data used to reach substantial empirical results as well as methodological frameworks that permit to collect these data and validate the main findings of this research.

Chapters 4-8 form the core of this study and look into the transition trajectories of Russia and China while benchmarking them with the achievements of the United States. These chapters start with an overview of the major strengths and weaknesses of the state planning science and technology system and explain what innovation transition means in today’s world. They also provide systematic evidence about the successes and failures of the Russian and Chinese effort to transform their national innovation systems and analyze what factors of the state planning S&T system continue to play critical role in the countries’ development today.

In chapters 6 and 8, I also touch upon an emerging technological field where most countries are just beginning to make tangible steps. Although nanotechnology is a relatively established area of research and development, nations started adopting special initiatives to support this field just recently. The world’s first National Nanotechnology Initiative was
launched in the United States in 2000 and now more than sixty countries have established similar instruments (Sargent, 2008; Shapira and Wang, 2010). China introduced initial nanotechnology programs in 2001 while Russia followed in 2007. By analysing recent nanotechnology developments, I try to answer whether a new technology-based growth strategy: a) may be implemented bypassing major system weaknesses and path dependencies; and/or b) it can help resolve the major challenges and break the existing lock-ins in the construction of effective national innovation systems in transition economies.

To address these questions more comprehensively, I adopt an innovative methodological framework that looks into the effects of nanotechnology in six key areas: knowledge flows and institutional development; research and education capabilities; clusters and networks; industrial and enterprise growth; regional spread; and product innovation.

Chapter 9 concludes this study by revisiting the main research questions, summarizing the empirical analysis and linking it explicitly to the conceptual framework and methodology. It also seeks to re-justify the particular choice of theoretical and methodological frameworks applied in this study as well as identify any findings that refute existing academic arguments.

In this chapter, contemporary developments in Russia and China are contrasted against the key features of the former S&T system and compared with each other. A number of system and policy complementarities are suggested based on the theoretical underpinnings related to the existing analytical frameworks applied for innovation research and the study of the policy learning process. Although both countries demonstrate a massive effort to construct effective national innovation systems, several challenges remain where Russia and China can potentially learn from each other.

To make this dissertation useful for a broader policy and academic community, I offer a number of policy recommendations that seem relevant for both countries based on this substantial analysis.
Chapter 2. Literature review and conceptual framework

In this chapter I discuss the major concepts related to innovation, its role in development and catch-up growth as well as existing approaches to the study of innovation at the national and global level. The chapter starts with a debate on the changing nature of innovation that has been recognized and analyzed substantively in the literature fairly recently. The systems-of-innovation approach is described as a useful concept for understanding innovation and development trajectories at the national level, although certain critique seems relevant and is studied extensively in the theoretical and empirical parts of this work.

In the second part of this chapter I touch upon issues of public policy dynamics, inheritance, government failure, and policy learning. These concepts are used to guide the empirical part of this research to much extent through offering a number of analytical frameworks to study and evaluate the public interventions of Russia and China in the areas of science, technology, and innovation. Similarities and complementarities of innovation policies as well as opportunities for policy learning between the two countries are studied in the light of this literature.

Finally, nanotechnology-related social science literature is discussed in much detail to help identify the ways of how this novel technological area can foster the general innovation effort of the selected countries as well as what is its role in the strategic transformation of national innovation systems in Russia and in China.

A conceptual framework concludes this chapter where I am revisiting the four key research questions to establish relevance of the literature review to the objectives of this study and guide the empirical part presented in the following chapters. Every section also has its more specific implications for the study to provide deeper insights into the theoretical contributions of this work.

2.1. The changing nature of innovation

Technological innovation is a multi-faceted phenomenon that is studied by a large group of scholars from a variety of disciplines. Economists, sociologies, education theorists, philosophers, geographers, and others look into this complex notion of human and social development. However, innovation did not attract their special attention for a long time as it was seen as only one of the factors of socioeconomic change.
In the early post-WW2 years, innovation was considered to be part of a linear process connecting basic science, applied research, technology, and commercialization in a stage-by-stage fashion. The famous report by Vannevar Bush (1945) stated prominently that basic science is the primary foundation and root for most innovative activity. Many would see this period as the era of 'big science' where teams and organizations amply sponsored by the government like the Manhattan Project in the USA or the Kurchatov Institute in the USSR were leading their isolated and secretive basic research leading to major technological breakthroughs and significant spill-overs to the civilian sector (Elzinga, 2012).

In parallel, Schumpeter (1934; 1942) was developing his theory of economic development where innovation is seen as a major driving force of growth with entrepreneurs assuming the main role for performing innovative activity and transforming research and development into commercial products, processes, and services. Nelson and Winter (1982) were among the first authors who further developed these ideas and attempted to elaborate a modern innovation theory.

Although not a theory in the strict sense, contemporary innovation scholars prefer to look at innovation as a complex process rather than a set of technological artifacts that are developed and introduced to our lives by a group of scientists, engineers and entrepreneurs. The most recent systems-of-innovation approach is considered a meso-level theoretical construct that is based on a set of other meta-theories in the domains of evolutionary economics, institutionalism, learning theory, and others.

At the same period, a group of scholars also described a number of other new features of the innovation activity that were broadly related to the changing nature of global communication and production processes. Freeman (1991) stimulated the debate on networks of innovation that reflects the changing practices of knowledge production, exchange and commercialization involving a wide set of actors who are often located far beyond the firm that is considered the center of innovative activity. Proceeding from the capabilities theory of the firm that puts the primary emphasis on the internal capabilities of the company to accumulate knowledge and skills underpinning its productive activity, Coombs and Metcalfe (1998) continued to talk about the so-called ‘distributed innovation processes’ that tend to provide a better explanation of why firms differ from each other in the market in the new economic environment. In fact, they argued, the firm’s capabilities are concentrated both within and
outside of its boundaries, and innovation occurs through a number of ‘co-operative arrangements’ and network structures that link firms with each other and with other ‘knowledge-generating organizations’. As a result, the competitive performance of firms depends not only on their capabilities to generate knowledge internally but also their differential ability “to manage the external collaborative relationships required by modern innovation conditions” (Coombs and Metcalfe, 1998, p. 4).

Chesbrough (2003) took this approach further by putting forward the concept of open innovation, where research, development and commercialization involve broader groups of actors including users, universities, entrepreneurs, etc. This latter work attracted particular critique for its rather applied and prescriptive approach where Chesbrough was looking to develop specific strategies for utilizing the capabilities of the user community and other organizations to improve the innovation performance of individual firms. Nevertheless, the practice of ‘user-led’ and ‘open innovation’ is widely spread today.

2.2. Heterogeneous systems of innovation

Many of these new developments in the modern innovation practice have become possible due to extensive globalization that has been a dominant process in the world system in the last twenty years. Although not considered a new phenomenon, the scale of contemporary convergence between nations, international division of labor and international trade is unprecedented. Inspired by the great advances in information and communications technologies, nations-states, multinational corporations, international organizations and social groups exchange goods, knowledge and services so quickly that no individual would foresee a century ago. Migration and long-distance travel have become a common mode of life for large parts of the planet’s population, and human flows signify tectonic shifts in the social structure of the contemporary world.

In the meantime, some scholars were too hasty to predict that this new era of globalization meant that the humanity had finally overgrown its multiple controversies and had entered into the age of eternal peace where history had ended (Fukuyama, 1992). This vision seemed to be reasonable in the aftermath of the Cold War when many post-communist states moved to transform into market economies and establish democratic regimes. Nevertheless, this promising process was stalled in several countries including the Third World economies that tried to implement neoliberal strategies to ensure rapid catch-up with the leaders. Today,
the crisis is observed in the Middle East (where Egypt, Tunisia, Libya have overthrown their long-established rulers, and Syria struggling to repeat the same), former Soviet Union (where Russia, Ukraine and Belarus are passing through a period of civil protests against growing authoritarianism), and Asia (where China seeks to balance its rapid economic upsurge with social and political discontent).

The contradiction between original expectations and reality led to serious discrepancies in international relations where advanced countries continue to insist that modernization (sometimes implied as westernization) is probably the best model of development and catch-up while transition economies and many developing countries find it difficult to adapt western practices on their soil. As Minogue (2002) would put it, there is much difference between universality and universalization, and it was the latter that the western countries tried to impose on other nations.

As noted, in innovation, similar processes have been happening in the last twenty years where understanding of the role of science and technology is now being revised following criticisms from developing countries. This section seeks to address these criticisms and discuss ways of how the contemporary approaches in innovation may be adapted to be used effectively for the study of less advanced countries and catch-up economies.

2.2.1. Systems of innovation

It has already been mentioned several times in this work that systems of innovation have become a prevailing approach in contemporary innovation analysis in the recent decades. Despite its shortcomings, the concept is a critical departure point in understanding how innovation is organized in various countries and also how the process may be improved and justified in order to achieve best possible results.

As a primarily economic concept, the systems-of-innovation approach puts the firm at the center of the innovation complex suggesting that all other agents including the government and academia play a supporting role providing incentives and facilitating the process of technology transfer and commercialization of scientific results and technological advances (Lundvall, 2007). Metcalfe and Ramlogan (2008) reinforce that “it is only the firm, of all the organisations within an innovation system, which has the unique responsibility to combine together the multiple kinds of knowledge required for innovation including knowledge of
markets and organisation. Many organisations, universities, research consultancies, individual inventors, may contribute necessary information flows to a firm but only the firm can combine those different flows into effective innovation” (p. 440).

Firms constantly interact with each other as well as other institutions including universities and public agencies, improve their competencies and learn through cooperation and competition. Market leaders form the core of the system while followers and imitators are learning from them like in Akamatsu’s (1962) wild-geese-flying model through spill-overs and continuous interaction.

Importantly, the environment, in which firms operate, is dynamic where phenomena are gradually unfolding “in a cumulative and thus path dependent way; and, quite separately, a dynamics of system behaviour which creates change and emerging structure from variety in behaviour” (Metcalfe, 1995, p. 28). This evolutionary development of the innovation system is accompanied by the periods of disruptive change called ‘creative destruction’ – a process when monopoloid entities beat their competitors out of the market and create new conditions where only followers can survive (Schumpeter, 1942).

A number of external factors influence the characteristics and development of the innovation system. Among others, Abramovitz (1986; 1989) mentioned the vital role of social capabilities in the ability of countries to catch-up and promote innovation. Freeman (2002) also noted that innovative firms are “embedded in a much wider socio-economic system in which political and cultural influences as well as economic policies help to determine the scale, direction and relative success of all innovative activities” (p. 194).

2.2.2. Critique of the firm-based approach

The firm-based approach that is prevalent in innovation analysis today has been under particular critique in the last decades, especially in organization science and learning theory. The systems of innovation and communities-of-practice have been coexisting for over two decades but have had limited exchange and spill-overs. Indeed, Metcalfe and Ramlogan (2008) mentioned communities-of-practice together with science and technology systems as “necessary parts of the innovation networks” where firms – “the unique organisations that
combine the multiple kinds of knowledge to innovative effect” – are crucial in the self-organization process (pp. 441-442).

In organization science, however, firms and communities-of-practice were not contraposed (Brown and Duguid, 1991). Both emerge and develop at the same time and provide important organizational background for learning and innovation that is ultimately fulfilled by the individuals wherever they work and innovate. In other words, the organization – be it a firm or any other market or non-market agent – does not contain the spread of knowledge but the boundaries of learning communities are blurred and knowledge (both abstract and practical) may freely flow across organizations and within them. This means that a market-based economic structure is probably the best vehicle to improve these flows and promote innovation but other forms of economy may also produce innovation at a comparable rate if they can ensure that similar mechanisms of knowledge exchange and learning are in place.\(^7\)

The concept of communities-of-practice was born in a desire to explain how non-canonical practices and tacit knowledge flow between various people and improve their everyday work practices, i.e. to supplement Arrow’s (1962) ‘learning-by-doing’ effect\(^8\) by other ways of gaining new competences and skills including ‘learning-by-communicating’ and ‘learning-by-interacting’. The new approach marked a shift in understanding how knowledge is transferred and shaped beyond the formal organizational norms, manuals and instructions, and explained why creating an innovative environment – often self-organized and spontaneous – is critical for the organization’s management (Lave and Wenger, 1991; Brown and Duguid, 1991).

In other words, it is not the firms as such that are crucial in the self-organization process as prescribed by the innovation scholars but the entire communities that may take various forms and permeate through the organizational boundaries into the broader social fabric.

\(^{7}\) For example, in his classical volume on innovation decision in Soviet industry, Berliner (1976) argued that – although different in nature and process – innovation was present in the command economy and hence a similar transition from the science and technology system to innovation system that occurred in the western world in the course of the twentieth century may be traced in the late Soviet Union and contemporary Russia (a subject that is, in fact, in the center of this study).

\(^{8}\) Arrow (1962) sought to develop an endogenous growth theory where knowledge and technological change play a primary role in economic development. The scholar analyzed the patterns of knowledge accumulation through continuous acquisition of new practices and experimentation. He concluded that the productivity function is in direct correlation with experience of the labor force, i.e. the ‘learning-by-doing’ pattern has a largely positive effect on economic growth.
The already mentioned debate on open innovation further reinforced the position on the diversity of self-organized environments for the innovation activity. Chesbrough (2003) studied the new forms of collaboration that involves much broader groups of people and distorts the view of a firm as a closed box managing the knowledge and transforming it into innovative products, processes and services. Among others, Linux emerged as a breakthrough case of community innovative potential without any formal corporate participation at the early stages of the project. The IBM joined the project only at a more mature phase when the benefits of being one of the agents in the new community rather than an umbrella R&D facility outweighed the potential reputational costs and provided important insights into the corporate strategy (Nambisan and Sawhney, 2008). Lee and Cole (2003) continue to offer a new community-based model of knowledge creation where “thousands of talented volunteers, dispersed across organizational and geographical boundaries, collaborate via the Internet [are able] to produce a knowledge-intensive, innovative product of high quality” (p. 633). As a result, crowdsourcing as a new phenomenon in the innovation process attracts increasing attention of the innovation scholars, marketing and management researchers, and other academics of various backgrounds (Howe, 2008).

Thus, the core of the innovation system seems to be much broader than just a set of leading innovative firms that possess the highest level of competitiveness and technological sophistication. It includes many other forms of social organization including communities of practice where not only learning and knowledge flows occur every day but also innovation is born and brought to market.

2.2.3. World-systems and varieties of capitalism

Social science offers several ways of capturing the diversity and increasing dynamics of the contemporary world. Among others, two approaches seem especially relevant: world-systems and varieties of capitalism. Both absorbed many advances of the latest theoretical developments and may be considered among the most comprehensive narratives today.10

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9 Crowdsourcing is a term that was introduced by Howe (2006) to describe a new innovation mechanism when an organization or individual would make an open call in search to resolve a particular problem to a broader public rather than a designated agent who would perform this task in a traditional problem-solving environment. The crowd is able to bring in new perspectives to products and services that would not be considered otherwise. Open source software projects and user-created environments including Linux or Wikipedia are among the most well-known cases of crowdsourcing.

10 Other approaches are also appropriate and are similar in their appeal to the two paradigms discussed here. For example, Souza Santos (1995; 2009) provides important critique of the canonical conceptions of Europe and
The world-systems analysis emerged as a response to the relative failure of existing approaches to address the diversity of economic, social and political structures in the world, and the growing gap between disciplines studying these issues from each other including sociology, economics, and political science. Earlier, development trajectories of less advanced countries were seen as part of a global route of growth where every nation had to pass through a set of stages, be it slave-owning era, feudalism, capitalism and communist in Marx’s terms or any other historical hierarchy. In this context any variables that did not fit into this grand narrative would be considered as an exception such as ‘Asiatic mode of production’\(^\text{11}\) (Wallerstein, 2004).

By mid-20th century, such universalization of approaches to development as a stage-organized process became unacceptable to a wide group of scholars both in developing countries and in Europe where diversity is innate and has not been successfully accommodated in the social, economic and political fabric as it was done, for example, in the United States.\(^\text{12}\) Wallerstein (2004) names four major concepts that led to the emergence of world-systems analysis: the concept of core-periphery coming from dependency theory\(^\text{13}\); Marx’s concept of ‘Asiatic mode of production’ and related debate among communist scholars in Europe; the

\(^{11}\)‘Asiatic mode of production’ is a concept used by Karl Marx and Friedrich Engels in the early 1850s to describe the inherent differences between the linear historical politico-economic development of Europe and a mode of production that existed in eastern countries where “Asiatic societies were held in thrall by a despotic ruling clique, residing in central cities and directly expropriating surplus from largely autarkic and generally undifferentiated village communities” (Lewis and Wigen, 1997, p. 94).

\(^{12}\)Although this point probably requires a bit of elaboration here, it seems a broad topic that needs much bigger space than is available in this study. What is important to mention, however, is that this success of the United States to construct a so-called ‘melting pot’ led to multiple interventions in the developing countries who either believed in the miracle of free market and open economy (as in Latin America) or had to survive a humanitarian intervention in more recent years (as in Iraq and Afghanistan). As known, the transferability of the US model appeared overestimated but the country still presents an important example of how various cultures, beliefs and values can co-exist in a nation-state political, economic and social structure.

\(^{13}\)The core-periphery model is based on an assumption that when a region, state, city, town or any other locality (the “core”) expands in economic prosperity, it must engulf a range of neighboring regions (the “periphery”) to ensure continuous economic and political success. In world trade, the “core” is traditionally situated in the advanced western countries while the periphery is located in the less developed countries (e.g. Africa or Latin America) that are still at the lower levels of economic and technological sophistication or have limited access to the world market.
historical debate on ‘transition from feudalism to capitalism’\textsuperscript{14}; and the debate about ‘total history’.\textsuperscript{15} As a result of these debates, the new approach was developed to study “historical systems” rather than nation-states to capture the broad complex of economic, social and political development of societies, or world-systems, over time and space, which is extremely heterogeneous and unique in a wide variety of national and regional contexts. Importantly, this historical approach also contained the dynamic view of reality following Braudel’s (1958) \textit{longue duree}\textsuperscript{16} where roots of contemporary problems are deeply embedded in the past.

Although the world-systems approach seems particularly relevant for the argument of this study, it has certain limitations that may be criticized. As a grand narrative, the theory seeks to fit in multiple aspects of economic, social, cultural and political development of nations, regions, and other entities. In doing so, the world-systems approach describes events in the causal link with the structure and characteristics of the unit of analysis. In other words, world-systems seem to be neat models that have particular rules guiding dynamic change in them. For example, Wallerstein (2004) explained the recent emergence of the Green movement by the aspiration to change the production systems in the world-economy that had dramatically reshaped through the increase of dumping space in international trade and limited access to natural resources by advanced countries. Although this explanation may be well valid, it seems that many other reasons could have been critical in bringing the green agenda in the political debates. Since it is especially difficult to locate where particular ideas and movements originate, it is problematic to balance all possible alternatives and competitive ideas at a given point in time and space. In fact, the green agenda could have well become a response of social

\textsuperscript{14} The historical debate on “transition from feudalism to capitalism” took place in mid-twentieth century and involved a group of Western economic historians seeking to understand the routes of modern capitalism. While one party led by an English economist Maurice Dobb sought the origins of the system in internal factors such as relations of production, another group of scholars led by an American Marxist economist Paul Sweezy credited the transition from feudalism to capitalism to a set of external factors, particularly trade flows, that led to the modern structure of production and class relations. This debate played a significant role in the emergence of world-systems analysis since it made many economist look more deeply in the historical data and raised important methodological issues relating to the unit of analysis that should include both internal (e.g., relations of production) and external (e.g., trade flows, international economic relations) factors (see more in Wallerstein, 2004).

\textsuperscript{15} The concept of ‘total history’ was developed by the Annales group in France that emerged in the 1920s as an opposition to the limited study of history from the solely political point of view. The French scholars proposed that the study of history should be “total” where researchers should strive to study historical development in its entirety including economic, social and political factors that create an integrated picture of the past.

\textsuperscript{16} As a leader of the Annales group in France, Fernand Braudel was embedded in the tradition of ‘total history’ and sought to study it in the historical dynamic where phenomena unfold under the impact of a variety of political, economic and social factors. The \textit{longue duree} represents a methodological model where dynamics of historical development are as important as the study of facts and artifacts.
awareness and political emancipation of large social groups particularly in western countries rather than a desire to overturn existing production systems.

Varieties of capitalism is another approach that is relevant in this discussion on heterogeneity of national systems of innovation (Hall and Soskice, 2001; Coates, 2005; Hancke, 2009). In substance, this paradigm appears to be closer to innovation studies since it similarly stems from the discipline of economics and seeks to explain national development in a broader context of growth, institutions and beyond. Coates and colleagues (2005) present a discussion of three major approaches to explaining development of advanced capitalist economies: mainstream neoclassical economics, new institutionalism, and neo-Marxism. Like world-systems analysis, varieties of capitalism strives to reconcile these approaches and find a common ground to explain “why advanced capitalisms vary in institutional form and in competitive performance” (Coates, 2005, p. xi).

In their seminal work, Hall and Soskice (2001) present an institutional view of economic and social analysis of development patterns in capitalist economies and suggest that it is not only institutions themselves that have significant impact on the national trajectories but also strategic interactions that are “central to the behavior of economic actors” (p. 5). Thus, the authors add important network and interactive learning component to the structural characteristics of the system that are not always enough to explain the major variables and events. However, despite this new, broader vision of the market environment, the varieties of capitalism does not resolve the major critique related to a large set of concepts including the systems-of-innovation that is a firm-centered view of economic reality. It is assumed that capitalist economies – regardless of their multiple variations – are all based on the belief in the power of the market and firms as “the key agents of adjustment in the face of technological change or international competition whose activities aggregate into overall levels of economic performance” (Hall and Soskice, 2001, p. 6).

Close to innovation studies, Amable (2000; 2003) contributes to this debate on varieties of capitalism. He proceeded from the institutional economic analysis to compare the diverse routes to the knowledge-based economy and society observed in the USA, Europe and Japan. The scholar argued that particular institutional ‘complexes’ play crucial role in identifying the ways of innovation development in various countries and determines the major variables of their technological change.
Based on the study of these institutional complementarities and hierarchies, Amable (2000) suggested that there are four idealized models of social systems of innovation and production (SSIP). Among others, with these models, he sought to overcome some weaknesses of the systems-of-innovation approach already discussed in some detail above. He wrote that “at a time when the internationalization of research is becoming more widespread, when diffusion of new techniques and modes of organization is becoming more rapid, it may be an exaggeration to maintain the strictly national nature of learning mechanisms. It seems preferable to consider the notion of social systems of innovation... which leaves open the question of the territory over which the cumulativeness of the interrelations and the coherence of the system operate” (p. 669).

Although focused on the developed capitalist economies, Amable’s four idealized models – market-based SSIP, social democrat SSIP, meso-corporatist SSIP, and public SSIP – may be relevant for the study of developing countries where public SSIP appears to be the closest institutional and social setting of innovation and production with its strong state and permanent public interventions in multiple sectors of national economy. A major limitation of this approach consists in its desire to explain key factors of economic and technical change by institutional dynamics (even in the broad Veblenian sense\(^\text{17}\)) disregarding many other social and cultural variables (including episodic changes and impacts) that may have an influence. In other words, even constructing and understanding the entire complex web of institutional complementarities and hierarchies may still be not enough to explain the challenges and successes of particular countries in their catch-up growth or sustained leadership. However, a crucial contribution is to the benefit of this work – that “it is more important to study the effects of interacting institutions or organizations than just to admit that ‘institutions matter’” (Amable, 2000, p. 680).

In general, varieties of capitalism – similar to world-systems analysis – seeks to claim comprehensive explanatory power in the study of contemporary capitalist economies and therefore has a number of limitations. The search of causal links in understanding diverse trajectories of national development leads to certain simplifications that tend to present social and economic reality in a more generic way. Moreover, the major problem of grand narratives

\(^{17}\) In his classical work, Veblen (1934) defines institutions as “prevailant habits of thought with respect to particular relations and particular functions of the individual and of the community; and the scheme of life, which is made up of the aggregate of institutions in force at a given time or at a given point in the development of any society” (p. 190).
dealing with their aspiration to find such causal links in social and economic reality concerns the fact that once they find particular mechanisms that they are able to describe and explain at a meta-theoretical level, they unintentionally come to establish certain norms connected to these causal relations between various events and phenomena, while many episodic and irrational factors (including arbitrary political decisions, fortuity, the role of chance in history and others) continue to ‘spoil’ this orderly view of the development process.

Epistemologically, critical realists (Archer et al., 1998; Sayer, 1992) assumed that social reality presents a complex phenomenon where individual’s perceptions and values play significant role in constructing the surrounding social structures and behaviors as well as in understanding how they work from the academic viewpoint. In this context causation is understood as particular generative mechanisms, i.e. dynamic behaviors of objects that get activated by a wide variety of constantly changing conditions rather than a simple conjunction of events. Hence, competitive theories may gain priority based on their practical adequacy and explanatory power that will be as close to understanding social reality as would be assumed by other researchers (Danermark et al., 2002; Sayer, 1992). And therefore, despite some reasonable critique presented here, both the world-systems and varieties of capitalism still remain among the most relevant theoretical constructs available in social science today.

While proving the diversity and heterogeneity of national systems, the world-systems analysis and varieties of capitalism also provide important methodological grounds for the comparative case study of Russia and China using the method of agreement.18 World-systems permit to hypothesize that the two countries’ contemporary challenges stem from similar legacies and historical trajectories that are in focus of this study. And varieties of capitalism explain the differences of economic performance based on similar historical roots and path dependencies.19

2.2.4. Implications for this study

Alongside the methodological guidance mentioned above, there are four other major implications out of this discussion on heterogeneity of innovation systems. Firstly, the world is very diverse, and cultural and institutional frameworks play significant role in defining

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18 Methodology will be discussed in more detail in the following chapter while it seems worth mentioning here that these paradigms provide essential epistemological platform to justify the use of particular techniques in this study.

19 In fact, varieties of capitalism may be applied to justify the use of both the method of agreement and the method of difference for the comparative case study of Russia and China. See more on this in sections 3.2 and 3.6.
development trajectories of particular countries. Russia and China are no exception and have their unique national features as well as much diversity between their multiple regions and multicultural populations. Both countries face a plurality of choices in transforming their national innovation systems, many of which can prove to be successful in future (cf. Breznitz, 2007).

Indeed, Breznitz and Murphree (2011) mentioned the particular harm of looking at China’s rapid emergence through the lenses of industrial and economic history of developed countries. The nation has been excelling in other, mostly second-generation, kinds of innovation that are not necessarily focused on developing novel technologies, products, and services.

Secondly, historical roots of entrepreneurship and market growth as well as general evolutionary dynamics are crucial in understanding the nature and behavior of firms and other agents in the innovation systems of various nations and regions. Lundvall (2007) already mentioned that developing countries present a different case from advanced economies where the systems-of-innovation approach was elaborated and tested and it is clear that “what is most relevant for developing economies is a broad definition of the NSI [national systems of innovation – E.K.] including not only low-tech industries but also primary sectors such as agriculture” (p. 113).

For example, Russia had undergone through a severe repression of most forms of entrepreneurship since 1920s and any market-style behavior was prosecuted until 1991. The situation is unlikely to have changed significantly in the last twenty years by the merit of rapid structural reform and ‘shock therapy’ alone since the values and beliefs of people are difficult to shift in a short period of time (Klochikhin, 2012a).

Similarly, Chinese culture has particular features where personal connections – or guanxi – play large role in developing business and getting good opportunities for growth (Kennedy, 2005; Li et al., 2006; various interviews, 2012). These social structures have long history and have been shaping over centuries hence making them very unlikely to change rapidly.

Thirdly, firms are not the only form of social organization participating in the innovation process as the central agent developing and delivering the final results. As discussed in
organization science and narrower debate on communities-of-practice, knowledge is created, utilized and implemented in valued products, processes and services in a much wider variety of settings. This means that in studying innovation trajectories in Russia and China it is also very important to see the broader institutional frameworks of these countries and identify the unique ‘points of innovation’ that may be located not only in a firm but also elsewhere and still remain the core of the system. These may include worker and inventor associations, public-private partnerships, public agencies, non-governmental organizations (NGOs), and others. The reasons for this special configuration of innovation agents in Russia and China may be embedded in the legacies of the command economy where tasks – and benefits – were distributed among various agencies that were dependent on the public management system and had to follow the instructions of senior bureaucrats irrespective of their natural role in the national innovation system as they would assume in a western-style market economy.

Finally, dynamics are very important in the study of national innovation systems in Russia and China since the longue durée has been mentioned as an important variable in the historical school of thought, especially in world-systems analysis described in more detail above. Historical path dependencies – understood in the context of evolutionary trajectories of national science and technology – have much influence on the contemporary challenges and advantages of the national system in the complex environment of accelerating technical progress in the world.

2.3. Innovation and development

It has been discussed in the preceding sections that the existing literature establishes a rather firm link between innovation and economic development. At the same time contemporary understanding of the development process has been extended significantly in the last two decades when development scholars and politicians managed to formulate the new agenda of global development that was most prominently set forth in the UN Millennium Declaration (2000) innumerating a number of objectives in the areas of fight against poverty, hunger, disease, access to education, equal political rights, etc. So, in this section I am seeking to take the debate on the innovation-development link a bit further and enquire whether this other literature allows us to identify the essential role of science, technology and innovation for a broader set of social, political and economic goals that would otherwise be neglected in the innovation research. I recognize that the emerging market that are the primary focus of this
study do have a different set of priorities as compared to less developed societies but it also seems important to remember that many of these more advanced countries have risen from the group of developing countries rather recently and continue to struggle with acute social and political challenges that might hinder their economic growth and effective use of innovation towards their primary development objectives.

So, I begin with identifying the particular lacunae that exist in the innovation research regarding this subject and follow to review the development studies literature that also appears to have addressed this topic quite extensively. A sub-section on theoretical complementarity of these two sets of literature offers a number of new insights about the role of science, technology and innovation in the broader development agenda and a new analytical framework is proposed to identify the potential impacts of innovation on the development process. This latter framework is further used to guide the empirical assessment of the early impacts of nanotechnology on the Russian and Chinese economy and society as described in the section to follow.

2.3.1. Innovation

As mentioned, the systems-of-innovation approach has become a dominant heuristic for the analysis of innovation processes across the world in the last twenty years. Despite its attention to the institutional and social externalities of the innovation activity, this approach remains quite biased towards the paradigmatic foundations of economics. Lundvall et al. (2002) noted that one of the major pillars of their approach is the shift from systems of production to the systems of innovation by integrating Leontief’s (1986) input-output analysis with innovation and entrepreneurship. Certainly, the authors continue to include the new vision of institutional variables and systems heterogeneity across various nations but the economics grounds seem solid in their framework.

In its turn, this attention to the shift from systems of production to systems of innovation pushed the researchers embracing the new approach to look primarily at advanced countries where this shift was particularly vivid and provided them with ample data to test the

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20 The input-output model is a classical approach in economics developed by Vassiliy Leontief (1986) to represent the interdependencies between different branches of national economy or different regional economies. In basic terms, the model describes the relations between various industries where an output from one sector may serve as an input to another through a set of institutional and economic links. Innovation and entrepreneurship have not been originally included as primary factors in this analysis where the systems-of-innovation approach sought to contribute to its further development.
updated methodologies. As a result, many developing countries and emerging economies were put aside before the new framework had matured since there was little available data and many failures in these countries’ STI strategies that would largely complicate innovation research in these locations. Today, Lundvall (2007) and some Globelics colleagues lament that this situation has created a large gap between innovation research in advanced and emerging countries that is quite difficult to resolve given that the institutional and cultural contexts differ significantly across nations.

More recently, researchers have paid increasing attention to the developing world (Metcalfe and Ramlogan, 2008; Cimoli, 2000; Kim and Nelson, 2000; Lee and Von Tunzelmann, 2004). OECD carried out several innovation policy reviews in Chile (2007), South Africa (2007), China (2008), Korea (2009), Mexico (2009), Russia (2011), and others. However, despite this massive effort, it seems that the systems-of-innovation approach has still much to go to transform itself into a truly global concept that will be valid across multiple nations and will absorb the modern understanding of development as a complex phenomenon stretching far beyond simplistic economic growth.

2.3.2. Development

Although the notion of development had been long linked to the process of economic growth, development studies have made a significant breakthrough in the last twenty years. This leap was primarily due to the penetration of multiple ideas in the world political agenda that had been ripening in the developing world throughout the second half of the twentieth century following the end of colonial era. Dependency theorists and neo-Marxists had been especially successful in Latin America where various political experiments eventually ruined the economy of several states putting them into deep recession following the world debt crisis and practical failure of neoliberal instruments. The work of these scholars as well as earlier reports on sustainability and limits to growth (Meadows et al., 1972; Brudtland et al., 1987) had substantial effect on the changing development landscape that now united the challenges of poverty, hunger, education, health, gender equality and sustainability. As a result, most of these ideas were ultimately reflected in the United Nations Millennium Declaration in 1999 that set eight broad Millennium Development Goals in the areas of education, health, gender, sustainability and else. The United Nations voted to half poverty and hunger by 2015, ensure that children everywhere have access to primary education, girls and women are not
discriminated, under-five mortality is reduced by two-thirds, stop the spread of HIV/AIDS, introduce norms of sustainable development and support the global partnership.21

These events meant that the development process should go far beyond economic growth and involve much wider social, political and economic phenomena. However, few governments have explicitly linked these goals to the progress in science, technology, and innovation, and often continue to bypass them in their strategic planning. Furthermore, the Millennium Declaration itself contained only several scattered references to the importance of technical progress and assistance (United Nations, 2000). This situation signifies the large lacunae in the study of innovation for development and instigates further research and the need for interdisciplinary exchange between innovation and development studies.

It must be noted here that a group of more developed countries often referred to as emerging markets have a rather different set of priorities as compared to other developing economies. It has already been mentioned in the introduction that these nations are more keen to pursue technological catch-up and industrial growth while having resolved many deeper social challenges in the previous of their development. However, there are two major factors that do link these economies to this wider innovation-development debate. First, many of these so-called emerging markets have risen from the group of developing nations only 30-40 years ago and hence continue to suffer particular path-dependencies and tensions that are caused by complicated social discrepancies. Among others, social inequality has risen significantly with multiple entrepreneurs using the new opportunities but leaving behind large groups of undereducated and underrepresented population. For example India’s pharmaceutical companies are among the most advanced in the world, most of their drugs and other products are exported to developed countries. As a result, a large part of Indian population does not have access to medical care and effective drugs, and 69 children die out of every 1,000 live births (Chaudhuri, 2008). Despite its huge economic success in the last decade, China also continues to be ranked as a country with medium human development index alongside Syria, Guatemala, Uzbekistan and so on. Approximately 16 per cent of Chinese population lives on less than US$1.25 a day (PPP) and only 68.7 per cent of children enroll in schools. Consequently, the nation’s human development index has been growing only 1.5 per cent per year between 2005 and 2010, which is 10 times less than the economy (United Nations, 2010).

The second factor relates to the experiences of a number of transition economies that are especially relevant for the objectives of this study. A special term of political and social ‘anomy’ describes the situation that prevailed in the former Soviet Union and some countries of Central and Eastern Europe. It was noted that the radical reforms following the USSR collapse caused a number of acute tensions in social and market relations leading to substantive psychological shock of the population and disappearance of trust between people (Medvedev and Tomashov, 2012). In science, these problems were especially noticeable since the research institutes and universities lost up to 90 per cent of the funding in the early 1990s and many individuals were basically left out in the wild without much experience outside of the academic world.

2.3.3. Reconciling the theories

Despite some tangible differences that exists in the areas of innovation research and development studies, some recent work also mentioned a number of substantial similarities between these two fields that allow us to have a better view on the innovation-development link in the broader socioeconomic and political context, where science and technology seem to play a rather crucial role (cf. Klochikhin, 2012c).

So, both development and innovation are systemic by nature. Kothari and Minogue (2002) mentioned that the development process is based firmly on three major pillars: the government, the market, and the community. All these elements are vital in delivering effective policies, industrial and economic growth, and social progress. Moreover, researchers note that various paradigms tend to prioritize only one of these system components: Marxist is more government-oriented; neoliberalism emphasizes the dominant role of the market with minor public interventions; and the critical theories such as feminism and sustainable development consider communities and civil society as the main balancing powers that can ensure proper political and economic choices.

Similarly, the ‘triple helix’ of the innovation system comprises three key components: the government, industry, and academia (Etzkowitz and Leydesdorff, 2000). The government contributes to the system balance by direct and indirect support measures; industry promotes technology transfer and commercialization of innovative products, processes and services; and academia provides training for future innovators, performs basic research and improves overall
innovation capabilities of the nation. All these system components are interlinked by multiple knowledge flows, interactive learning and competence-building.

*Education* also remains one of the critical system elements both in development and innovation theory. Constant learning and training ensures fast technological progress and improved technology transfer mechanisms in the innovation system while universal primary and secondary education opens the window of opportunities for the poorest people in developing countries and hence its promotion is part of the UN Human Development Index\(^\text{22}\) and one of the key Millennium Development Goals.

The notion of uniqueness of local and national contexts is at the heart of the development and innovation systems. Contemporary development scientists recognize that many public and private practices must be adapted before being introduced in less advanced countries to ensure best possible returns. At the same time Nelson (1993) discovered that most innovation systems are different in one way or the other and it is difficult to provide particular policy recommendations without knowing the history, institutional and cultural environment of particular countries.

There also seems to be a consensus that the capability of the society to absorb new social and economic initiatives and products of technological change is equally important for the development and innovation process. Green (2006) notes that the success of development policies and initiatives largely depends on the proper balance of interests between the developer and the developee. In other words, the goals of development agencies and governments, on the one hand, and vulnerable social groups, on the other, may be different in the short and long run. And thus two factors are essential in gaining successful results: not only the ability of the development agency or the government to implement their strategies; but also the ability of the developees to absorb and incorporate them.

Similarly, Cohen and Levinthal (1990, p. 128) elaborated the concept of absorptive capacity to define “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends” that is critical to its innovative capabilities.

\(^{22}\) The United Nations Human Development Index is a complex indicator that is calculated out of three major variables marking life expectancy, education and income indices. The index is one of the recognized methods to rank countries based on their economic and social well-being as well as desire to balance their economic aspirations and societal prosperity.
Fagerberg (2005) continued to conclude that this capacity is critical for the success of firms in catch-up economies to increase their competitiveness and grow in the world market.

Finally, both categories of development and innovation have a strong link to the notion of economic growth. Castells and Himanen (2002) suggest that, despite common prejudice, strong economic growth and social state can coexist in the contemporary world. They study Finland to demonstrate how extensive public investment in research and development does not hamper the development of one of the most equal societies on the planet largely due to the combination of skilled labour force, viable financial system and innovation culture.

2.3.4. Innovation for development

Based on these theoretical complementarities, it seems possible to elaborate a number of potential effects where innovation can contribute to the development process. Among others, Klochikhin (2012c) included the following areas where such effects can be observed: institutional and network development, rising employment, improved research and education capabilities, industrialization, urbanization, cluster growth, and direct technological applications that are aimed to resolve particular social and economic challenges.

So, it was concluded that if considered from the systemic perspective innovation is capable of promoting the development of universities, research institutes, industry, and government agencies that are involved in the innovation processes either through direct operation or through the policy mechanisms. An effective innovation system can also contribute to linking these institutions together that may, in turn, provide an important platform for knowledge exchange as well as improve social coherence and community-building.

Rising employment seems to be a more contentious effect of innovation growth. On the one hand, process innovation often leads to reductions of staff due to adoption of new automatic ways of production. On the other, product innovation has been reported to improve employment both in quantity and quality since businesses have to expand to absorb new technologies and production lines and workers have to increase their competencies to produce more sophisticated goods and services (Pianta, 2005).

Research and education capabilities are difficult to calculate but their usefulness for the broader development process has been considered indispensable since better education and
learning opens new windows of opportunity to the wider distribution of knowledge and innovation activity where universities play a critical role.

*Clusters and networks* lead to similar concentration of people and industry in particular locations, which makes it easier to manage and govern them making policies more effective and business environment more competitive. Mytelka and Farinelli (2000) mentioned particular advantages of cluster development for the economy and society.

Finally, innovation brings about essential improvements to social life through introducing *new products and services* that may be valuable in resolving particular development problems. Heeks (2010) noted that many new applications of information and communications technologies have given wider opportunities to the African people who have invented many new uses for the mobile phones and other applications facilitating their everyday lives.

2.3.5. Implications for this study

The major theoretical underpinning of this study derived from this discussion on the link between innovation and wider socioeconomic development consists in the fact that, among other things, the empirical analysis of emerging economies should take significant account of a wide set of factors related not only to the issues of economic growth but also social and political development. Hence, it is critical to evaluate the current policies of catch-up countries from the perspective of a crucial need to balance rapid economic and technological advancement with the resolution of important social tensions and political fragilities. In this context, it seems particularly important that both Russia and China recognize their unique institutional and social conditions and do not leave out their historical and cultural legacies but try to use them for the benefit of rapid transition to a modernized and effective economy and social balance. Many complexities of these large countries are difficult to untangle but they may be helpful in finding their unique ways to prosperity and innovation growth. The possibility of rapid transformation seems to have already been proven possible by several success stories in East and South East Asia, and Russia and China can potentially follow.

2.4. Nanotechnology

In this section, I present my conceptual framework related to a specific S&T area – nanotechnology. The detailed analysis of this technological field has a particular relation to the fourth research question of this study where I seek to estimate the role of novel technologies in
the strategic transformation of national innovation systems in Russia and China. I start this section with a review of the major developments that occurred in this area over the last 10-15 years and then proceed to discuss the literature analyzing the transformative capacity of nanotechnology as well as related path dependencies. A six-impact framework is derived from the preceding analysis of the potential impacts of innovation on the broader development process and is discussed in particular relation to nanotechnology.

2.4.1. The context

Nanotechnology is one of the rising topics in contemporary international political and academic discourse. The number of publications in the field rose from 18,085 in 2000 to about 65,000 in 2008 with an average growth rate of 23% per year (Roco, 2011). More than sixty countries have established national nanotechnology programs to support nano development and accelerate commercialization of their applications (Shapira and Wang, 2010; Sargent, 2008). The global market for nanotechnology-enabled products is predicted to reach $2.6 trillion by 2014 (Hullmann, 2007). Finally, the Nobel Prize was awarded to Andrey Geim and Konstantin Novoselov in 2010 for breakthrough work on graphene, a nano scale material, which has a potential to replace silicon in the semiconductor industry in the near future.

The conceptual inspiration for nano scale research and development was given by Richard Feynman in 1959 in his famous speech “There’s Plenty of Room at the Bottom”, in which he suggested that the next scientific and technological breakthrough might come from the manipulation of individual atoms and molecules allowing us to create new materials with unique attributes. However, only the inventions of 1980s (scanning tunneling microscope in 1981 and atom force microscope in 1986) made it possible to carry out actual research at the nano scale and study the attributes of new particles and their capability to create the next technology wave and revolutionize the market.

Today, the International Organization for Standardization (ISO) defines nanoscience and nanotechnology (NST) as the process of “understanding and control of matter and processes at the nano scale, typically, but not exclusively, below 100 nanometers in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications”. The definition also includes “utilizing the properties of nano scale materials... to create improved materials, devices, and systems that exploit these new properties” (ISO, 2012). Thirty-four countries already participate in 28 ISO published standards on nanotechnology.
Roco (2004) suggested that nanotechnology will go through four evolutionary stages: passive nanostructures; active nanostructures; 3-D nanosystems and systems of nanosystems; and heterogeneous molecular nanosystems. The first generation includes applications that are aimed to improve properties of already existent products and create nanocoatings, nanostructured metals, polymers and ceramics. Active nanostructures are capable of self-transformation in the changing external environment. These include transistors, amplifiers, targeted drugs, etc.

The third generation of nanostructures is supposed to present novel applications in the fields of “directed self-assembling, artificial tissues and sensorial systems”, “quantum interactions within nano scale systems”, “nano scale electromechanical systems (NEMS)”, etc. The fourth stage of nanotechnology development is believed to start by 2015 and present heterogeneous molecular nanosystems, “where each molecule in the nanosystem has a specific structure and plays a different role” (Roco, 2004, p. 896).

Since the launch of the U.S. National Nanotechnology Initiative, many developing countries have been active in this research area and have already achieved substantial results. According to Maclurcan (2005), by mid-2000s nineteen developing countries had started national nanotechnology programmes with further twelve demonstrating individual or group research in nanotechnology, and 13 countries expressing interest in establishing national initiatives in future. Court et al. (2004) categorized these countries into front runners (China, South Korea, and India); middle ground (Thailand, the Philippines, South Africa, Brazil, and Chile); and up and comers (Argentina and Mexico).

2.4.2. Transformative capacity

One of the major debates in the social science studies of nanotechnology concerns the assessment of its potential advantages for the catching-up economies that could use as a new transformative platform influencing the institutional and sociotechnical environments (cf. Burgi and Pradeep, 2006; Niosi and Reid, 2007).

Among others, Barker et al. (2011) noted that nanotechnology is “perceived by many as the next ‘transformative technology’ – like electricity or the Internet – [that] encompasses a broad range of tools, techniques, and applications that manipulate or incorporate materials at
the nano scale in order to yield novel products... [that] may enable new or improved solutions to problems that have been challenging to solve with conventional technology” (p. 278).

The estimates of this transformative capacity are debatable and range from very optimistic to quite cautious. Burgi and Pradeep (2006) point that, compared to earlier technological waves and other general purpose technologies, it is likely that the potential impacts of nanoscience and its deriving technologies “will be stronger, because nano has the incomparable force to pervade all societies and economies, from the pre-industrial to knowledge societies, from ancestral to highly industrialized economies and is not necessarily subjected to a nation’s current development stage and/or geographical location” (p. 647).

In a more cautious prediction, Niosi and Reid (2007) suggest that only the largest developing countries will be capable of using the emerging opportunities of nanoscience and nanotechnology because only they seem to host “the amounts of human capital and funds allowing them to get involved with these advanced technologies in their early phases” (p. 437). Sigurdson (2005) continues that China pays significant attention to information and communications technologies (ICTs) but in parallel makes large investments into nano- and biotechnology because “this offers much better entry possibilities for China than microelectronics, where a research front was already established in the late 1940s” (p. 292).

Important insights from other rapid innovation-based industries are also relevant here. Breznitz (2007) showed that – despite their very different policy and institutional regimes – Ireland, Taiwan and Israel achieved serious success in building up effective IT industries where they developed a significantly different set of capabilities that are yet all very appropriate. Similarly, nanotechnology may emerge successfully in a number of previously ‘unknown’/underdeveloped countries that will quickly embrace the new markets and develop their national innovation capabilities. The major concern, though, is whether these emerging industrial/sociotechnical systems are sustainable, as Ireland’s model appeared to be highly fragile during the latest financial crisis.

In the meantime, the concept of ‘waiting games’ has been gaining particular weight in nano-related debates. Rip et al. (2007) noted that companies and institutions developing new technologies and related regulations may be put in a situation of an innovation impasse where

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23 Sociotechnical systems have been primarily studied by scholars in science, technology and society. Such systems “encompass production, diffusion and use of technology” and are generally defined as “the linkages between elements necessary to fulfill societal functions (e.g. transport, communication, nutrition)” (Geels, 2004, p. 900).
both parts will be waiting for the other one to make the first move, especially in disruptive fields where the degree of uncertainty is particularly high. Robinson et al. (2012, p. 543) give an example: “a company in the emerging field of nanomedicine waiting for regulatory decisions by the traditional organisations mandated to make these decisions, whilst the latter waits for the new technology to stabilise so that its risks and benefits can be assessed.”

Waiting games are primarily a structural problem that does not allow new technologies to reach the markets and enter the dynamic social environment, i.e. innovation actors do not enter into the promise-requirement cycle because “the promises are open-ended, and eventual demand is not articulated” (Parandian et al., 2012, p. 565). In this context, the hype created around nanotechnologies in the recent years prevents actors from investing in concrete developments because of the high uncertainty in respect of where breakthroughs are to happen in future.

Thus, waiting games may present a particular obstacle on the way to applying nanotechnologies in their full transformative capacity due to the lack of experimentation and slow emergence of new markets.

2.4.3. Path dependence

Nanotechnologies are considered to be an emerging S&T area that stretches across multiple disciplines and industrial sectors. A particular question that has been raised in literature concerns whether nano-related R&D will be implemented in a small number of clusters and regions where nano-related activities have already accumulated some experience and research, i.e. will follow a path dependent route being performed in organizations with most relevant capabilities, or it will be carried out by a wide range of institutions and firms that will engage into the area due to its big promises (Huang et al., 2011).

In response to this question, Zucker and Darby (2005) and Zucker et al. (2007) found that nanotechnology is most promoted in areas with traditionally high levels of scientific expertise and technical capabilities and few spill-overs and inconsistencies have been evidenced in the United States so far. Shapira and Youtie (2008) generally confirmed these findings but also pointed that several new nanoclusters have been emerging in the US where high concentrations of human capital and effective networks had had a positive effect.
In the meantime, several related questions have gained little or no attention in the social science literature on nanotechnology. At the national level, it seems particularly interesting whether nano-related R&D occurs in the areas where countries have traditional strength. For example, would nanomedicine be one of the priority areas in the United States that is especially mighty in pharmaceutical business and medical science? Or would Russia have some advantages in the areas of physics and mechanics where it has built particular potential starting with the Soviet times?

Similarly, there has been little debate on policy path dependencies in the area of nanotechnology. Are the new nano growth strategies different from all other technology-specific policies adopted at the national or regional level? Do they occupy a unique place in overall STI policies of various countries? Is there any particular evidence of inheritance in nanotechnology policies that would serve either as a constraint on current choices or provide additional learning opportunities?

This study aims to touch upon these complex issues in the context of Russia and China but a deeper analysis seems to be required to address them in full detail.

2.4.4. Six-impact framework

Different approaches have been pursued by social scientists who aim to assess the impacts of nanotechnology on economic and society. Some would follow the instrumental argument where nanotechnology is presented as a set of technical artifacts with superior capacity to resolve existing development problems as compared to other general-purpose technologies. Such research would be primarily focused on the study of particular applications and products where nano-enabled devices have positive impact on water purification, better medical treatment and improve living conditions of vulnerable groups of population (cf. Juma and Yee-Cheong, 2005; Mnyusiwalla et al., 2003; Salamanca-Buentello et al., 2005).

Other researchers have been applying a contextual approach seeking to understand a wide complex of social, economic and scientific factors influencing the development of nanotechnology and its impacts on broader society. Invernizzi and Foladori (2005) questioned whether the benefits of nano-enabled products will actually reach the poor and whether they will resolve the deficiencies of existing socioeconomic structures or, instead, “exacerbate existing gaps and further the technological and socio-economic isolation of the poor.” Hassan
(2005) and Cozzens and Wetmore (2011) continued to discuss the issues of global inequality and social discrepancies that may prevent even distribution of the advantages gained through nanotechnology applications among the world countries and various communities. Other authors also questioned who will bear the majority of cost dealing with the development of expensive nano R&D facilities and technology diffusion (Invernizzi et al., 2008).

Proceeding from this contextual viewpoint together with a broader understanding of development issues, discussed in section 2.3 above, Klochikhin and Shapira (2012a) proposed an analytical framework that may be applied to provide an assessment of early the socioeconomic effects of nanotechnology in six key areas: institutional development, knowledge flows, and network efficiency; research and education capabilities; industrial and enterprise development; regional spread; cluster and network development; and product innovation.

**Institutional development, knowledge flows, and network efficiency** imply the establishment of new mechanisms and improvement of existing institutions for interactive learning and competence building that may explicitly serve the objective of promoting nanotechnology but can also have positive effects on broader S&T development. Some of these institutions are designated specifically to reach the goals set forth by the national nanotechnology strategy (e.g. Rusnano in Russia or Nanopolis Suzhou in China) while others are organized as special programs and departments inside existing agencies (e.g. special nanotechnology fund allocated by Shanghai municipal government).

The problems of human capital and institutional complementarities appear to be central in assessing early impacts of nanotechnology in this area. Bonaccorsi and Thoma (2007) already observed that such complementarities are bigger in nanoscience and nanotechnology compared to other areas. While in some countries this situation will mean closer links between industry and universities, in others the government and academia may find more opportunities for collaboration.

Methodologically, improved institutional frameworks and knowledge flows may be traced through co-authorship and co-patenting analysis to see whether there is an increased number of collaborative links between various organizations that will signify faster and more productive exchanges that are supposed to have positive effect on the national S&T and innovation environment. In this, it seems appropriate to assume that once the new institutions
are established in the area of nanotechnology they are highly unlikely to be dissolved once the program is over (unless they are purely mission-oriented in nature).

The improvement of **research and education capabilities** is expected to result in a more active cross-disciplinary collaboration and training at universities. Since contemporary science works with phenomena of increasing complexity, today’s researchers need to have a much wider set of available methods and tools to resolve emerging problems and sustain rapid technical progress. In this sense, Rafols and Meyer (2007) evidenced that nanoscientists refer to a wide variety of disciplines in their publications and use diverse instrumentalities to achieve scientific results. Thus, improved research and education capabilities will most likely be reflected in growing interdisciplinary links between various research areas that would have been considered quite far from each other before nanotechnology has deserved critical attention at the global agenda.

**Industrial and enterprise growth** present a mainly economic effect that nano scale research and development may have in various countries. The forecasts of the future size of the market for nano-enabled products and processes range from US$ 1 trillion to US$ 2.6 trillion in the next three to five years (Hullmann, 2007; Roco, 2011). Nanomaterials have been already widely used in the primary sector (e.g. nanocatalysts in oil and gas industry), building industry (e.g. nanoglass) as well as in microelectronics and elsewhere (e.g. medical nanodevices and nanocoatings for high-precision components). The interest of incumbent and new firms in the area of nanotechnology is expected to be evidenced in the growing number of relevant patents granted to the companies located in various countries.

Another effect in this area has been more difficult to capture, that is job growth. Witnesses at the hearing in U.S. Senate (2011) testified that the public investment in nano scale research and development is very likely to produce large returns in the labor market that will be able to offer more positions to highly-skilled engineers and scientists. Roco (2011) reported that in the global primary workforce in nano-related facilities reached 400,000 people in 2008. In the meantime, other studies found mixed influences of new technological projects on jobs in various countries. Cozzens et al. (2008) observed that while the introduction of new nano-enabled products rarely lead to job cuts, multinational corporations who are taking the jobs in and out of developing countries may have negative effect on the local labor market leading
potentially to unemployment and poverty. Nevertheless, lack of generalizable data and evidence prevents us from making any firm conclusions.

Most countries of the world suffer from uneven distribution of the development outcomes among various regions, especially if they are as big as Russia and China. **Regional spread** is a possible positive effect of nanotechnology that is associated with improved S&T infrastructure and innovation capabilities in various locations that have experienced particular lack of manpower and advanced facilities before. In this context, programs pursued by the governments affecting remote and underdeveloped regions may serve as an important springboard for these locations to take off in their innovation development. For example, in China reportedly every region has at least some nanotechnology activity today (Klochikhin and Shapira, 2012a). The early impacts of nanotechnology in this area may be traced by the changing cross-regional distribution of nano-related publication and patents as well as industrial output. Cross-regional links between R&D and industrial organizations are also supposed to improve the effectiveness of the innovation system.

Linked to the regional spread, is the emergence of **new industrial and science clusters and formal networks** around nano scale research and development. In this context, it is important to analyze whether nanotechnology is capable of breaking existing path dependencies with regard to concentration of S&T and research-intensive industrial activity in a limited set of locations, as also briefly discussed in section 2.4.3 above. The co-location of major nanoscientists and companies may lead to the formation of new synergies and rapid growth of emerging clusters that may further have positive spill-overs to entire regions.

Several nanotechnology-related **product innovations** have been already introduced into the world market. However, the classification of these goods remains quite unclear: many of them would have only one nanometer dimension or one nanotechnology dimension while other parts are based on traditional technologies. Moreover, several scandals around allegedly nano products have already shaken the consumer attitudes in Germany where Magic-Nano Glassversiegler and Magic-nano Keramikversiegler were reported to have serious health risks which later appeared to have no nano-sized particles at all (Bowman and Hodge, 2007). As a result, it is widely witnessed that nanotechnology has created mostly incremental improvements to the already existing products and applications while waiting games are also preventing the market from taking off immediately (Parandian et al., 2012).
Although particularly useful as a heuristic, the proposed analytical framework is not bereft of certain limitations. Other potential impacts may be also discussed by other researchers who are seeking to study deeply the effects of nanotechnology on society and economy at the national and local levels, and in this context the presented framework should not be considered as a comprehensive set of effects that any given technology may have on individual countries and regions. It may also prove difficult to capture particular effects at the early stages of nanotechnology development because the markets are not mature yet and statistics are not always available, especially at the micro level. So, other techniques of data collection and inquiry may be useful to supplement bibliometric and patent analysis and interviews that are primarily used in this research.

2.4.5. Implications for the study

Nanotechnology development of Russia and China is discussed in detail in chapters 6 and 8. This analysis seeks to answer two major research questions:

- Can nano growth strategies be implemented bypassing the major system weaknesses and path dependencies in Russia and China? and

- Can they help resolve the major challenges faced by the transition economies in their effort to construct effective national innovation systems?

The response to these questions depends largely on whether nanotechnology proves to have enough transformative capacity to push the countries onto new development trajectories, and if the technology itself is free from historical path dependencies and policymakers have special freedom of choice in this emerging area.

Regardless of its limitations, the six-impact framework seeks to provide an effective analytical framework for the assessment of the early impacts of nanotechnology in Russia and China. Several methods and techniques discussed in chapter 3 below are applied to operationalize this heuristic and estimate the effects of nano scale R&D on national and regional development of two countries as well as on the wider innovation system transformation.

The broader concepts of system weaknesses and path dependencies are linked to the discussion of dynamic change in S&T and innovation systems of Russia and China, as reviewed
in more detail in sections 2.2 and 2.3. The challenges faced by Russia and China in their transition from state planning S&T systems to market-oriented innovation systems are studied meticulously in chapters 4, 5, and 7 that precede deep analysis of the nanotechnology trajectories of these countries.

2.5. Policy

This section is dedicated to the subject of science, technology and innovation policies and related concepts. It seeks to guide my analysis of the massive effort undertaken by the Russian and Chinese government to foster innovation growth and emergence of full-fledged national innovation systems. I start with a review of the changing rationales in the STI policy process that is best described by the shift from market failure to system failure. Next, I am touching on the subject of government failure that may be an important obstacle on the way of adopting and implementing effective policies. The concepts of inheritance and dynamic change in public policy seek to provide grounds for an empirical study of policy path dependencies and key factors hindering rapid progress in Russia and China. Finally, the concept of policy learning seems to be crucial to understand the mechanisms of adaptive policy making and transfer of relevant public administration practices from foreign countries and own national historical experience.

2.5.1. From market failure to system failure

Most contemporary policy theories come from economics and seek to build their argument on a number of assumptions dealing with the rational choice and behavioral characteristics of individuals who are supposed to be the major policy objects and who are constrained by the institutional and social norms and cultural values.

The most well-known approach to policymaking and policy analysis is based on the concept of market failure that assumes that individuals are rational human beings – “self-interested, self-controlled, and therefore capable of acting to maximize subjective expected utility subject to constraint” – and markets are the major (and the only) entities that are capable of mediating cooperation between individuals for their mutual benefit (Kleiman and Teles, 2008, p. 632). So, public interventions are only necessary in the cases when markets fail to ensure the so-called Pareto improvement when all those affected by a particular action or event can gain benefit as opposed to the Pareto optimum when no individual can get new
benefits without worsening the position of another individual (Bator, 1958). The reasons for market failure may include uncertainty, information asymmetry, ‘free rider’ problem, and others.

In real life, the market failure approach has a number of limitations. The market does not represent the only form of social organization that is guiding the process of economic and social development. Other non-market institutions may play similar role in creating or resolving the failures of mutually beneficial cooperation including other forms of the failures of private choice and voluntary action. Among others, Kleiman and Teles (2008) suggest that the classical market failure should be supplemented by the failures of individual rationality that depend on the inclination of human beings to temptation, moral hazards, procrastinations, etc. For example, heavy smokers would continue buying cigarettes despite rising prices due to more taxation that, despite benefiting non-smokers, harms the pockets of these smokers. In policy, such situation would mean that direct public interventions including regulations, taxes and prohibitions may be less effective than indirect policies of information and persuasion. However, a danger of excessive or ineffective public measures remains when the government seeks to oversee the imperfect behavior of its citizens in a paternalist way. Side effects are also a plausible scenario when positive impact on one area of social life and economy may appear to be hazardous for a different field.

In science, technology and innovation policy studies, another approach has been used as an alternative to the classical market failure in the recent decades – system failure. This model has emerged in close connection to the increasing popularity of the systems-of-innovation approach discussed in the previous sections. These contemporary approaches are considered the ‘third-generation’ STI policies that were preceded by the linear models of innovation governance (Bush, 1945) and chain-linked innovation model that presented the new interactive vision of the innovation process where multiple feedback loops connect research and commercialization, i.e. scientific and technological knowledge with capabilities and resources of individual firms (Kline and Rosenberg, 1986).

The system failure approach implies the intricate complexity of the innovation process that is built in interactions between different organizations and institutions in the systems often developing in an unplanned manner. The market-failure-based policies seek to repair the failures of private firms and bring the system to some ideal or optimal state. Although putting
similar trust in the self-regulating power of the market, the system failure approach states that there is no such ideal or optimal state of the innovation system because it is path dependent and the outcomes are often unpredictable. Hence, STI policies aim at particular systemic problems that would improve rather than remedy the innovation system and take it to the new stage of development. Among others, such systemic problems include infrastructure provision and investment problems, transition problems, lock-in problems, institutional change, network problems, capability and learning problems, unbalanced exploration-exploitation mechanisms, complementarity problems, and others (Chaminade and Edquist, 2010).

In practice, Boekholt (2010) mentions that the ‘system failure’ model has become a norm in many countries in the last decade, although the systems-of-innovation approach remains a typically “European concept that is not always used so explicitly in non-European countries” (p. 345). That is, it is mainly European nations who have adopted the new approaches and policy instruments in their innovation development consistent with the system failure while many other countries continue implementing public measures from the previous generation of STI policies, e.g., grants for individual firms, support of public scientific institutions regardless of their embeddedness in the commercialization process, creation of technology transfer offices in universities, establishment of large-scale mission-oriented projects, etc.

In most cases this slow transition to the new-generation models may be explained by the cultural and institutional contexts. In some countries, such as the United States, market mechanisms have proven to be quite efficient and the Bayh-Dole Act\textsuperscript{24} seemed to be a good tool to ensure smooth technology transfer and innovation growth. However, lately, the Obama Administration had to rethink its policies in the aftermath of the 2008 financial crisis and introduced a number of measures to promote innovation including the appointment of the first White House Chief Technology Officer and the Chief Information Officer (Shapira and Youtie, 2010). Another sign of these new developments in the U.S. innovation thinking has been the recent rise of interests in science of science policy (Lane and Black, 2012).

In other countries, such as Russia and China, the system failure approach would probably mean skipping the ‘second-generation’ policies that have not been implemented in

\textsuperscript{24} The Bayh-Dole Act was enacted by the U.S. Congress in 1980 and increased controls of universities, federal labs, small firms and non-profits over intellectual property resulting from federally funded programs and projects. The Act had significant impact on the rise of patent activity, increase of technology transfer and commercialization, and emergence of multiple start-ups and spin-off companies.
the previous period due to the specificities of the state planning system and mere absence of market economy and respective institutions, most importantly private firms, whom these policies would primarily target. Thus, we see the establishment of large public foundations that would provide financial (and non-financial) support to individual companies that are usually start-up firms (e.g., RUSNANO and Russian Venture Corporation), increasing role of national science foundations for the transformation of universities and public research institutes (e.g., National Natural Science Foundation of China), and launch of large-scale mission-oriented projects (e.g., Russia’s federal targeted programs and China’s mega-projects).

2.5.2. Government failure

One other concept should not be forgotten in policy theory and policy practice – the one of *government failure*. Kleiman and Teles (2008, p. 626) mention that policy analysts (and policy makers) often shy away from “comparing the efficiency of the institutions of voluntary choice, left to their own devices, with the efficiency of state action, or with the efficiency of private action as modified by regulation.” This comparison appears to be more critical in countries with inefficient governments and high corruption since public interventions there may have disastrous effects due to the imperfections of the national bureaucracy and its desire to achieve personal benefit rather than to serve the national interest.

Kleiman and Teles (2008) mention seven reasons that may cause government failures to happen: inadequate penetrative capacity; inadequate voluntary cooperation; institutional overhead; voter attention and inattention; the path dependence of political decision making; competition for technical expertise; and weak administrative culture. The first two reasons deal with the governments’ limited access to information (due to lack of voluntary sharing of information from citizens) or inability of bureaucracy to adequately process and use such information in order to introduce proper measures.

Institutional overhead comes from the disruptions in principal-agent relations in the policy process caused by subversion, shirking or graft. These failures may be resolved by tighter rules and tougher control but the latter may be as costly and dangerous as corruption leading to bureaucratic ‘red tape’.

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25 The principal-agent problem is a common concept in political science and economics that is used to describe the issues related to the difficulties of motivating one party (“agent”) to abide by the rules set by and in the interests of another (“principal”) rather than in his or her own interests. The dilemma plays primary role in defining the degree of policy governance as well as studying the behavior of policy stakeholders who may subvert from acting in the best interest of the “principal”, shirk or graft.
Voter attention and inattention present a challenge for the policy process in democratic regimes. Individuals rarely spend reasonable amount of time to study the ideologies and views of the candidates they are likely to vote for, which may lead to a bias in policies for smaller but better organized groups that lobby their interests through voting and acting as single units.

Policies are also path dependent and former decisions limit the incumbent governments’ choices to much extent. The ability to overcome these path dependencies depends on the form of government and the readiness of society and interest groups to approve these changes and put up with the transaction costs implied by such reforms.

Competition for technical expertise is always present in market economies where public and private sector compete for the best talent and highly skilled personnel. A balance between the public and private spheres must be sustained in order to ensure that market failures are well spotted and governments are accountable to the market agents.

Administrative culture is crucial in ensuring that public agencies make proper decisions and are adaptive to changing environments. Good administrative culture is a result of long-term development and effective leadership and hence the impact of ad hoc measures is limited in its emergence and modification. Where there is weak administrative culture, agencies are slow to respond to new economic and social conditions and may lose their authority and legitimacy in the long run.

2.5.3. Inheritance and dynamic change in public policy

Inheritance in public policy may serve as a crucial constraint on the number of choices available to the incumbent government, especially in democratic regimes (Kay, 2006; Rose, 1990). Continuity is an important characteristic that either ensures the gradual system transformation or slows it down by preventing radical changes and institutional reform. So, on the one hand, dictatorships are better-off due to their exceptional power in resource mobilization and enforcement of strategic decisions but, on the other hand, they are very fragile and resilient to any drastic change and may eventually lead to severe leeway of their countries as they might have taken them forward just several years ago. (Take for instance the results of the Stalinist modernization of 1930s that allowed the Soviet Union to become a superpower winning the Second World War together with other allies but ultimately led to the
collapse of the country in 1991 due to its ideological and institutional rigidities that appeared to be incapable of absorbing and guiding required change).

Pierson (2004) also mentioned that inheritance – or policy path dependencies as other scholars would call it – is highly dependent on the institutional context. Systems are generally more likely to change existing commitments where fewer veto points exist although new agendas are difficult to gain weight in the narrow political environment with limited carrying capacity. Meanwhile, systems with multiple veto points are difficult to re-evaluate existing commitments where a wide variety of interests are balanced but may prove easier to shift wider agendas and introduce new programs.

Kleiman and Teles (2008) discuss several forms of institutional settings where path dependencies may change at different rates. Corporatist systems with few large organization systems may find it easier to introduce incremental changes to existing policies but will have to struggle to find support for a major reassessment that implies large expenses. In contrast, interest group systems with a large number of small organization units are difficult to re-evaluate existing commitments as this process would disrupt the fragile balance of interests while large costs may be well distributed among a wider set of interest groups where they lose control of the policy agenda.

Similarly, geographically centralized systems are difficult to push incremental policy changes but if they gain control over the agenda they can implement reforms of much larger scale. In contrast, decentralized systems imply political battles on a number of fields both geographical and inter-departmental, and hence may prove easier to gain support for minor changes but are difficult to achieve a consensus for wider reforms.

The view of public policies in the evolutionary perspective, implied by the study of inheritance and path dependencies, raises the importance of policy dynamics as a critical variable in the policy process. The design, implementation and evaluation of public interventions are highly dependent on their adaptability to the rapidly changing social, economic and political environment.

Among others, Kay (2006) mentioned that policy is a complex choice of instruments, implementation mechanisms, responsible agencies, monitoring and evaluation procedures, etc. This choice occurs in an increasingly complex system of interactions, ideas, preferences,
institutions and else. Therefore, it is becoming more and more difficult to apply static models of policy analysis to understand its roots and foresee its future development. Dubbing many institutionalist ideas, Kay concludes that “the dynamic perspective on the policy level of description leads to analysis of contingent conjunctures as opportunities, strategic actions, beliefs about links between action and consequence, as well as preference formation and strategic rationality” (p. 27). Thus, he emphasizes the role of cultural and historical factors.

In innovation studies, the problem of capturing the dynamics of the innovation system and ensuring the policy adequacy in the highly volatile and institutionally different contexts has been a growing concern. It was noted that, despite its rapid dissemination, the systems-of-innovation approach retains major flaws that prevent it from providing a good analytical and operational platform to account for the rapidly changing STI environment. As a result, partly due to these theoretical flaws, “actual policy making often follows the old linear mode or, while claiming to be designed from a systems perspective, applies a ‘one-size-fits-all’ approach” (Smits et al., 2010b, p. 417).

As an alternative, a system-evolutionary approach to innovation policy was proposed to capture the innovation dynamics and guide the policymaking process to better choices in highly volatile and institutionally different contexts. Such ‘strategic policies’, as Smits et al. (2010b) call them, would account for the long-term objectives of system transformation and innovation development in addition to the existing operational policies that serve the immediate needs of keeping the economy competitive. They imply an elaboration of a new set of policies that would be consistent with an innovation system transformation and a new global and domestic context and will guide the nation through this period of change. Three components are essential in strategic policies: incentives and related programs, institutional and regulatory changes, and other actions including setting a long-term innovation agenda and planning strategic institutional transformations.

Major difficulties remain on the way to operationalize the system-evolutionary approach to innovation policy. Smits et al. (2010b) associate a number of systemic instruments with strategic policies that would address four key functions: “reshaping of innovation systems, building platforms for learning and experimenting, stimulating demand articulation and vision development, and providing a tailor-made strategic intelligence infrastructure” (p. 442). However, as authors mention, there is no persistent monitoring, evaluation and analysis of the
impacts of these instruments on the transition of innovation systems, and hence they remain a sort of ‘soft’ instruments that are probably too vague for the policymakers to apply in a competitive political environment due to their difficult verifiability and low level of codification that would allow for easier communication to national bureaucracies, parliaments, and voters. At the same time the system-evolutionary approach may still be used as a good starting point and a heuristic in further STI policy studies in various contexts including Russia and China, who are going through the period of drastic structural change of their innovation systems and seek to adopt effective policies to support this process.

2.5.4. Policy learning

Learning about ways of public and private management across nations and time has occurred for many centuries. Peter the Great, the Russian emperor, went on a ‘Great Embassy’ to the Netherlands to learn how to build ships and create a mighty army that would defeat Sweden and Turkey to gain access to the Baltic and the Black Sea. Or Japan learnt much from the United States in constructing its economic miracle after the Second World War.

However, the concept of policy learning – or lesson-drawing in public policy – has deserved reasonable attention of social scientists only recently (Rose, 1993; 2005). It is argued that two major factors have pushed researchers and policymakers to spend more time on studying this phenomenon: increasing uncertainty in political decision-making and increasing convergence of public policies across nations (Freeman, 2008). Both are results of globalization that has been especially vivid after the collapse of the Soviet Union in 1991 and rapid expansion of the world capitalist system and democratic regimes.

Yet, increasing similarity in public policies and interdependence of various nations does not mean that all states are alike today. Rose (2005, p. 10) mentions that a lesson in public policy “is not a photocopy of a foreign programme, nor is it a model devoid of national context. A lesson is created by ‘re-contextualizing’ the generic model. This requires filling in details that are necessary but not integral to a programme, such as rules for employing its civil servants.” Hence, simple imitation may be disastrous if the program is not contextualized but rather copied blindly and brought without change on the domestic soil from abroad.

Thun (2004) came to similar conclusions in his test of applicability of rational imitation at the sub-national level. The scholar studied whether various regions in China (particularly
Guangzhou and Shanghai) can benefit from the assumption that decentralization leads to better quality and flexibility of public policy. The findings point that, although change is observable, institutional contexts present important constraints on any policy modification stimulated by decentralization.

This view is also echoed by Shipan and Volden (2012) who argue that policy learning is a special case of policy diffusion. The latter is broadly defined as “one government’s policy choices being influenced by the choices of other governments” (p. 788). Other forms of policy diffusion include competition, imitation and coercion. While sometimes imitation may be beneficial, it often leads to understudied and inappropriate policy choices. Similarly though, wrong lessons may be drawn from others’ experience and competition may cause a ‘race to the bottom’ in certain redistributive programs. Coercion is usually possible in countries that have suffered a military defeat or severe economic crisis in the recent part, and winners of the conflict or bigger economies can make other countries adopt particular policies that they deem appropriate for their successful transition.

In general, policy learning may occur in two directions: across time and across space (Rose, 1993). Policymakers and analysts may draw lessons from the past through analogies where the outcomes and conditions of various programs and actions in history seem similar to the present challenges. However, the danger is in the assumption that the conclusions valid for the past would be as appropriate for the present while the circumstances might have changed dramatically. Therefore, blind copying of the past programs may be as dangerous in learning across time as it is in lesson-drawing from the experience of other countries and regions.

Similarly, when learning across space, lesson-drawing is only possible “if policymakers in different governments face a common problem” (Rose, 2005, p. 18). This means that a certain level of similarity is required to ensure effective policy learning across nations. In this sense, similar challenges emerging from the common past or in similar areas are a critical prerequisite for lesson-drawing. Both negative and positive lessons may be learnt by comparing various programs addressing similar issues. In other words, policy learning accepts the contingency of public policy where it can provide conditions for both the success of the program and also of its potential failure.

In this respect, Shipan and Volden (2012) mention an interesting example of Germany that uses its economic power to bring about austerity measures in Greece to save the Eurozone today.
In innovation studies, the ideas of learning in public policy have attracted increasing attention in recent years. Gu and Lundvall (2006) argued that adaptive innovation policies are essential for successful catch-up and fundamental transformation of national innovation systems. The researchers mentioned two sources of learning: international experience and domestic experimentation.

Boekholt (2010) discussed a variety of strategic intelligence tools that allow for effective policy learning. These include foresight, technology roadmaps, systemic evaluations, benchmark studies, sector and cluster studies, and others. The researcher argued that these tools may be used to improve policy learning across all stages of the policy process including policy design, implementation and evaluation. At the same time proper learning culture in public organizations is a critical factor in ensuring that lessons are applied successfully.

In the meantime, several reasons may lead to a failure in policy learning. Rose (2005, p. 104) mentioned that when drawing a lesson one must be sure that “there is a fit between what policymakers want to do and what they can do.” Policy path dependencies, resource constraints and cross-national differences are among the major causes of failed attempts to adopt best practices found either in history or abroad. For example, lack of money, inappropriate legal frameworks, poorly qualified personnel, interdependence of programs or bad policy governance and organization may serve as critical limitations preventing the transfer of successful programs. Hence, accuracy of analysis is essential in policy learning and application of lessons.

2.5.5. Implications for this study

Today, science, technology and innovation policies in many countries are going through a transition from the ‘second generation’ to ‘third generation’. The concept of system failure has not gained priority in every nation yet but its gradual adoption is observed in most states including Russia and China. So far, the new approach may be applied as a useful analytical tool to analyze how governments promote innovation and where they fail to address the needs of national systems consistently and effectively. Likewise, the system-evolutionary approach to innovation policy may serve as a good heuristic to analyze the ‘strategic policies’ that Russia and China apply in their transition to effective national innovation systems. Besides, the

27 See in Rose (1993, pp. 118-142) for a more detailed discussion on the reasons for failure of lesson-drawing in public policy.
knowledge and experience of more advanced countries that have already turned to the ‘third-generation’ STI policies may be used to accelerate transition in catching up economies and give them important advice on what instruments to adopt in their particular contexts. However, blind policy imitation may have disastrous effects and adaptive policy learning seems to be a better alternative.

Like overall comparison, policy learning is possible (and probably desirable) between Russia and China because they have much similarity between them due to common historical and structural backgrounds. Their mutual learning may prove to be an effective way of collaboration and lead to improved governance of innovation systems in both countries. Yet, differences should be taken into account to reduce the risk of failure and prevent negative effects of simplistic policy transfer. At the same time learning from the past seems to have limited utility in Russia and China: the communist rule has changed radically the cultures and institutional regimes so that many preceding trajectories were either eradicated or modified dramatically.

The concept of government failure is also especially important to analyze public policies in Russia and China where corruption is high and inefficacy of public institutions is widely observed. The optimal scale of public interventions must be reached to ensure the balance between the costs and benefits of policy action in the area of science, technology and innovation.

The final implication links to the previous one and emphasizes the role of inheritance in public policy. Both path dependence of political decision making and discontinuity in the Russian and Chinese STI policies play critical role in the promotion of innovation development and the construction of an effective innovation system. On the one hand, the choices of the incumbent leadership are limited by the policy actions of the previous period especially the remaining structures of the state planning science and technology system and traditions and norms of public management linked to these structures. On the other hand, discontinuities of the political past dealing with the radical changes in history – the rapid transformation in China after 1978 following the abandonment of Mao Zedong’s policies and the Gang of Four process, and the flash-like liberalization in Russia after 1991 – also create particular problems for the contemporary policymakers. Cultures and institutions are persistent and are difficult to change overnight but a mismatch in the pace of reform and ways of thinking between policymakers...
and the innovation community may be similarly dangerous. Therefore, the innovation policy dynamics and the process of system transformation must be well tuned to ensure best possible results.

2.6. Conceptual framework

To conclude the literature review I revisit the four key research questions of this study and link them explicitly with the concepts and analytical frameworks discussed in the preceding sections:

- How can Russia and China exploit their science and technology history to promote indigenous innovation development and resolve the weaknesses of the former state planning system?

In responding to this question, I seek to analyze the major challenges and opportunities presented by the historical legacies of Russia and China that are linked to the common state planning past where the state was playing an exceptionally strong role in guiding the directions of economic, social, and political development. The concepts describing the changing nature of innovation help me relate these legacies to the requirements of today where science, technology and innovation are co-developed by a wide set of actors united by various collaborative arrangements and striving to learn from each other in the increasingly interconnected and interactive world.

As Russia and China retain a number of unique social, economic and institutional features, I am also seeking to apply the notion of heterogeneous systems of innovation as well as theories describing the broader development agenda to include into my analysis a wider range of crucial factors guiding the countries’ catch-up trajectories. The world-systems approach and varieties of capitalism also support this vision of high significance of contextual factors that are peculiar to individual countries and regions. The concept of the world-systems also provides a solid theoretical and analytical foundation for the historical approach that I am undertaking to analyze the transition trajectories of Russia and China by tracing them back to the twentieth century.

A critique related to the particular reliance of the systems-of-innovation approach on the role of firms in the innovation process allows me to adapt this useful heuristic to the context of transition economies where the state is still playing an extremely strong role and the
private sector has a range of distinct features that make it substantially different from the business environment in the developed countries.

- Are there any particular complementarities between the Russian and Chinese innovation that can contribute to their socioeconomic development?

In answering this question, I am building upon the historical evidence of inherent similarities between the S&T systems constructed in Russia and China following the establishment of communist regimes in the first half of the twentieth century. The systemic complementarities are allowed by the world-systems approach and varieities of capitalism and can be traced in the comprehensive historical analysis by comparing how individual factors behave in various environments. Therefore, I begin the empirical part with describing the key strengths and weaknesses of the state planning S&T system and analyze evidence of their existence in both USSR and China. Next, I take these system features to present Russia and China and try to understand whether any of them survived in the course of substantive transition reform undertaken by both countries in the last 30-40 years (basically since 1991 for Russia and since 1978 in China). The strong features of the state planning S&T system are then analyzed from the point of view of their utility for the current objectives of strategic transformation of national innovation systems and broader socioeconomic environment.

- What are the current and emerging opportunities for mutual learning between the two countries?

This question relates specifically to the public policy analysis. Based on the preceding analysis, I aim to study here whether Russia and China share a number of common problems that allow them to learn from each other and potentially transfer useful policy practices by adapting them to their unique institutional and socioeconomic environments. The concept of system failure permits to apply a modern analytical framework to the analysis of such learning opportunities as well as study them in dynamics by utilizing a system-evolutionary approach. The discussion of policy path dependencies and government failures points at particular difficulties preventing smooth policy transfer and implementation due to the deficiencies of the innovation policy system. Finally, the concept of dynamic change in public policy provides some additional routes for the study of specific mechanisms that would help to introduce adaptive innovation policies and transfer the best practices successfully.

- What is the role of leading-edge and novel technologies in this process?
Here I am studying the role of nanotechnology in the overall process of innovation system transformation in Russia and China. The transformative capacity of this novel technological area is still unclear and the empirical analysis allows me to address this theoretical and methodological gap more comprehensively in this research. The six-impact framework is an innovative analytical approach that has been already used by me and the main supervisor in Klochikhin and Shapira (2012a). As mentioned in section 2.4.5, by utilizing this framework I am seeking to understand whether nanotechnology can help both countries resolve the major challenges on the route to successful transformation of their innovation systems. The answer to the second question regarding the opportunities for implementing nano growth strategies bypassing the major system weaknesses and path dependencies builds largely upon the preceding analysis where the main characteristics of system and policy path dependencies are already discussed in much detail.
Chapter 3. Data and methodology

This study has become a result of a long journey with a major goal to find ways how to accommodate the diversity of innovation trajectories in the contemporary world and capture the dynamics of system transitions in Russia and China that continue to attract increasing attention today.

The major challenges are linked to the largely interdisciplinary nature of this study, which sources its main concepts, theories and methodology from innovation research, international political economy, area studies, policy studies, history, and development research.

The process of conducting this research has been non-linear and reiterative and many nominal stages overlapped but if presented in a flowchart it would look as follows:

Figure 1. Research process

- **Stage 1.** Broad discussions; literature review and documentary analysis
- **Stage 2.** Search of a ‘reference point’ for the comparative case study of Russia and China
- **Stage 3.** Finalization of research questions and objectives
- **Stage 4.** Identification of relevant methodologies
- **Stage 5.** Focused literature and documentary review
- **Stage 6.** Secondary data analysis
- **Stage 7.** Primary data collection
- **Stage 8.** Analysis and reiteration

**Stage 1.** Broad discussions; literature review and documentary analysis. At this initial stage, I sought to engage with the wider context of innovation studies and science and technology
development of Russia and China – both theoretically and empirically – in order to articulate my specific research interests and proceed to the choice of methodology and the key focus of this work.

Stage 2. Search of a ‘reference point’ for the comparative case study of Russia and China. Here, I was looking to understand what grounds can allow me to discuss existing similarities between the two countries and opportunities for mutual learning between them with a primary goal to identify a proper research design of this study.

Stage 3. Finalization of research questions and objectives. After finding a proper ‘reference point’ to build up my case study and rationalize the major arguments – common state planning legacies and other historical similarities – I proceeded to formulate particular research questions and objectives of this study presented in the introduction to this dissertation.

Stage 4. Identification of relevant methodologies. Although a number of particular techniques are relevant to answer the proposed research questions, I had to limit myself to a manageable set of methods that would be both doable within the time constraints of the PhD program and epistemologically grounded and verifiable through triangulation and other mechanisms. In table 1, I present a general chart of the methods used in the course of this work where a number of techniques were applied to support the major findings.

Table 1. Methodology

<table>
<thead>
<tr>
<th>Main methods</th>
<th>Supporting methods</th>
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<tr>
<td></td>
<td>Qualitative</td>
</tr>
<tr>
<td>Comparative case study</td>
<td>Benchmarking</td>
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<td></td>
<td>Social Network Analysis</td>
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<td></td>
<td>Interviews</td>
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<td>Literature review</td>
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<td>Documentary review</td>
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Stage 5. Focused literature and documentary review. Here, I performed a targeted literature and document search related to the major research questions in the areas of history of science and technology in state planning systems, policy briefings and reports, political speeches, media articles, and else. This review provided grounds for further verification of gained assumptions and knowledge about innovation system and policy transition in Russia and China by secondary data analysis and field interviews.

Stage 6. Secondary data analysis. At this stage, bibliometrics and patent analysis were used to study large datasets derived from the international and national sources of data with an objective to support/verify the major findings retrieved from the preceding literature and documentary review.

Stage 7. Primary data collection. Over forty interviews were conducted during field trips to China and Russia. The group of interviewees included top policymakers, bureaucrats, scientists, researchers, engineers, entrepreneurs and investors to ensure the widest possible representation of the interest groups, knowledge and perceptions about science, technology and innovation development in the target countries as well as the policy environment and strategic planning.

Stage 8. Analysis and reiteration. At this stage, data from three major sources – literature, secondary data analysis, and field interviews – was triangulated to achieve the best possible verification of findings. I also returned to study broader paradigms to provide a better articulation and explanation of the findings of this study.

3.1. Data

Based on a broad qualitative comparison of innovation trajectories in Russia and China, this study could not do without a large set of macroeconomic and research and development (R&D) statistical indicators that help to provide a more accurate benchmarking. In general, Russian and Chinese statistics remain quite unreliable with a number of methodological shortcomings despite a massive effort to bring the national norms in tune with the international rules and regulations (Graham and Dezhina, 2008; Huang, 2008; Schaeper, 2009). Part of the problem is in the remnants of the former accounts system used in command economy. Among others, Fortescue (1990) mentioned the ambiguity of the indicator showing the number of ‘science and pedagogical personnel’ in the Soviet statistics that makes it almost
impossible to identify how many people are actually involved in the R&D process rather than participating in the general training. And some Russian interviewees pointed at the difficulties of separating private and public-sector organizations since the Russian government continues to hold large stakes in the research institutes and large companies (various interviews, 2012).

Today, several sources publish extensive statistical data including the Russian statistical agency (Rosstat), Higher School of Economics in Moscow, the National Bureau of Statistics of China. In the meantime, credible data is also available through the United Nations and World Bank who are opening up their detailed databases.

Secondary data for bibliometrics and patent analysis is derived from Thomson Reuters Web of Science (for publications) and Derwent Innovations Index (for patents). These repositories provide access to the major peer-reviewed publications and patent information and seem to be among the best sources for global and national data in the relevant fields. Some limitations deal with the publishing and patent culture of Russia and China discussed in more detail in the following chapters. In general, Chinese researchers appear to be more open to peer-reviewed English-language publications today that are referenced in the Thomson Reuters Web of Science while Russian scholars are still focused on the Russian-language journals and international data may not be the best indicator of the country’s scientific activity. At the same time other sources – including literature and documentary analysis and field interviews – confirm the major findings as exemplified throughout this study and suggest that the margin of error is quite minor.

Primary data is semi-structured and derives from over forty interviews with Chinese and Russian policymakers, business representatives, scientists and researchers (see in more detail in section 3.4).

3.2. Comparative case study

Comparative case study analysis does not represent a particular method but rather a wide set of qualitative and quantitative techniques. The choice of these techniques depends on a number of factors including the object of analysis, its major characteristics and hypothesis of the study. A general logical schema is supposed to guide the comparative inquiry. Mill’s (1843) five methods represent one of the routes to follow. Although it is usual to use the joint method of agreement and difference, the major premises may be deconstructed to find the right
balance between the two approaches. In this study, I choose to follow the method of agreement assuming that state planning legacies represent a critical similarity between Russia’s and China’s innovation transitions and have significant impact on the contemporary challenges and policies. In general, the method of agreement represents a logical sequence where a scholar has to trace the similar outcomes of an event to its potentially common causes: “If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon” (Mill, 1843, p. 454). Hence, I conjecture that the similar challenges observed in Russia’s and China’s innovation development today are the result of the common past.

These methodological assumptions are also in line with the key epistemological grounds of this study elaborated in the preceding sections: both world-systems analysis and varieties of capitalism suggest that historical path dependencies and institutional complementarities are crucial in the research of contemporary events and phenomena and thus may serve as an important reference point for a comparative case study.

3.3. Bibliometrics and patent analysis

Bibliometrics and patent analysis are generally considered as good quantitative techniques to observe the dynamics of science and technology activity, effectiveness of technology transfer and commercialization. In the meantime, some caution is needed since the data used for such analysis is often messy and should be structured. So, it seems important to supplement these methods by a number of other qualitative and quantitative techniques that would allow for better clarity and verification of results. Among others, some researchers use web-scraping to analyze unstructured data from websites related to their research objects: firms, NGOs, agencies, and other organizations (Youtie et al., 2012).

In this study, I primarily use bibliometrics and patent analysis to study the patterns of nanotechnology development in Russia and China supplementing my results with some findings on the U.S. and global nanotechnology growth found elsewhere in literature (e.g., Shapira and Youtie, 2008; Shapira and Wang, 2010; Shapira et al., 2011; Youtie et al., 2011). To ensure robustness of the chosen methodology, I apply the search-query method developed by a team of researchers at Georgia Institute of Technology to capture the widest and cleanest possible list of publications in the area of nano scale research and development beyond the simplistic
‘nano*’ search term (Arora et al., 2012; Porter et al., 2008). VantagePoint software is used for data cleaning, data mining and analysis.  

3.4. Interviews

The interviews were conducted at the last stage of analysis to best formulate the questions and gain clarifications and explanations of particular events and phenomena that would be impossible to get in any other way including literature and documentary review, bibliometrics and patent analysis. Semi-structured interview protocols were prepared based on research questions and major assumptions that guided this study (most importantly, the hypothesis that Russia and China face very similar challenges today due to their common state planning legacies and akin science and technology structures). Over forty interviewees were selected among the policymaking, academic and business communities and in various locations; in China, I visited Beijing, Shanghai and Suzhou, and in Russia, I conducted interviews in Moscow, Barnaul and Perm. Among others, the list of my interviewees included representatives of the Chinese Academy of Sciences, Suzhou Industrial Park, Shanghai Nanotechnology Promotion Center, National Center for Nanoscience and Technology of China, National Engineering Research Center for Nanotechnology of China, Russian Academy of Sciences, Skolkovo Foundation, various government agencies, firms and venture capitalists. The data collection and interview process was also facilitated by my prior experience in the Russian government system and journalism.

3.5. Content analysis

The technique of content analysis is used briefly in chapter 6 dedicated to the subject of nanotechnology development. This method is applied to identify the role of nanotechnology in the overall innovation discourse at the top political level in Russia as reflected in the presidential speeches and public remarks. One of the main methodological challenges of this analysis is the language requirements as most speeches and other press materials are rarely translated from Russian into English seriously limiting access to them by a large number of high-quality researchers mainly concentrated in the western countries. Exactly for this reason and limited access to data this approach has not been applied to the other case country China.

28 VantagePoint is a customized datamining tool for science and technology analysis and is developed by Search Technology Inc., Atlanta, GA, USA. See more at www.thevantagepoint.com.
The theoretical framework for content analysis was derived from Stemler (2001) and the US General Accounting Office (1996) who suggested a detailed description of the content analysis techniques and gave a brief overview of its main advantages and disadvantages.

According to the US GAO (1996), the objective of content analysis may be descriptive, normative or impact evaluative. This study followed the descriptive route since the primary objective has been to identify the current state of innovation discourse in Russia rather than compare it to any ideal norm existent in the contemporary world.

Besides, given the relative complexity of this study, the major focus was put on nominal variables abandoning any ordinal (e.g. strongly negative, moderately negative, moderately positive or strongly positive attitude towards nanotechnology in the innovation discourse in Russia) or interval variables. In order to reduce the distortion of final results and resolve another limitation of content analysis, I applied seemingly unambiguous variables aiming to increase the reliability of research conclusions. So, instead of using some vague terms like vision or view I applied the search terms like innovation, high technology, modernization, nanotechnology, etc.

The official website of the Russian President – www.kremlin.ru – served as a major data source. Here, the main challenge consisted in the fact that the website had had two versions in the period from 2000 to 2010. So, the search was split into the periods from 1 January 2000 to 6 May 2008 and from 7 May 2008 to 30 November 2010 taking 7 May 2008 as the breaking point because this was the day of President Medvedev's official inauguration. Luckily, the search system of both websites is the same provided by Яндекс.Server, which prevented any divergence of results due to the technical issues.

Overall, the web search returned the following results:

- Innovation (noun) – 246
- Innovation (adj)\(^{29}\) – 507
- Modernization (noun) – 834
- Modernization (adj) – 38
- High technology – 796
- Highly technological (first spelling) – 476

\(^{29}\) Given the rules of the Russian grammar, words had to be used in different forms in order to ensure the good quality and entirety of collected data.
The search results overlapped extensively between different terms. So, the data was retrieved from the website leaving out any obvious duplicates. The overall amount of items gathered reached 1,461 (of initial 3,057).

The collected data included different types of presidential speeches ranging from governmental meetings and discussions to foreign trips, interviews and press conferences. So, the data was further cleared to remove any words said by other people rather than the President himself (e.g. ministers, journalists, other leaders, etc.).

The recording unit of the analysis was defined as the whole piece of information retrieved from the official website of the Russian President regardless of its type or contents. Search terms were highlighted and analyzed in context. Any irrelevant units were left out (e.g. speeches devoted to the subjects of modernization of the United Nations or NATO; modernization of the Russian judicial system, etc.). The overall amount of units diminished to 1,050 (of initial 1,461).

Resultant textual units were classified according to the most relevant categories:

- general (units devoted to the subject of the overall modernization of the country be it purely economic or socio-economic, political, educational and else, e.g. “the goal of modernization of economy, social sphere and judicial system” or “modernization of the Russian state in all spheres”);
- economic and industrial development;
- social policy (primarily healthcare and housing);
- military sector;
- agriculture;
- education and science;
- transport and infrastructure;
- energy;
- international cooperation.
Certain limitations apply to this analysis:

a) Although the search terms were chosen carefully, the meaning of them can still differ in various contexts and depend on the person pronouncing it (Presidents Putin and Medvedev can have different understanding of different words like modernization or innovation). For example, the term 'modernization' may be applied to economy or specific industry as well as to the political or judicial system of the country. As a result, contextual analysis of the usage of such words remains highly subjective leading to potential misinterpretation of the context and misclassification of the textual units.

b) The quality and quantity of the collected data depends significantly on the ways of work of the presidential press office as different managers may apply different techniques on disseminating information about President's activities. For example, the first report on the one-to-one meeting with a government minister dates back to 2004. However, this does not mean that President Putin did not meet any of his ministers in this format before: this is just a new form of media communication. So, this fact may potentially lead to some misinterpretation during the analysis.

c) Some events like big meetings and conferences may have been linked to more than one report on the website (e.g. one foreign trip can be reported in the forms of direct negotiation, press conference, interview, etc.). So, this may hinder correct classification in terms of quantity and lead to further misinterpretation.

d) Different kinds of speeches and meetings may have different public influence and therefore differ in significance. Content analysis does not permit to take into account this factor.

3.6. Limitations and variations

Some limitations of the chosen methods have already been mentioned in the preceding sections and deal primarily with the limited access to credible data and different academic cultures of the countries in focus. Others may include limited time to conduct a broader set of interviews with the stakeholders involved in science, technology and innovation policy and development in Russia and China. With Russia, this limitation seems to be compensated by my previous experience and education in the Russian university system as well as in journalism. With China, the regular contacts and support from the colleagues at the Beijing Institute of Technology through the Innovation Co-Lab may also be an appropriate excuse. Language
barrier has been a particular obstacle in content analysis preventing me from conducting a similar study of the role of nanotechnology in China’s political discourse.

In terms of methodological variations, it is also possible to use the method of difference\(^{30}\) in the comparative case study here that is allowed by the epistemological grounds of the varieties of capitalism. One may assume that Russia and China have gained completely different results in their innovation transitions – the former is losing its last remnants of the former Soviet S&T and industrial might while the latter has emerged as the second largest economy in the world with large promise of rapid innovation development. Therefore, these different outcomes of the innovation transitions may come from differences in the historical choices although starting from a similar point: Russia has been chosen the radical route after 1991 while China has been implementing gradual reforms since 1978. Such perspective could lead the system comparison of Russia’s and China’s innovation to a different route that would require the choice of other research questions and research design as well as renewed justification of the methodological selection. However, these assumptions seem relevant and provide an interesting alternative to how this study might have been constructed otherwise.

\(^{30}\) “If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause, of the phenomenon” (Mill, 1843, p. 455).
Chapter 4. State planning S&T system

This chapter analyzes the key features of the state planning S&T system as it existed in the countries of the socialist world before 1991. It aims to study whether the individual factors of the state planning S&T and innovation practices would behave similarly in the unique environments of the USSR and China. This analysis allows me to further proceed to the comparison of the contemporary innovation system of the two countries based on the evidence of their inherent complementarity due to the common legacies and remaining characteristics.

For the ease of narration and analysis I have divided the twenty-five strengths and weaknesses of the state planning S&T system derived from the literature into four large groups: social and political status of science and technology; quality of science, technology and innovation and technology transfer; science, technology and innovation policy system; and system of intellectual property rights protection.

4.1. The context

The state planning science and technology system had practically existed in its classical form until the collapse of the Soviet Union in 1991. Although multiple modifications of the system were spread across the so-called Communist bloc including China, Yugoslavia, Poland, Bulgaria, Romania and others, most variations were a very close copy of the Soviet S&T structure where basic research was produced in the Academy of Sciences, industrial institutes delivered specialized applied research and development and the primary function of universities was teaching rather than research. It is not an objective of this work to follow the genesis of this system but one can assume that its major elements and management practices come from a broader set of state planning theories of government and industrial management developed in the early years of the Soviet Union in the 1920s and 1930s and also by the large community of Marxist scholars throughout the nineteenth and twentieth centuries.

In general, the state planning S&T system was built on the linear view of the innovation process. Like Bush (1945), the Soviet strategists believed that innovative products, services and processes are a result of a step-by-step movement of ideas and knowledge from fundamental science through to applied research, development and commercialization (or better say introduction – vnedrenie – to the national production and distribution system).
In this context, Radosevic (1999) argues that the state planning (or socialist) system was a classical science and technology rather than an innovation system since R&D and innovation activities were clearly separated from production in socialism. Users’ learning and ‘learning by doing’ in production were significantly underdeveloped where externalized R&D and engineering served as the major source of innovation. A universal pattern of science and technology activities was spread across the entire economy often regardless of sectoral and regional differences whereas contemporary innovation systems imply a wide diversity of innovation patterns in various sectors and locations.

The reasons for the wide spread of the state planning practices in public management of science and technology are ambiguous. Most of them can probably be explained by what Shipan and Volden (2012) call coercion when the policy adopted by the Soviet Union was diffused to other countries after the Second World War through the imposition of communist regimes in Central and Eastern Europe and sustenance of status quo by the use of force (as vividly demonstrated in German Democratic Republic in 1953, Hungary in 1956, and Czechoslovakia in 1968). In other countries, the adoption of Soviet science and technology practices would probably be explained by what Rose (2005, p. 51) called “too big or too good to ignore.” China, Vietnam, Cuba and some others followed the Soviet model because of their ideological beliefs rather than because the USSR imposed communism in these countries by the use of force. At the same time military might did play an important role in their choices since the communist governments often had to make their way through difficult regime change, civil war and conflict with the capitalist nations where they used the Soviet army to help them hold political power.

Yet, some cross-national differences still existed. Radosevic (1999, p. 284) summarizes five major variables that defined how close countries were to the Soviet S&T model:

- “the degree to which R&D activities were carried out within industrial enterprises (share of ‘in-house’ R&D)”;
- “the degree to which R&D was carried out in extra-mural organisations (share of industrial institutes)”;
- “the degree to which universities played a teaching versus research role (share of higher education institutions in gross expenditures for R&D)”
• “the degree to which the role and functions of Academies of Sciences were different (Academies of Sciences as government bodies or loose associations of institutes”; and
• “the degree to which economies were open or closed for S&T co-operation (CMEA (Commonwealth for Mutual Economic Assistance) membership and progress in socialist economic reforms).”

One way to capture these cross-national differences is through the analysis of patent applications. Radosevic and Kutlaca (1999) study the number of foreign US patents by institutional sector in 1969-1994 and find that Hungary and former Yugoslavia had the highest share of enterprise patenting; Bulgaria and Czechoslovakia had a balanced distribution between enterprises and industrial institutes; Poland and Romania were dominated by extra-mural patenting; and the role of enterprises in Soviet patenting activity was marginal (see Table 2).

Table 2. Number of foreign US patents by institutional sectors in socialist countries, 1969-1994 (%).

<table>
<thead>
<tr>
<th></th>
<th>Former Soviet Union</th>
<th>Bulgaria</th>
<th>Former Czechoslovakia</th>
<th>Hungary</th>
<th>Romania</th>
<th>Poland</th>
<th>Former Yugoslavia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academy of Sciences</td>
<td>15</td>
<td>4</td>
<td>27</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Enterprises</td>
<td>11</td>
<td>49</td>
<td>41</td>
<td>81</td>
<td>25</td>
<td>24</td>
<td>62</td>
</tr>
<tr>
<td>Industrial institutes</td>
<td>56</td>
<td>40</td>
<td>25</td>
<td>12</td>
<td>50</td>
<td>37</td>
<td>6</td>
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<tr>
<td>Government</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Universities</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Foreign</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>28</td>
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<tr>
<td>Non-classified</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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</table>


A similar analysis involving China, based on official statistical data, shows that in 1985-1991, most patents registered by China’s patent office were produced by industrial enterprises and foreigners. Universities and research institutions also had a tangible role. At the same time large share of individual (non-service) patents in the overall amount of patents granted by SIPO complicates the analysis since it is unclear where these individuals are employed and how they were using their intellectual property (see Table 3).

Since the Patent Office of China, predecessor of the current State Intellectual Property Office, was founded only in 1980 and the patent law was introduced in 1985, patent data is only available starting with 1 April 1985 for this analysis, as reported in the China Statistical Yearbooks.
Table 3. Number of SIPO patents granted by institutional sector, 1985-1991.

<table>
<thead>
<tr>
<th>Institutional sector</th>
<th>Share in total SIPO patents granted in 1985-1991* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities and colleges</td>
<td>5</td>
</tr>
<tr>
<td>Research institutions</td>
<td>8</td>
</tr>
<tr>
<td>Industrial and mineral enterprises</td>
<td>16</td>
</tr>
<tr>
<td>Government agencies and organizations</td>
<td>4</td>
</tr>
<tr>
<td>Non-service**</td>
<td>56</td>
</tr>
<tr>
<td>Foreign***</td>
<td>11</td>
</tr>
</tbody>
</table>


* Data for 1985 is referred to the period from 1 April to the end of the year.

** SIPO distinguishes between “service” and “non-service” patents. “Service” inventions are made by an employee of a company or organization as part of his or her duties. In such cases, the company or organization has the right to apply for a patent and will become a patent assignee after grant. “Non-service” inventions are made by individual inventors.

*** Includes both “service” and “non-service” patents.

If only invention patents are taken into consideration given that they generally seem to be more important for ‘hardware’ innovation growth, industrial enterprises have twice as few inventions as universities and research institutes (see Figure 2).

Figure 2. Number of SIPO invention patents by institutional sector, 1985-1991.


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32 Although I do not analyze patterns of patenting activity by individual institutional sectors here, it seems most interesting that individuals who were granted non-service patents produce significantly more utility patents than inventions while universities tend to apply for both invention and utility patents, industrial enterprises focus on utility and design patents, and foreigners produce much more designs than two other types. These differences in patterns of patenting activity provide interesting material for deeper analysis of institutional and organizational settings that account for them and can be further studied in a separate work.
In general, the analysis of Chinese patent distribution among institutional sectors might demonstrate two things: universities and research institutions had more capacity and motivation to produce ‘hardware’ inventions while they lacked experimental facilities and had smaller role in development to deliver new utility models. In contrast, R&D process at Chinese enterprises was more oriented at practice where utility models and designs played a bigger role. Hence, it seems possible to assume that there is particular proximity of innovation models in former Soviet Union and China before 1991 where extra-mural research and development had more significance in designing new technologies and products while their incremental improvements were usually produced at industrial enterprises. At the same time the rising share of industrial enterprises in the patent distribution might also be a sign of China’s strong desire to follow the recognized international practice in innovation and integrate into the world economy.

It must be also noted that the major similarity of different state planning systems was primarily observed in their ‘hard’ structure rather than in ‘soft’ characteristics where major innovation outcomes and particular research areas are taken into account. Take for example the differences in quantity and disciplinary distribution of scientific output in former Soviet Union and in China between 1978 (when Deng Xiaoping announced the new Open Door Policy) and 1991. The USSR produced the total of 469,668 articles in 1978-1991 while Chinese researchers kept to 57,981 publications in the same period (see Figure 3).

Figure 3. Number of scientific publications by former Soviet Union and China in 1978-1991.

![Figure 3. Number of scientific publications by former Soviet Union and China in 1978-1991.](image)

Source: own calculations based on Thomson Reuters Web of Science.\(^{33}\)

\(^{33}\) Data includes publications in science, social science and arts and humanities.
The disciplinary distribution of Soviet and Chinese science is also quite diverse. Right after the disaster of the Cultural Revolution China produced only 215 publications in 1978, most of which were in the areas of general and internal medicine, entomology, zoology and astronomy. At the same time the USSR already had an established profile in chemistry, physics, materials science, metallurgy, engineering, and biochemistry (see Table 4).

Table 4. Top-10 subject areas of scientific publications by Soviet and Chinese scientists in 1978 (and the number of records in each category).

<table>
<thead>
<tr>
<th>USSR</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chemistry – 5,270</td>
<td>1. General &amp; Internal Medicine – 51</td>
</tr>
<tr>
<td>2. Physics – 4,524</td>
<td>2. Entomology – 42</td>
</tr>
<tr>
<td>7. Biochemistry &amp; Molecular Biology – 1,000</td>
<td>7. Sociology – 7</td>
</tr>
</tbody>
</table>

Source: own calculations based on Thomson Reuters Web of Science.

By 1991, the specialization of Chinese science had become more vivid and concentrated in the subjects of physics, chemistry, engineering, mathematics, materials science and some others. Certain interdisciplinary links could be observed between instrumentation and nuclear science and technology and physics; materials science and metallurgy; physics and materials science (see Figure 4). These links may point at particular specializations of the Chinese economy and R&D at that period which would probably be focused on producing nuclear equipment, metal goods and developing mechanical methods of new materials production.

In the meantime, advantages of the Soviet Union in physics, chemistry, engineering and materials science had been basically preserved. Two facts seem interesting in this analysis. First, physics had surpassed chemistry as the primary area of specialization in Soviet science by 1991 as compared to the previous period (5,270 publications in chemistry and 4,524 in physics in 1978 versus 8,896 publications in physics and 7,330 in chemistry in 1991). A plausible explanation of this shift is provided by Balzer (1989) who mentioned the special status of theoretical research in the Soviet Union over applied work and development in the Soviet
Union as well as lack of S&T equipment and basic supplies that are needed on larger scale in chemical experiments rather than in physics.

Secondly, the particular configuration of scientific disciplines and interdisciplinary links observed in 1978 and 1991 may point at certain path dependencies in Soviet science that are analyzed in more detail with respect to nanotechnology in chapter 6. Figure 5 demonstrates that biology and physiology already presented a separate cluster of Soviet science in 1991 and had been developing independently of some other broader disciplines, such as materials science, polymer science and instrumentation. Figure 11 depicting Russia’s interdisciplinary links in nanotechnology generally repeats this picture and shows that biochemistry and biophysics are isolated from other areas of nano scale research, particularly chemistry, electrochemistry, nuclear science and energy whereas in China these interdisciplinary connections do exist and seem to provide a better platform for the rapid catch-up in the field of biotechnology and pharmaceuticals (compare with Figure 18 on China’s nanotechnology).
Figure 4. Top-20 areas of scientific specialization in China and their interdisciplinary links, 1991.
Figure 5. Top-20 areas of scientific specialization in former Soviet Union and their interdisciplinary links, 1991.
Despite these disciplinary differences, Russia and China continued to share common practices and structure of the science and technology system. Several strengths and weaknesses are peculiar to S&T in command economy (see Table 5 for a full list of characteristics of the state planning S&T system that I analyze here). These are relative to the context and may have lost their advantageous status in the recent decades. For example, block system of science finding is useful to ensure stability and continuity of scientific enquiry in a command economy but may be harmful in the market environment where competition and adaptation are key to effective technology transfer and commercialization. Similarly, free flow of knowledge as a public good is useful in a closed system where the government can control the distribution of S&T results by secrecy and direct involvement while intellectual property rights protection is essential in the market economy.

Yet, most of these strengths and weaknesses continue to hold their status in the contemporary conditions and present a good framework for the analysis of historical path dependencies and dynamics of innovation system transition in Russia and China.

Table 5. Strengths and weaknesses of the state planning S&T system.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High profile and continuity of science</td>
<td>• Lack of S&amp;T equipment in research institutes</td>
</tr>
<tr>
<td>• Support of highly-qualified S&amp;T personnel</td>
<td>• Inhibited information flows</td>
</tr>
<tr>
<td>• Good level of theoretical research</td>
<td>• Separation of research and teaching</td>
</tr>
<tr>
<td>• Massive resource allocation to S&amp;T</td>
<td>• Technological ‘backwardness’</td>
</tr>
<tr>
<td>• Block system of science funding</td>
<td>• Low productivity and rates of return on investment (ROI)</td>
</tr>
<tr>
<td>• Prioritization of most important S&amp;T projects</td>
<td>• Weak technology diffusion</td>
</tr>
<tr>
<td>• Knowledge as a public good that can be freely used by all agents</td>
<td>• Risk averse culture</td>
</tr>
<tr>
<td></td>
<td>• Weak computing capability</td>
</tr>
<tr>
<td></td>
<td>• Inadequate infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Poor training of researchers</td>
</tr>
<tr>
<td></td>
<td>• Rampant departmentalism and political involvement</td>
</tr>
<tr>
<td></td>
<td>• Emphasis on the military</td>
</tr>
<tr>
<td></td>
<td>• Corruption and nepotism</td>
</tr>
<tr>
<td></td>
<td>• Lack of enterprise autonomy</td>
</tr>
<tr>
<td></td>
<td>• Reluctance to dissolve unsuccessful SOEs</td>
</tr>
<tr>
<td></td>
<td>• Imbalance between risk and reward for innovating</td>
</tr>
<tr>
<td></td>
<td>• Lack of mission-oriented approach</td>
</tr>
<tr>
<td></td>
<td>• Low patenting activity</td>
</tr>
</tbody>
</table>

Source: adapted from Klochikhin (2012a).
4.2. Social and political status of science and technology

The state planning S&T system, in all its forms and variations, implied high profile and continuity of science. Technical progress was considered as one of the major drivers of socioeconomic development in Marxist ideology and was hailed by the communist leadership. Moreover, Balzer (1989) mentioned that the regime has often sought legitimacy through scientific achievements. In Soviet Union, it became especially vivid after the breakthroughs of the 1950s and 1960s leading to the launch of Sputnik and first manned flight to space.

Society also paid large attention to the scientific achievements in command economy (Kuchment, 1990; Lubrano, 1987). The circulation of scientific and popular science journals and books was rising despite any economic and social hardship. For example, in 1922 – right after the civil war – Soviet Russia published over 36% of scientific, popular science and student literature in the overall number of books (see Table 6). In the 1970s, the circulation of popular science literature reached 70 mln copies that practically covered the entire population of the former Soviet Union (Vaganov, 2012). Surveys showed that science career was persistently ranked among the top choices of profession. As Balzer (1989, p. 146) concludes, “science ha[d] a very high profile in the system of Soviet cultural values.”

Table 6. Number of titles published in Soviet Russia in 1922 by type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of titles</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialized</td>
<td>3,179</td>
<td>40.6</td>
</tr>
<tr>
<td>Scientific</td>
<td>1,055</td>
<td>13.4</td>
</tr>
<tr>
<td>Fiction</td>
<td>997</td>
<td>12.7</td>
</tr>
<tr>
<td>Popular science</td>
<td>869</td>
<td>11.4</td>
</tr>
<tr>
<td>Political</td>
<td>666</td>
<td>8.5</td>
</tr>
<tr>
<td>Student textbooks</td>
<td>561</td>
<td>7.1</td>
</tr>
<tr>
<td>Reference books</td>
<td>321</td>
<td>4.1</td>
</tr>
<tr>
<td>Other</td>
<td>106</td>
<td>1.4</td>
</tr>
<tr>
<td>Children’s books</td>
<td>86</td>
<td>1.1</td>
</tr>
</tbody>
</table>


In China, the situation was less continuous. In the years of the Cultural Revolution (1966-1976) science and technology were heavily attacked and criticized for ideological reasons. Inspired by the success of agricultural collectivization in its early stages, the Great Leap Forward put a stake on the country’s rural population who were supposed to take China to the next stage of industrial development and allow to catch up with Great Britain in steel
production. Most universities were closed and many scientists lost their jobs (Sigurdson, 2005; Xue, 2006).

It was only in 1978 that Deng Xiaoping launched the Four Modernizations and Open Door Policy that reversed the trend and revived the prestige of science and technology in society and economic growth as the ‘first production power’. As a result, higher education boosted in the last decades with student enrolments rising from 0.86 mln in 1978 to 9.03 mln in 2002, and the one-child policy made a significant contribution to this development (Sigurdson, 2005).

In the meantime, this high political and social status of science and technology had its drawbacks. Fortescue (1990) noted that influential members of the Academy of Sciences could usually enjoy ‘personal access’ to the Soviet leadership, which implies a number of serious administrative obstacles on the way to the national leadership and grants political access only to the selected ones often irrespective of their academic merit. In this situation, corruption and nepotism were quite common, and high-level scientists and engineers would often promote their cronies and get increased funding for their institutes and projects through lobbying activities involving key decision-makers in the USSR. Balzer (1989, p. 160) reinforced that “the directors of institutes wield tremendous power, and have been in position to control not only resources but also promotions, publications and even housing opportunities.”

Suttmeier (1985) takes a deeper look into corruption in Chinese science following broader frameworks developed in science, technology and society studies. He defines corruption in Merton’s (1973) terms where it is understood as deviance from four pillars of the normative structure of scientific community: “Communalism – scientists are expected to share the results of their work with the larger collegial community; Organized skepticism – scientists are expected to subject the research findings of others to scrutiny and be prepared, if necessary (and if feasible), to replicate the research being scrutinized; Universalism – scientific claims, if true, are regarded as being true everywhere, and are not contingent upon geography,

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34 Four Modernizations are a doctrine originally set forth in 1963 by Zhou Enlai, first Premier of the People’s Republic of China, to promote development in the fields of agriculture, industry, national defense, and science and technology. In 1978, these goals were adopted by Deng Xiaoping and became the main objectives of the reform era.

35 It seems interesting that the Soviet leadership already used this definition of science in 1961 when a long-term program of the Communist Party was adopted to declare that “science is becoming in full measure a direct productive force” (Zaleski et al., 1969, p. 394). Strangely, though, Russia and China chose different directions to move from this common starting point in their reform.
history, personality, or politics; and *Disinterestedness* – the search for new knowledge is being conducted without regard for reputation and/or material gain” (Suttemeier, 1985, p. 51). In this context, classical norms of scientific activity were corrupt in a variety of forms in China but – similar to the USSR – many of them were dependent on the behavior and values of individual leaders. It was noted that the affairs of S&T units, or *danwei* – research institutes, hospitals, factories and institutions of higher education – were often decided regardless of existing norms but rather “according to the whim of the leader” (Ibid, p. 53). Instances of deviance were often reported when this ‘unitism’ (*danwei zhuyi*) contradicted the principles of ‘normal’ science and even the expectations of the Communist Party and the units’ leaders created a somewhat normless scientific environment in their institutes for the sake of personal gain. Moreover, this authoritarianism in Chinese science often led to the coercive appropriation of research results by the seniors over their subordinates. And particular theories were promoted as orthodox ones, based on political and ideological standards.36

In addition, large-scale S&T projects and high profile of science in socialism were often implemented regardless of the environmental and human cost. Balzer (1989, p. 147) mentioned that “in Soviet doctrine, nature has persistently been viewed as something to be transformed.” During Stalin rule, the construction of the Dnepr hydropower plant and the Magnitogorsk iron and steel factory led to catastrophic results for locals and workers many of whom died in the process or continued to live in unbearable conditions after the construction was finished (Graham, 1998). In 1986, almost all Europe, particularly Ukraine, Belarus and Finland, suffered from the Chernobyl disaster that had become one of the major failures of ruthless technical progress in the Soviet Union.

Similarly, over a hundred thousand people were displaced in the construction of the Three Gorges dam in China when the streambed of the river had to be changed in order to meet the country’s rapidly rising demand in electricity (Sigurdson, 2005).

Quite expectedly, high profile of science in state planning S&T system also came with close attention of the political leadership and their regular involvement in defining the ways of scientific and technical progress. Lysenkoism and Stalin’s theories of linguistics are considered among the major distortions to the development of science in the USSR. Both set

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36 Suttmeier (1985) noted that this latter form of corruption was less vivid in China than in the Soviet Union where Lysenkoism and Stalin’s theories of linguistics gained priority because of top-level political endorsement while China’s Communist Party was more eager to support competition among schools of thought in their country.
the Soviet genetics and linguistics\textsuperscript{37} back for several decades when only in the 1960s ‘real’ scientists could use their argument to put the development of these disciplines back to the right track (Graham, 1998).

Balzer (1989) mentioned that in the later years the situation had improved significantly, although particular instances of political involvement were often witnessed at the elections of the members of the Academy of Sciences and in favoring particular schools of thought when the Party leadership would express its preferences quite openly.

In the Chinese case, Suttemeier (1985, p.52) reinforced:

When we consider some of the salient properties of autonomy – freedom to decide the direction of research, control over rewards and sanctions, the use of quality control mechanisms appropriate to science, and autonomy in scientific communications – a case could readily be made that none of these properties have obtained in China since the mid-1950s. Instead, organized science has been penetrated by political and administrative considerations designed to inhibit the emergence of any type of autonomous community.

4.3. Quality of science, technology and innovation and technology transfer

The high social and political status of science and technology in command economy allowed them to support good level of continuity and stability. Block system of funding permitted scientists to pay little attention to how they allocate their time and resources. Researchers could continue their projects over extensive periods without much account for tangible results. This environment allowed for longer-term planning and less constraints on ‘blue skies’ research and theoretical enquiries that could bring breakthrough results in future.

At the same time continuity and stability did not only have positive outcomes. Despite high profile and massive resource allocation, science and technology demonstrated poor productivity and low rates of return on investment in state planning S&T systems. Supported by stable funding, research institutes, universities and enterprises often wasted time and resources on unreasonable projects. Moreover, funding was distributed irrationally in the Soviet Union. Balzer (1989, p. 149) noted that “some elite institutes and military facilities spend lavish amounts on unneeded equipment, while other installations wait years for crucial

\textsuperscript{37} Similar is true to cybernetics and economics that were labeled as ‘pseudo-scientific disciplines’ during Stalin rule and several talented scholars were killed for their commitment to normal scientific argument including Nikolai Kondratieff, the author of the well-known theory of economic cycles.
instruments.” Similarly, some institutes were overstaffed by highly qualified personnel, while others were in desperate need of scientists and engineers.

In general, Zaleski et al. (1969) noted that the productivity of research in the USSR was arguably much lower than in the United States. Productivity of development was similarly reported lagging behind the United States quite significantly in the 1960s, except possibly for the high-priority sectors. Fortescue (1990) also mentioned that both fundamental science and applied research were seriously lagging behind the West with both physical (uneven funding, lack of equipment, etc.) and moral (authoritarian managers, ‘nobody cares’ problem, lack of motivation, etc.) factors contributing to such state of affairs.

Another reason for this poor productivity and low innovation output of science and technology in the USSR was that theoretical research was particularly favored by the political and academic leadership while applied work and innovation were difficult to push through in the Soviet system. These preferences were aggravated by the serious lack of S&T equipment (Zaleski et al., 1969). Besides, Balzer (1989) pointed at appalling problems with basic supplies and materials that had reportedly ruined massive efforts to apply expensive equipment imported from abroad for rapid S&T development because it could not be used due to these other minor problems existent in individual institutions. Housing, deficit of food and consumer goods were another implication of inadequate infrastructure that led many Soviet scientists to delve deeply into shopping and other household cares instead of devoting their time to scientific labor.

This poor infrastructure did not correspond with the high ambition of catching up with the world technological leaders or sustaining leadership where it was previously achieved. Balzer (1989, p. 150) concluded that “institutional barriers, a lack of crucial equipment, and the tendency to replicate successes rather than to push for further discoveries” marked most areas in the Soviet science and technology.

In China, the prestige of theoretical work was arguably lower than in the Soviet Union that can be probably explained by the divergent tracks of innovation transition that the countries were following after the Open Door Policy was introduced in 1978, although

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38 In the meantime, the authors also continued that any conclusions should be considered highly tentative in such comparison due to the lack of uniform data and difficulties of comparing publication output because of the inadequate expansion of publication facilities in the Soviet Union.

39 For example, in nuclear fusion, lasers and superconductors where Soviet scientists did pioneering research and were the leaders at one time.
Suttmeier (1989, p. 379) did mention the problem of “the maladjustment of theory and practice”, as it was frequently said that “Chinese science ha[d] a capacity for theoretical understanding, but an incapacity for linking theory to practice.”

As noted by Sigurdson (2005), lack of natural resources – especially compared with the USSR – was one of the major reasons why China decided to make a stake on importing foreign technology and collaborating with the western world to improve its own innovation capabilities. This decision had likely led to a better balance between fundamental science, applied research and development. However, as evidenced by the recent shortfalls of the ‘technology-for-market’ strategy in China\(^{40}\), these divergences did not necessarily mean the particular difference in the challenges that both China and Soviet Union were facing in their reform.

One of these challenges – **weak technology diffusion** – is peculiar to both countries. Although technological achievements were generally considered as a public good, free flow of knowledge and ideas as well as established technologies was significantly hindered by underdeveloped S&T and industrial infrastructure. Beside inadequacies in equipment and social well-being, **weak computing capability and inhibited information flow** were a serious problem. Among others, Wolcott and Goodman (1988) reported that the Soviets were seriously lagging behind in computing with no signs of emerging catch-up. Some other assessments also pointed at the lack of access to supercomputers by Soviet scientists where their use was already a norm in the West.

These problems did not only hinder progress in particular disciplines but also inhibited communication and information flow in the USSR in general. Photocopying remained a tightly controlled technology and reprints were uncommon. Beside practical insulation of research groups inside the country, the Soviets had little chance to communicate with the world scientific community where new ideas could be tested and regular benchmarking would help to identify the most important directions of S&T development.

One more thing contributed to weak technology diffusion. **The Soviet economy was primarily ‘production-oriented’** where enterprises lacked autonomy and motivation to make innovation decisions. Factories lacked research labs and development facilities. Personnel

\(^{40}\) The strategy and its relative failure are discussed in more detail in the following chapters.
employed by industrial R&D centers were reported to being paid no more than 50 per cent of the salaries at equivalent positions at research institutes (Zaleski et al., 1969).

General lack of development facilities across the entire economy was a serious problem. Zaleski et al. (1969) mentioned that only 8.4 per cent of research institutes and independent design bureaus in Leningrad had experimental factories in 1966. Academy research institutes and higher education establishments had even harder conditions. Strikingly, even enterprises were often rejected to build an ‘experimental base’ despite their economic successes and mission to develop new products. Fortescue (1990) reported that the gross R&D spending in the Soviet Union was distributed in a proportion of 10:60:30 with regard to basic science, applied research, and developmental work respectively, whereas a proportion of 10:30:60 looks more effective from the western experiences. At the same time the United States spent 65.5 per cent of total R&D expenditure on development in 1963-1964 with further 34.5 per cent allocated to basic and applied research (OECD, 1967).

Similar problems have been observed in China where manufacturing was a major reason for economic success. The bias towards production has likely contributed to the lack of innovation capacity in enterprises especially in the publicly owned sector and probably has its roots in the historical commitment to central planning. Sigurdson (2005) mentioned that before the reforms began in 1978 the link between clients and consumers of S&T results, i.e. enterprises, and their suppliers, i.e. research institutes, was inhibited. Liu and White (2001, p. 1098) reinforced that “the dominant performance criterion for primary actors was output scale, without any explicit attention to efficiency nor, in practice, quality of the output.”

In general, industrial innovation faced serious difficulties in China. Fischer (1989, p. 121) noted that “outmoded products, obsolete technologies, and a reliance on reverse engineering (that is, the design or redesign of products based on imitation or careful review of others’ innovations) as a primary source of new product and process ideas” were widely spread and considered as a norm.

The researcher continued to name several reasons for poor industrial innovation in China before 1989 that coincided largely with what was observed in the USSR: heavy bureaucratization of science and technology; low investment in civilian R&D; dismantling and destruction of much Chinese economy during and after Second World War and subsequent civil war; inhibited information flow; discontinuity of STI policy witnessed during the Great Leap...
Forward and Cultural Revolution; neglect of indigenous innovation capabilities due to heavy reliance on reverse engineering; general inadequacy in the planning mechanism; low level of motivation in Chinese enterprises to innovate; and other factors generally attributable to the state planning system on the whole (Fischer, 1989, pp. 121-122).

In the last years of its existence, the USSR made particular effort to replace block funding substantially by contract research to improve the opportunities for technology transfer and bring research closer to the needs of industry and society. However, this reform had limited success and was hindered by many other problems of the state planning system (Balzer, 1989; Fortescue, 1990).

As a result, this situation led to serious technological ‘backwardness’ of the Soviet Union in the 1980s that was evidenced by large groups of population not only in science but also among general public (Balzer, 1989; Schroeder, 1989). Earlier, Bergson (1974) also noted in his seminal quantitative comparative study of the Soviet economy that technological progress had proceeded at a rather modest rate in the USSR.

Lack of sophisticated equipment was observed not only in scientific labs and research institutes: Soviet industry was also constrained by unreliable machines. Solovyev and Novikov (1988) cited in Balzer (1989) reported that the average mean time before failure of Soviet robots was less than a week (80 to 100 hours), while western equipment could work reliably for 5,000 to 10,000 hours. Soviet Union was lagging behind in the development and production of supercomputers and PCs. A 1989 report showed that out of 68,000 schools only 7,000 had a single computer (Remnick, 1989).

This technological backwardness was further accentuated by the lack of imported equipment. In a 1989 survey, 65.5 per cent of scientists reported that they were using only equipment produced in the USSR or East European countries; 5 per cent of respondents were using equipment produced in the USA and one third were utilizing technology from Western Europe and Japan that accounted for slightly over 20 per cent of their project equipment (Sternheimer, 1989).

China made similar efforts to improve industrial innovation starting with early 1980s to provide more incentives for improvement and technological advancement. Most of these policies were based on the assumption that market mechanisms can be more effective in
particular instances where dynamic innovation was required. Among others, enterprises were
given more autonomy and freedom in the use of investable resources that can be further
applied to promote research and development. Bank loans were also introduced to improve
capital flows that were otherwise distributed through government subsidies. One of the major
decisions taking China on an arguably more successful development trajectory than former
USSR was the decision to reorient the economy from heavy industry as prescribed by the Soviet
economic theory to light, consumer-oriented industry (Fischer, 1989).

In the meantime, risk aversion and conservatism was another drawback of continuity
and stability in state planning S&T systems. Balzer (1989) noted that stable funding and political
support often hindered change in Soviet science where traditional disciplines guarded their
boundaries and did not welcome much interdisciplinary research that would allow for spill-
overs and idea exchange between close areas, e.g. biochemistry and materials science. Figure 4
also supports this vision and shows lack of interdisciplinary links in the USSR in 1991. In wider
context, stability and predictability of outcomes was preferred by most Soviet citizens at the
expense of market risk, competition and dynamic growth.

In the Chinese case, corruption in science also favored particular theories and schools of
thought, as mentioned by Suttmeier (1985). However, in contrast to Russia, the Chinese culture
favors entrepreneurialism that creates a better environment for experimentation in science
and social life (Li et al., 2006). Although generally this feature would be more advantageous for
interdisciplinary development and reduced dogmatism, it also “often rewards opportunism”
(Suttmeier, 2008, p. 10).

In innovation, an imbalance between risk and reward was also an important factor. The
incentive system in command economy often rewarded formal rationality that was risk averse
and rarely led to breakthrough technological advancements (Balzer, 1989). Careers in the Soviet
Union and China often depended on personal connections and loyalty whereas pure merit was
rarely rewarded sufficiently to justify the risk. So, many Chinese managers interviewed by
Fischer (1989, p. 123) would note that “there was simply no need to innovate because either
market demand so exceeded supply that it made innovation unnecessary or there was no direct
financial linkage between market needs and enterprise benefits to make innovation worth the
enterprise’s while.” Berliner (1976) described similar challenges in the Soviet Union where the
marginal profit from introducing new products and processes was quite small compared to the
profit gained through better production output even if it was based on obsolete technologies. He wrote that risk per se must have been better rewarded and stimulated to increase competition and desire to innovate.

**Enterprise autonomy** also played an important role in defining the rate of innovation and productivity in both the USSR and China. Berliner (1976) noted that Soviet factories did have much freedom of choice in their internal management and planning especially after the 1965 economic reform. At the same time all external links and supply chains were mediated and coordinated by a massive bureaucracy either at the national or republican level. Although the overall professional level of Soviet bureaucrats was quite high, imperfect planning and distribution multiplied the faults of the economic structure and prevented much innovative activity.

In China, the situation was slightly different. Despite the overall negative account of the limited autonomy in Chinese science shared by Suttmeier (1985), some post-1978 reforms led to a rapid rise of entrepreneurship and business autonomy in the country. Huang (2008) reported that multiple township and village enterprises organized by the municipalities in the 1980s were genuine small- and medium-size enterprises that boosted China’s economic growth and brought about much positive change primarily in rural areas. At the same time these small firms were mostly engaged in low-tech production and trade that in its quantity might have been impressive but lacked distinct characteristics of high-tech research and development.

Where R&D happened, though, were the large cities such as Shanghai and Beijing. And in this context Huang (2008) gave quite a negative account of the ‘urban’ way of Chinese capitalism, as he calls it, because of the lack of entrepreneurship, risk, and much dependence on the central and municipal government in these cities that were associated with large state-owned enterprises and job security. At the same time Sigurdson (2005) mentioned that many developments in the new era after 1978 were quite positive: ministries and agencies lost direct control of a majority of their enterprises that were corporatized and were listed on stock exchanges in Shenzhen, Shanghai and Hong Kong.

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41 Interestingly, one of high-level interviewees whom I met in China in May 2012 also mentioned that large cities like Shanghai and Beijing are quite risk averse due to their historical proximity to the large enterprises in the former case and the central government in the latter. These features continue to influence the routes of China’s innovation development today like they did in the past and are discussed in more detail in chapter 7.
So, one may generally assume that China and the USSR were quite similar in the dependent status of large enterprises throughout the state planning period but they might have followed divergent transition tracks due to the differences in culture, although they are not the sole factor accounting for all such divergences.

So, Li et al. (2006, p. 118) mentioned that the study of firm strategic behavior in China would be incomplete without considering the influence of such factors as “long-term orientation and critical roles played by strong leaders”, “Yin and Yang”, “harmony”, “middle way of thinking”, “holism”, and “adaptability characteristics of Chinese culture as a starting point of understanding how the culture influences the formulation and implementation of strategies in Chinese firms.” These features seem to be quite distinct and unique to the Chinese culture. Meanwhile, Soviet (and later Russian) engineers and scientists were reported as being risk averse and quite detached from the mission of their institutes and factories – more like in Shanghai than in rural areas of China (Balzer, 1989; Berliner, 1976).

4.4. Science, technology and innovation policy system

Generally speaking, there was no innovation policy in the state planning S&T system as it would be understood today. Since the link between science and technology and production was orchestrated through a number of intermediaries under the direct control of the government, there was no need to adopt a particular policy to facilitate network connections and interactive learning between the actors of the system. So, Zaleski et al. (1969) discuss the government policy on science, technology and industry in their comprehensive report on the Soviet R&D.42

Direct support of science, technology and industry through massive resource allocation and block system of funding were the most popular policy instruments used by the socialist bureaucracy. Multiple studies reported that the Soviet R&D budget equaled and in some areas exceeded the one in the United States amounting up to 3 per cent of GDP. Science funding alone increased dramatically since mid-1960s and reached 5% of national income in 1986 (Fortescue, 1990). Earlier, it was reported that the science budget was about three times as

42 Such policy structure does not necessarily mean that the Soviet Union was lagging behind developed countries since innovation policy had not been on the agenda before the systems-of-innovation approach brought up the new understanding of how innovation should be governed. Otherwise, many western countries were following Bush’s (1945) linear model of S&T and innovation management, and the USA has practically not implemented system failure approach to full extent until present. More details may be found in chapter 9 of this work.
high in 1967 as it was in 1958, which shows the commitment to S&T development by the Soviet leadership after the successes of the Sputnik and first manned space flight (Zaleski et al., 1969).

Soviet science and technology also enjoyed huge manpower employed at the Academy of Science, industrial institutes and factory labs. Despite the significant differences in statistical accounts and challenges of arriving at comparable data, most western analysts concluded that the USSR employed much more research workers than any other country of the world. The personnel employed in all research institutes regardless of their function amounted to an impressive 4.55 mln people in 1986 and those engaged only in research work or holding advanced degrees represented a large group of 1.52 mln people in 1987 (Fortescue, 1990).

China had much more modest input into its science and technology before 1991. The first available figure for the gross R&D expenditure in the World Bank database\textsuperscript{43} is 0.57% of GDP in 1996, which would be a good indication of the small investment in science and technology by the Chinese government in the preceding period. Another available statistic comes from China Statistical Yearbook on Science and Technology that is accessible from the year 1991; it indicates that China spent 0.71% of GNP\textsuperscript{44} for research and development in 1990 and further 0.72% of GNP in 1991 and 0.7% of GNP in 1992.

In terms of manpower, China couldn’t boast large student enrolment either: 0.86 mln students were registered at the institutions of higher education in 1978, 1.14 mln in 1980, 1.70 mln in 1985, and 2.06 mln in 1990 (China Statistical Yearbook 2003). It must be noted, though, that in the post-1978 period the nation made significant effort to expand its university system and offer an increasing number of undergraduate programs while depending largely on foreign universities to train Chinese students for advanced degrees. As a result, about half of all students studying abroad returned home to contribute to their country’s S&T growth in 1978-1990 (see Table 7).

\textsuperscript{43} The World Bank has provided open access to a number of statistical indicators that are compiled by the Bank using various data sources. The database is available at data.worldbank.org.

\textsuperscript{44} Gross National Product.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of students studying abroad</th>
<th>Number of returned students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>860</td>
<td>248</td>
</tr>
<tr>
<td>1979</td>
<td>1,777</td>
<td>231</td>
</tr>
<tr>
<td>1980</td>
<td>2,124</td>
<td>162</td>
</tr>
<tr>
<td>1981</td>
<td>2,922</td>
<td>1,143</td>
</tr>
<tr>
<td>1982</td>
<td>2,326</td>
<td>2,116</td>
</tr>
<tr>
<td>1983</td>
<td>2,633</td>
<td>2,303</td>
</tr>
<tr>
<td>1984</td>
<td>3,073</td>
<td>2,920</td>
</tr>
<tr>
<td>1985</td>
<td>4,888</td>
<td>1,424</td>
</tr>
<tr>
<td>1986</td>
<td>4,676</td>
<td>1,388</td>
</tr>
<tr>
<td>1987</td>
<td>4,703</td>
<td>1,605</td>
</tr>
<tr>
<td>1988</td>
<td>3,786</td>
<td>3,000</td>
</tr>
<tr>
<td>1989</td>
<td>3,329</td>
<td>1,753</td>
</tr>
<tr>
<td>1990</td>
<td>2,950</td>
<td>1,593</td>
</tr>
</tbody>
</table>


Irrespective of the levels of resource allocation, central authorities in all state planning regimes appeared to be quite unwilling to support industrial innovation activity beyond narrowly assigned missions of separated science, technology and production. Although some research institutes were funded and supplied by the separate article in the Soviet budget, others were left to the will of individual ministries and enterprises that were uneager to support R&D effort since production output was the major indicator by which they would be assessed. Zaleski et al. (1969) concludes that the Soviet model was more effective in resource mobilization when the objective was to stimulate production based on imported technology while it failed to organize an effective innovation system in a more complex environment when the USSR reached a particular level of S&T development where it could produce its own innovations.

China seems to have been experiencing similar challenges. The post-1978 reforms boosted economic growth through increased manufacturing and rapid adoption of western technology. At the same time knowledge spill-overs between multinational corporations and local businesses appeared to be quite limited and the technology-for-market strategy was basically recognized as ineffective after the new mid- and long-term development plan was adopted in 2006 (Fu et al., 2011).

Another problem was poor training of researchers and engineers due to the notorious separation of research and teaching in the Soviet-type education system. Heavy teaching load
did not allow lecturers and professors devote significant time for research tasks, which led to their falling out of advanced scientific development. In the 1980s, the policy in the USSR was aimed at stimulating more full-time researchers to take on teaching responsibilities at higher education establishments and several departments were established by individual research institutes at universities and ‘branch’ institutes but multiple flaws were still reported by the Soviet and western commentators. Several surveys showed that less than half of all university graduates had appropriate training to work at research institutes and R&D facilities where they were allocated in accordance with the former assignment system\(^\text{45}\) (Fortescue, 1990).

Similar developments were also taking place in China where the nation was overcoming the disaster of the Cultural Revolution in the 1980s and was rapidly rebuilding its universities and also attracting back many Chinese scholars who left to study abroad, the large group called returnee scientists. These education reforms in China were realized in a very similar context to the Soviet one. It was reported that in the first batch of post-1949 changes China had substantially emulated the Russian model, closed down 65 private universities and consolidated 227 Chinese universities into 181 universities, polytechnic institutes, medical schools, branch institutes, and others (Xue, 2006). Like in the USSR, the reorganized universities and institutes were subordinate to both the Ministry of Education and other ministries and government agencies depending on their specialization.

A major education reform was launched in 1985. The new policy was based on two major doctrines called 3Ds and 3Cs and was supposed to introduce drastic changes in the governance and functions of the Chinese university system.

3Ds stood for decentralization, depoliticization, and diversities. Many authorities were transferred from the central government to the provincial and municipal level to ensure better governance of the local universities. Academics also got more freedom in developing independent curricula that would not be following the political guidelines of the country’s leadership. Diversity meant significant changes in authorized range of education services including the freedom to establish private universities and schools (Xue, 2006).

\(^{45}\text{In the socialist system, the doctrine of zero unemployment meant that every citizen had the right for a job. In such system, every graduate was assigned to a particular organization based on their achievements, specialization and knowledge. As a rule, the best students were given priority of choice while the rest were usually allocated the remaining openings in other parts of the country. Personal connections could also play a role.}\)
3Cs included commercialization, competition, and cooperation. These meant more cooperation with industry and local governments, commercialization of education services in terms of charging tuition fees, and competition for students, funding, faculty members, donations, etc.

Following these massive changes, China was much quicker to realize that universities must play a significant role in both teaching and scientific research and probably appears to have been more effective in the implementation of the reform compared to other socialist economies. Research institutes were not the only producers of S&T output but had to compete with universities that were recognized as an integral part of the Chinese emerging innovation system (Xue, 2006).

Other policy instruments adopted by the socialist governments included prioritization of most important S&T projects and support of limited competition between a number of research institutes and design bureaux working on similar issues. For example, several organizations could be working to design the military aircraft of similar type and were experiencing quite a strong pressure to excel in producing the best possible project.

In general, the policy was quite fragmented and clearly differentiated between priority and secondary sectors. Hence, research and development was very unevenly distributed across various sectors of the national economy and led to the continuous leadership of the USSR in some spheres but very serious backwardness in others.

Military and space technology attracted most attention of the Soviet government. Inspired by the success of the Sputnik and first manned flight to space, these sectors were getting most resources, best personnel and most advanced equipment. Chemical industry, electronics and engineering industries enjoyed less support but were the primary sectors in civil production. The remaining sectors – primarily consumer goods – were largely considered as secondary and were often allocated the budget leftovers and worst available personnel distributed by the government through the assignment system.⁴⁶

As a result, Berliner (1976) pointed that the priority sectors were basically taken out of the national economy and existed in an isolated and greatly favorable environment that allowed them to enjoy time and resources that they needed to produce the best possible

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⁴⁶ See previous note on the assignment system in the socialist education system.
results while other sectors had to resolve the difficult social issues including ensuring zero unemployment and providing multiple social amenities to their workers regardless of the level and quality of production.

This situation led to an interesting paradox where knowledge spill-overs were limited not only by the inhibited information flow and secrecy barriers but also by the lack of interest to the latest technological achievements on the part of non-priority sectors. Campbell (1972, p. 607) supported that “whatever weaknesses there may be in the mechanism for identifying managerial innovations, and evaluating them as potentially worth transferring, or in taking measures to diffuse them, the most serious bottleneck in the diffusion process seems to be on the receiving end... because the incentive system is such that management has no real interest in improving aspects of its performance.”

There was also another important difference between priority and secondary sectors in the central planning economy: the former were primarily mission-oriented and were expected to achieve competitive results while the latter were left to themselves where their output was mostly measured in produced units rather than innovativeness and R&D achievements. One reason is that the military and space industries were exposed to serious international competition where any failures – if tested – would be measured by “unavoidably real criteria” (Nimitz, 1974, p. 43), whereas in civil sectors the only real criteria was the (dis)satisfaction of consumers, which was treated as a primarily political rather than economic matter in the communist ideology.

In China, prioritization of most important S&T projects also followed the mission-oriented approach. The policy was implemented in several phases based on official programs and plans for science and technology where particular objectives were set forth. So, the first Perspective Program of S&T Development was implemented from 1956 to 1967 and prescribed to strengthen China’s S&T system quickly based on its own national resources. The second program covered the period from 1963 to 1972 aimed to improve the living quality of the people through rapid growth of agriculture and industry. The third phase realized between 1978 and 1985 included the goals significantly improving the quality of S&T experts, acquiring advanced equipment, establishing a number of experimental bases, and achieving the goals of mechanization and electrification by the end of the 20th century. Other programs were
adopted after the collapse of the Soviet Union and are now at the seventh phase of policy planning.

Liu and White (2001) further supported that two major motivations guided China’s technology strategy in the early years of the communist rule: desire for national self-sufficiency in the conditions of diplomatic isolation and mission orientation. Beside the targeted programs mentioned above, China set other objectives that it successfully achieved in the 1960s including developing atomic and hydrogen bomb and launching satellites.

Sigurdson (2005, p. 38) concluded that “after years of experimentation China has been able to establish a relatively complete system of science and technology programmes, which include both mission-orientated programmes mainly for R&D activities, and government-guided programmes mainly for the commercialization of R&D results and the industrialization of high-technology products.” Some of these programs were started in the post-1978 era and will be discussed in more detail in chapter 7 since most of them continue to be implemented and play a major role in China’s transition to the effective innovation system.

It is noteworthy, though, that the military and space technology did not achieve as high status and advancement in China as it did in the USSR. Originally, the military industry got most assistance from the Soviet Union and a certain bias in policy must have existed, when a massive international technology transfer took place with over 11,000 Soviet specialists being on site in Chinese military facilities between 1950 and 1960. However, the harsh deterioration of Sino-Soviet relations after 1960 led to the disruption of virtually all S&T links and a serious lag of Chinese military and space technology over time. Only two areas were reported as keeping mostly up to date: nuclear technology and infantry weapons plus some achievements in satellite technology (Frieman, 1989).

Finally, “the socialist economy [found] it very difficult to dissolve unsuccessful enterprises” (Berliner, 1976, p. 531). Despite multiple efforts to boost productivity of lagging industries, many administrative barriers, bias towards military technology and resource constraints did not allow the socialist governments to construct a system where Schumpeterian (1934) ‘creative destruction’ would be effectively implemented by pushing out the unsuccessful enterprises and rewarding the most innovative ones. A major reason seems to reside in the ideological commitment of socialism to the ideals of a worker state where societal

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47 See page 19 for a definition of ‘creative destruction’.
well-being was primary and economic effectiveness was secondary. In such system, the government would be supporting demand for any enterprise regardless of its poor performance in an aspiration to sustain job security and not to let any social tension.

The general political environment contributed largely to the distinct style of socialist science, technology and industrial policy making. Rampant departmentalism was a widely observed phenomenon in an overly bureaucratized command economy where individual ministries and agencies enjoyed huge authority and decision power with regard to their subordinates and had to compete harshly for resources that were distributed from one ‘bag’ in Moscow according to the neatly constructed five-year plans. Likewise in China, several cases pointed at a number of “unresolved bureaucratic rivalries”, where “bureaucratic entities develop[ed] routines and vested interests built around technologies that bias[ed] later technological choices” (Suttmeier, 1989, p. 378). This constant struggle between ministries would also contribute to weak technology diffusion and inhibited information flows where knowledge was intimately guarded by the leaders of individual agencies and institutes as a tool in interdepartmental and interpersonal wars (Balzer, 1989). It seems that under such circumstances no consistent systemic innovation policy would have ever been possible.

4.5. System of intellectual property rights protection

In the communist ideology, knowledge was generally understood as a public good that should be freely exchanged and available to anyone who wanted to apply it in the production process or scientific experimentation. In practice, though, the government had put a number of administrative barriers that hindered scientific communication to much extent. In an underdeveloped patent system, technology could basically become ‘proprietary’ in two ways: first, the government would use strict secrecy norms on what it considered critical for national security; and second, the free flow of knowledge and ideas could be inhibited intentionally through creating administrative barriers in individual institutes and enterprises. For example, directors of research institutes could ‘protect’ the achievements of their colleagues to be able to present them personally at important political and administrative meetings and lobby more powers and funding in future. Suttmeier (1985, p. 53) called such academic and industrial leaders “monarchs” in a “small kingdom”.

In the Soviet Union, the original legal framework for intellectual property rights (IPR) protection was established in 1919 but reviewed by the decrees of 1924 and 1931. The latter
was in force with revisions until 1991 when a new law was introduced “On inventions in the USSR” that was further replaced by the Russian patent law in 1992. Throughout the period between 1931 and 1991, two official types of IPR existed: inventor certificates and patents. The former did not grant assignees with an exclusive right to use the invention but the inventor could get royalty fees from enterprises and other entities where his or her invention was applied. No duties were paid to the state by the assignee of the inventor certificate. Patents were given for the period of 15 years and granted the assignee with an exclusive right to apply the invention either individually or at a privately-run enterprise.48

Unlike the USSR, China did not have a developed patent system until mid-1980s. The original patent law was adopted in 1985 and was revised twice in 1992 and 2000 with a number of procedures established to enforce the abidance by the legal norms, which had become a result of both internal and external pressure to improve patent system. Since its enactment, the Chinese patent system aimed to be in line with the international standards and practices to allow for the country’s smooth integration into the world economy (Lin and Zhang, 2008).

In the meantime, despite these changes and desire to promote IPR protection, the number of utility patents granted to both Soviet Union and China by the U.S. Patent and Trademark Office (USPTO) remained miniscule compared to developed countries and increasing quite slowly compared to other emerging markets (see Table 8 for a comparison with the USA, Japan, the UK, and South Korea). The lag created by the principles of the state planning economy seems to be a serious obstacle on the way to a better IPR protection system.

Table 8. Number of utility patents granted by USPTO to Soviet Union, China (except Hong Kong), USA, Japan, the UK and South Korea, 1985-1991.

<table>
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<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USSR</td>
<td>147</td>
<td>116</td>
<td>121</td>
<td>96</td>
<td>161</td>
<td>174</td>
<td>178</td>
</tr>
<tr>
<td>China (except Hong Kong)</td>
<td>1</td>
<td>7</td>
<td>23</td>
<td>47</td>
<td>52</td>
<td>47</td>
<td>50</td>
</tr>
<tr>
<td>United States</td>
<td>39,556</td>
<td>38,126</td>
<td>43,156</td>
<td>40,498</td>
<td>50,184</td>
<td>47,391</td>
<td>51,177</td>
</tr>
<tr>
<td>Japan</td>
<td>12,746</td>
<td>13,209</td>
<td>16,557</td>
<td>16,158</td>
<td>20,169</td>
<td>19,525</td>
<td>21,025</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2,493</td>
<td>2,407</td>
<td>2,774</td>
<td>2,583</td>
<td>3,099</td>
<td>2,792</td>
<td>2,802</td>
</tr>
<tr>
<td>South Korea</td>
<td>41</td>
<td>46</td>
<td>84</td>
<td>96</td>
<td>159</td>
<td>225</td>
<td>405</td>
</tr>
</tbody>
</table>


48 These norms were set forth and summarized here based on Decree No. 3/256 of the USSR Central Executive Committee and Council of People’s Commissars from 9 April 1931; and Decree No. 584 of the USSR Council of Ministers from 21 August 1973.
4.6. Summary

This chapter has discussed the major characteristics of the state planning S&T system and its variations in the USSR and Russia in much detail. It seems obvious that many features of the system dominated the S&T and innovation development of both countries over long periods of time and were not eliminated immediately by the massive reform started in China in 1978. This analysis permits to conclude that both Russia and China embarked on their transition routes with a wide set of persistent state planning legacies that may be possibly traced in both countries until today. The next chapters address this assumption thoroughly and provide grounds for the study of the role of nanotechnology in the strategic transformation of the national innovation systems in the selected countries.
Chapter 5. Russia: innovation system and policies

In this chapter, I focus on the study of the innovation system transformation of Russia over the last twenty years following the collapse of the Soviet Union. I apply the same framework as used in the previous chapter to understand whether the main characteristics of the state planning S&T system persist and hinder (or help) effective national innovation development and foster the government’s effort to ensure rapid catch-up with the world economic leaders. The social and political factors are taken into account with respect to the wider understanding of development process, as discussed in section 2.3.

The second part of the chapter is devoted to the detailed policy analysis aiming to discuss the main instruments applied by the Russian government to overcome existing challenges and system path dependencies. In these sections, I also study the main deficiencies of the country’s innovation policy derived from inheritance and path dependencies as well as government failures. System-evolutionary approach permits to put this study in a dynamic perspective.

As a result of this analysis, I seek to understand the major problems faced by the Russian government in its development agenda to further compare them to the ones faced by China. This analysis aims to identify whether the two countries share a significant number of common problems due to the complementarity of their innovation systems allowing them to learn from each other and transfer particular policy practices.

5.1. The context

In the recent decades Russia has gone through a variety of events that had a massive impact on its political, social and economic foundations. After the collapse of the Soviet Union, the country experienced years of ‘shock therapy’ and ‘wild capitalism’ following a series of neoliberal reforms that put the nation on the verge of total destruction both politically and economically. Largely prescribed by monetarists and mainstream economists, these reforms proceeded largely from the assumption that the proper economic structure will automatically change the cultural and institutional frameworks. The reality was reverse: the society was not ready for such substantial changes; trust disappeared between its members; and effective market mechanisms were slow to emerge (Medvedev and Tomashov, 2012). Since mid-1990s,
the country had to change its development track reversing some of the earlier reforms and adopting more institutionalist approaches.

The Putin era starting in 1999 set forth the priority of restoring the international status of Russia, rebuilding its economy, and preventing further dissolution of the nation that began in the early 1990s. Modernization and innovation growth were explicitly put on the political agenda. A number of federal programs, large-scale projects and development institutions were established to ensure the diversification of Russia’s economy and its transition from resource-orientated to innovation-driven growth, as prescribed by the Concept for Long-Term Socioeconomic Development of Russia until 2020 (Concept-2020). The Concept defined that in ten years “Russia’s economy will not only retain its world leadership in the energy sector but also will achieve high level of knowledge-based and high-technology competitiveness... Russia may get hold of 5–10 per cent in the world hi-tech and intellectual property market in 5–7 and more segments.”

Yet, Russia has been repeatedly reported to have been unable to rebuild the former scientific and technological strength and oversee a successful system transformation that would imply better science-industry links, dynamic market, and vibrant networks of interactive learning and competence building (Radosevic, 2011). In the international arena, the notion of ‘broken BRICs‘ has been emerging to describe the failure of the four countries to catch up with the world leaders especially with respect to Russia and Brazil (Sharma, 2012).

Several studies noted that the reasons for these negative trends may be found in historical path dependencies and system lock-ins that must be traced back to the Soviet era or even earlier (Radosevic, 2003; Klochikhin, 2012a). As mentioned, many strengths and weaknesses of the state planning S&T system persevere in transition economies and explain their multiple failures on the way to effective innovation growth.

5.2. Innovation system

Contemporary Russia faces a difficult challenge of transforming the state planning S&T system into an effective innovation system. The market and the government have to work together to develop multiple links of interactive learning and competence building in the national economy and connect research, development and production into a network of innovative new enterprises, research institutes and enterprises. Yet, several problems continue
to prevail in Russia’s innovation environment and policy has been often reported unable to address them effectively.

5.2.1. **Social and political status of science and technology**

The substantial changes of the early 1990s put Russian science on the verge of a catastrophe. Universities and research institutes lost 31-35% of their personnel and up to 90% of government funding (Graham and Dezhina, 2008). The number of researchers per million has been continuously decreasing from 7,266 in 1991 to 2,912 in 2000 and further 2,602 in 2009 (Klochikhin, 2012b).

Yet, Graham (1998) and Radosevic (2003) testified that despite multiple challenges Russian science managed to survive in the difficult period of transition. Foreign foundations played significant role in saving the S&T sector from disaster supporting most capable researchers that had to be “on leave” from their primary employers receiving little or no salary in the 1990s (Graham, 1998). This foreign aid came in the most difficult times when Andrey Geim, now Nobel Prize laureate, condoled that many scientists had to seek employment elsewhere some even going to the marketplace as ordinary tradesmen (Geim, 1995). Others fled abroad in search of better opportunities; it was estimated that somewhere between 25,000 and 100,000 highly skilled scientists and engineers left Russia in the last two decades (Klochikhin, 2012a).

Amidst this hardship, the Russian scientific community had a real chance to reform dramatically its organization that held back many young scholars from realizing their ambition and achieving high status based on merit rather than loyalty and personal connections. The government was busy resolving other burning issues and the problem of political involvement was almost inexistent.

Nevertheless, Graham (1998) concluded that scientists dallied away instead of launching an effective reform of the Academy of Sciences. In the 1980s, the dissatisfaction with existing S&T organization was growing rapidly. Younger researchers were impatient with the system of perks and privileges that distributed unevenly among individual scientists and organizations. A mass protest was organized to support Andrey Sakharov, a genius physicist and human rights champion, when the Academy leadership decided to deprive him of the member status following his conflict with the political establishment.
Once the Soviet Academy of Sciences was disbanded in 1991, the Russian researchers had a unique opportunity to create a new organization where the problems of privilege and inequality could have been resolved. One route was to create an honorary club of best scientists like the UK Royal Society, or another to establish a not-for-profit organization like the US National Academies that could represent the scientific community effectively and lobby its interests in the political arena. But it failed: many of the junior scholars hoped once to be elected as corresponding or full members of the Academy themselves – hence, why should they destroy the system that can provide such beautiful returns when one passes through decades of silent discontent and humility (Graham, 1998).

As a result, corruption and nepotism continue to dominate in Russia’s S&T organization. Individual academicians, most of whom made their careers in the Soviet times, are using their status for gaining ‘personal access’ to the political leaders and impede any systemic reform by protecting their institutes from any necessary and sometimes painful change, as one interviewee would complain. Schiermeier (2008) nicely described how President Putin was pushing Mikhail Kovalchuk, a brother of his close associate and head of the Kurchatov Institute, to be elected as full member of the Russian Academy of Sciences.

These cases of corruption and nepotism have been aggravated by a more systemic process of ‘governmentalization’ of the Russian Academy of Sciences. In 2006, the Academy lost its semi-autonomous status and was turned into a full-fledged state institution where the government has tighter control of its assets and a louder voice in administrative and governance affairs (Graham and Dezhina, 2008).

In other aspects, Vaganov (2012) painted a gloomy picture of social attitudes to the Russian science today. The author reported that, according to an opinion poll, Russians put science only at 11th position out of 13 most prestigious professions.

The circulation of popular science magazines has also been in sharp decline since 1991. While in the 1980s the Soviet Union published a copy for every 20.4 people, in the 2000s the coverage dropped drastically to about 140.2 people per copy in contemporary Russia (Vaganov, 2012; see Table 9 for more details). Other countries have also seen certain decline in popular science but not as sharp as in Russia: the United States printed a copy for every 18.2 people in the 1980s and a copy for every 30.1 people in the 2000s.
Table 9. Circulation of top popular science magazines in Russia in the 2000s.

<table>
<thead>
<tr>
<th>Title</th>
<th>Circulation, millions</th>
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<tbody>
<tr>
<td>“Around the World” (Vokrug sveta)</td>
<td>0.25</td>
</tr>
<tr>
<td>“GEO”</td>
<td>0.22</td>
</tr>
<tr>
<td>“National Geographic – Russia”</td>
<td>0.2</td>
</tr>
<tr>
<td>“Popular mechanics” (Popularnaya mekhanika)</td>
<td>0.12</td>
</tr>
<tr>
<td>“Computerra”</td>
<td>0.064</td>
</tr>
<tr>
<td>“What’s New in Science and Technology” (Chto novogo v nauke i tekhnike)</td>
<td>0.061</td>
</tr>
<tr>
<td>“Technology to the Young” (Tekhnika – molodezhi)</td>
<td>0.05</td>
</tr>
<tr>
<td>“Science and Life” (Nauka i zhizn)</td>
<td>0.044</td>
</tr>
<tr>
<td>“The World of Science” (V mire nauki)</td>
<td>0.015</td>
</tr>
<tr>
<td>“Young Natural Scientist” (Yunyi naturalist)</td>
<td>0.014</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.038</strong></td>
</tr>
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</table>


5.2.2. Quality of science, technology and innovation and technology transfer

Continuity and stability are no longer the features of the Russian science and technology. The disastrous effects of the 1990s can still be seen in multiple research institutes and universities lacking both equipment and qualified personnel. Several accounts suggest that the Russian science is now in deep crisis and their little hope for improvement. So, economist Ruslan Grinberg lamented in 2007 that Russia had “only six or seven years until the Soviet science and technology potential has totally vanished” (Grinberg, 2007). Similarly, the recent report by a group of top-level scientists suggests that “the contemporary state of the Russian science, judged by a number of objective indicators, is catastrophic” (Russian Association for the Advancement of Science, 2012, p. 5).

Among others, these opinions are supported by the low publication output of the Russian science. The number of articles indexed by Thomson Reuters Web of Science has been stable in Russia over the last years (Figure 6). Onishchenko (2011) noticed that the Russian scientists working on the synchrotron of the Kurchatov Institute produce about 20 publications per year while their foreign colleagues working in similar facilities would be publishing 200-400 papers annually.

Besides, the S&T staff is rapidly aging: less than 20% of them are now 29 years old or younger. Most PhD students choose to leave academia after graduation in search of better salaries while less than a third of them actually fulfill the requirements for the degree of the
candidate of sciences (State Council of the Russian Federation, 2009). Others choose to leave the country. Graham and Dezhina (2008) described the ‘brain drain’ process in three successive stages: the first wave included scientists with big names who could easily find a position abroad and migrated in the early 1990s; mid-career researchers started leaving Russia in the late 1990s and early 2000s fed up with bureaucracy and lack of finance for their experiments and advancement (Andrey Geim and Konstantin Novoselov, 2010 Nobel Prize winners, would probably belong to this group); and now younger generation leaves Russia soon after university graduation to achieve advanced degrees in western schools. So, lack of middle-age personnel, ‘brain drain’, low salaries in academia and lack of middle-qualified technical specialists are among the key problems facing Russian science today (Klochikhin, 2012b).

Figure 6. Number of scientific publications by the Russian scientists, 1994-2011.

Education system, supposed to provide the ‘fresh blood’, remains quite poor in preparing qualified R&D personnel. World Economic Forum (2012) ranked the quality of Russia’s education system in the 86th place between Suriname, Ethiopia, and Italy. While the higher education sector has expanded dramatically after 1991 with multiple private universities opening doors to the high school graduates, the current situation has deserved much critique for the poor quality of training and uncontrolled commercialization of higher education. As a result, over a million of fresh university graduates are struggling to find employment every year and about 60 per cent end up doing jobs quite remote from their primary area of specialization (Smolyakova, 2012).
Private sector development has also been quite slow to contribute to rapid innovation growth. A number of factors hindered progress in the last decades. Firstly, mass privatization in early 1990s has been considered largely illegitimate when a narrow circle of oligarchs and corrupt bureaucrats captured property through allegedly fraudulent schemes (confirmed by President Putin in his electoral article for the Vedomosti daily – Putin, 2012). Secondly, corruption tainted any change in Russia in the last decades. Kommersant daily (2012) reported that the Russian budget has lost at least 57 bn roubles (US$ 1.9 bn) in the last years, based on the criminal cases now pursued by police. The average bribe has risen from 9,000 roubles (US$ 300) in 2008 to about 1,000,000 roubles (US$ 35,000) in 2012.

Low productivity has also been a rising concern. McKinsey (2009) estimated that the productivity of the Russian economy is only 26% compared to the United States (based on the comparison of five major sectors). The authors of the report also noted that 30% to 80% of the productivity of Russian enterprises is lost due to bad management systems. Expert and analytical systems get 10 times less investment in Russia than in the United States, and resource management systems receive 5 times less money. The problem is aggravated by the extreme wear of fixed assets that reached more than 50% with a rate of renovation at about 2% per year, which is twice as bad as in the developed countries (Glazyev, 2007). These challenges are further deepened by non-transparent regulation, underdevelopment of the financial system, and lack of skills of the personnel. Commitment to extensive growth and low competition are named among the most important reasons for low productivity (McKinsey, 2009).

In regulation, the general imperfections and the recent anti-liberal laws passed by the State Duma have been widely discussed (BBC, 2012; Klochikhin, 2013). According to the Center for Legal and Economic Studies, every 1 out of 6 entrepreneurs is in jail for economic crimes that are often a result of vague legislature and corruption schemes (TV Rain, 2012).

Finally, it seems difficult to transform the culture of the Russian society in several years when throughout the Soviet era any entrepreneurial behavior was harshly prosecuted and risk averse culture prevailed in virtually any sphere of social life.

In this context poor technology transfer and science-industry links remain a major challenge. The World Economic Forum (2012) classified the Russian economy in transition from efficiency-driven mode to innovation-driven, where competition is based on product and
process innovation rather than labor costs and networks are built around research and development. Nevertheless, the outcomes of this transition have been doubtful so far. According to a report by Russia’s Ministry of Economic Development (2010), the deficit of the Russian technological trade balance reached -$1,000.8 mln in 2009 dropping from about $20 mln net surplus in 2000. Moreover, Radosevic (2011) mentioned that Russia remains in the group of countries where R&D is performed mainly by business enterprises while most funding comes from government, which makes it difficult to construct a market-oriented and independent innovation system.

State corporations and development institutions were specifically created to resolve these tensions. However, multiple reports illustrate that they practically failed to improve the situation dramatically. Among others, Rusnano received 130 bn roubles (US$ 4.3 bn) five years ago but was able to spend only 10 bn roubles (US$ 0.33 bn) on nanotech projects with 5 bn roubles (US$ 0.165 bn) wasted on its own operational costs up to 2010 (Rosbalt News Agency, 2009). Given the lack of financial transparency and actual corruption in state corporations, former President Medvedev called these types of organization “generally vicious in current circumstances” and gave an order to audit their activities.

5.2.3. STI policy system

Many features of the Soviet science, technology and innovation policy system persevere in contemporary Russia. The problems of ‘personal access’, corruption and nepotism are not rare in news reports (cf. Schiermeier, 2008); instances of political involvement and bureaucratic intervention in the governance of scientific community are also regularly reported; and the government is rapidly regaining control over the Russian Academy of Sciences and other S&T organizations.

Meanwhile, some positive trends are noticeable. The gross R&D expenditure is consistently growing from 1.05 per cent of GDP in 2000 to 1.24 per cent of GDP in 2009 (although intramural R&D expenditure by enterprises has increased just marginally from 0.2 per cent of GDP to 0.24 per cent of GDP over the same period – see Table 10). The government is paying increasing attention to the subject of economic modernization and innovation-driven growth with the new strategies adopted recently to ensure long-term planning and development including Innovation Russia-2020. Multiple institutions and high-tech clusters have been established since mid-2000s including Russian Venture Corporation, Rusnano,
President Putin is chairing a special Council on Economic Modernization and Innovation Development.

Table 10. Main economic and R&D indicators of Russia, 2000-2009.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2005</th>
<th>2009</th>
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<tbody>
<tr>
<td>GDP (billion, constant 2000 US$)</td>
<td>259.71</td>
<td>349.85</td>
<td>397.95</td>
</tr>
<tr>
<td>GDP per capita (constant 2000 US$)</td>
<td>1,775</td>
<td>2,443</td>
<td>2,805</td>
</tr>
<tr>
<td>Capital import/export by the private sector (billion US$)</td>
<td>-24.8</td>
<td>-0.1*</td>
<td>-56.1</td>
</tr>
<tr>
<td>Gross R&amp;D expenditure (as % of GDP)</td>
<td>1.05</td>
<td>0.2</td>
<td>1.07</td>
</tr>
<tr>
<td>- Including private sector R&amp;D expenditure (as % of GDP)</td>
<td>0.2</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>High-technology exports (billion, current US$)</td>
<td>4.19</td>
<td>3.69</td>
<td>4.6</td>
</tr>
<tr>
<td>Export market share of R&amp;D intensive industries (%)</td>
<td>0.20</td>
<td>0.22</td>
<td>0.17**</td>
</tr>
<tr>
<td>Technological trade balance (million US$)</td>
<td>20</td>
<td>-1,000.8</td>
<td></td>
</tr>
<tr>
<td>Patent applications (residents)</td>
<td>23,377</td>
<td>23,644</td>
<td>25,598</td>
</tr>
<tr>
<td>Researchers in R&amp;D (per million people)</td>
<td>2,912</td>
<td>2,740</td>
<td>2,602</td>
</tr>
<tr>
<td>R&amp;D personnel (people)</td>
<td>887,729</td>
<td>813,207</td>
<td>742,433</td>
</tr>
<tr>
<td>- private sector</td>
<td>590,646</td>
<td>496,706</td>
<td>432,415</td>
</tr>
<tr>
<td>- public sector</td>
<td>255,850</td>
<td>272,718</td>
<td>260,360</td>
</tr>
<tr>
<td>- higher education (e.g. universities)</td>
<td>40,787</td>
<td>43,500</td>
<td>48,498</td>
</tr>
<tr>
<td>- non-profit sector</td>
<td>446</td>
<td>283</td>
<td>1,160</td>
</tr>
</tbody>
</table>

Source: Klochikhin (2012b).

* 2006 and 2007 were the only years with positive capital import/export balance with $41.4 and $81.7 bn coming (returning) into the country respectively.

** Data available for 2008.

The Russian policymakers also managed to revive a particular strength of the Soviet S&T system that is prioritization of the major mission-oriented projects. In the 2000s, the government has launched a series of federal targeted programs to support priority areas in nuclear energy, global navigation satellite system (GLONASS), nanotechnology, training of scientific and pedagogical personnel, etc. Nevertheless, the recent failures of the Russian space and military programs and large corruption scandals point at serious drawbacks of these initiatives. One reasons has been the plunge of competition in many priority areas including military research, e.g. in the missile design and construction, which has led to disastrous effects (Myasnikov, 2006).

49 See more at http://programs-gov.ru.
The scientific community is also quite negative in its assessment of the state of the Russian science today. Beside calling the situation to be “catastrophic”, the recent report by the Russian Association for the Advancement of Science (RAAS, 2012, p. 5-6) noted that “the overall S&T funding in contemporary Russia is significantly lower than in the USSR and in many other developed and developing countries. However, the major reason for these challenges is organizational. In particular, it is most pernicious that there is no sound national strategy of S&T development.”

The system reform has been difficult to pursue in an environment where individual academic and business leaders are always lobbying ‘special conditions’ for their respective institutes and enterprises. One interviewee in Russia suggested that the policymakers have eventually decided to break the monopoly of the Academy of Sciences to produce quality scientific output and are seeking to create a structure parallel to the Academy.

Universities are supposed to be a good alternative where research can be pursued by a large group of capable scholars. However, the weaknesses of the Soviet S&T system, where teaching and research were clearly separated, prevent Russia’s R&D from rapid transformation. To accelerate the process, the government has established nine federal and 29 national research universities with substantial finance allocated to buy new equipment and support S&T personnel. However, the indicators of success are mostly quantitative and may provoke a return to the ‘fraudulent behavior’ of the planning economy when the enterprises and research institutes often forged their indicators to satisfy the central authorities and conceal their shortfalls. Among others, the Ministry of Education and Science estimates the share of profit from R&D work in the total profit; share of students in the priority fields of research and education in the total number of students; share of S&T personnel between 30 and 49 years old, etc. (Russia’s Ministry of Education and Science, 2009).

Despite these reforms, various interviewees in Russia and abroad as well as my personal experience working at a Russian university would suggest that the teaching load remains quite high with virtually no possibility of large-scale research done in the higher education establishments. This situation has basically perpetuated the faults of the Soviet S&T system where poor training of researchers was one of the major weaknesses.

Several setbacks have been also evidenced in some key achievements of the transition period. Most scientists hailed the growth of the grant-based system where individuals could
apply based on merit rather than administrative status. Grants are distributed through the Russian Foundations for Basic Research and for the Humanities as well as through international foundations. However, in recent years the government has taken tighter control over these organizations and basically banned the activities of the foreign NGOs while budgets have been plummeting for individual-based grants (Graham and Dezhina, 2008). The peer-review system for the grant allocations has also been criticized on several occasions where funding would be usually given to some ‘insiders’ (Sinitsyna, 2012).

After a brief reduction of the military spending, the experts are worrying about the rising ‘military bias’ of the federal budget planning until 2020. The military bias in public policy has been quite vivid in the last two years. The 2012 budget increases the national security and law enforcement spending by 50% and the national defense by 20%. The government is set to spend around $700 bn for defense and weaponry in the current decade (Privalova and Kogan, 2011).

In general, the Russian STI policy remains quite non-transparent with poor mechanisms of policy evaluation and rising accountability issues. The policy design and implementation as well as feedback loops between the academic and policy communities are basically ineffective, with both scientists and policymakers mentioning various problems that they encounter in their activities. The former complain about their inability to influence policy decisions with only a few famous scholars sitting on special commissions and coordinating national projects; and the latter are inconvenient with the fact that some scientists get too much load in terms of publicly funded projects and focus on short-term results to build their careers, which reduces the overall effectiveness of S&T development (various interviews, 2012).

The policy evaluation process also needs significant improvement with the wider involvement of the expert community and independent agencies. In Russia, the Ministry of Education and Science is often the major designer, implementer and controller of the major STI policies (Dementyev 2009).

Besides, rampant departmentalism remains a persistent feature in the Russian political system. Despite the fact that the number of ministries and agencies has been significantly reduced in Russia as compared to the Soviet Union and the government structure has changed from the sectoral approach to more functional, the tradition of rampant departmentalism has had certain continuity in the country. For example, the Ministry of Economic Development and
the Ministry of Finance are the two struggling agencies that support contradictory positions based on their different competencies: while the former strives to diversify Russia’s economy and reduce the taxes the latter overlooks the budgetary system and is strict in reducing the tax burden (Kuvshinova and Tovkailo, 2012). This departmentalism is further aggravated by the lobbying activities of various agencies for budget allocations.

5.2.4. System of intellectual property rights protection

The contemporary patent system in Russia is largely based on the internationally recognized norms and standards. The 1992 patent law and Part IV of the Civil Code enacted in 2008 have laid the foundation for effective intellectual property rights protection and better interest in patenting. Russia’s accession to the World Trade Organization with its TRIPS (trade-related aspects of intellectual property rights) agreement in summer 2012 is also expected to have a positive effect in near future.

Nevertheless, several challenges have been mentioned despite these developments. The Russian residents applied for only 28,722 patents in 2010 as compared to 293,066 patents in China and 241,977 in the United States. The growth of the number of patents has been quite slow with almost the same 23,377 patent applications in 2000 (Figure 7). Moreover, government policies have been quite inconsistent with limited incentives for patenting: research institutes have to pay taxes for their granted patents right after they register them in their accounts (Medvedev, 2011). Several scandals have also dealt with improper copyright protection and royalty fees (Lenta.ru, 2012; Tomskaya, 2009).

Figure 7. Number of patent applications by Russian residents, 2000-2010.

5.3. Science, technology and innovation policies

After the USSR collapsed, Russia’s science, technology and innovation policy was balancing between preservation, restructuring and survival. So, the policy environment of the 1990s united the strategies aimed to preserve the Soviet S&T potential through a number of organizational and functional instruments; policies seeking to turn the former state planning system into a market-oriented R&D structure; and micro-strategies pursued by individual institutes and scientists to survive in the conditions of poor funding and plunging prestige of science and engineering in society (Radosevic, 2003).

Preservation strategies are pursued by the Russian government until now, although much less intensely. Some academic leaders continue to sympathize with the Soviet S&T model where science played a special role and was allocated with massive resources, as vividly exemplified by the RAAS recent report (2012). The major reason for such persistence of preservation strategies in contemporary Russia probably deals with the relative failure to transform the former S&T structure into an effective national innovation system, and thus they are continuously pursued by some groups of the national elite. Radosevic (2003) provided some particular measures taken by the Russian government soon after 1991; these include the 1992 presidential decree “On Emergency Measures for Preservation and Development of the S&T Potential of the Russian Federation”, 1994 State Duma resolution “On the Crisis Situation in the Russian Science”, 1995 government decree “On Governmental Support for the Development of Science and Technology”, 1996 presidential decree “On the Measures for the Development of Basic Research in the Russian Federation and the Status of the Academy of Sciences”, and others.

Restructuring has proven to be the most difficult task for the Russian policymakers in the conditions of lack of funding, institutional and cultural rigidity, and lack of public administration experience in the market economy. Perhaps, the major modernization effort has started only in the 2000s, especially after 2003 Annual Address to the Federal Assembly of the Russian Federation, when President Putin was talking primarily about military R&D. The economic situation became particularly favorable after the Iraq War when oil prices skyrocketed and presented a great opportunity for Russia to carry out a major reform. Among others, the government developed a number of long-term concepts of socioeconomic and S&T development, published a List of Critical Technologies to prioritize the national effort, and
adopted a Strategy for Innovation and Science Development until 2015. Nevertheless, the Ministry of Economic Development concluded in 2010 that “despite serious efforts to support innovative activity, the government did not succeed in breaking existing negative trends of development” (p. 14).

Survival is the third strategy that has been pursued at the micro-level by individual scientists and institutes in the conditions of serious lack of resources, equipment, and low demand for research and development in industry. This strategy has almost died out completely by now because the government pays increasing attention to the R&D sector but it has given important experience to the scientific community that today has the competences of pursuing scientific research in a highly unfavorable environment. Meanwhile, the data available for the 1990s is quite gloomy. Only 50% of researchers employed in R&D were reported to do actual research rather than gaining their income from other activities (Tichonova, 1998). The average share of non-R&D activities in research institutes increased from 8.5% to 20.9% between 1989 and 1996 (Dynkin et al., 1999).

In general, all three strategies of preservation, restructuring and survival have been influenced throughout the entire transition period until now. Graham and Dezhina (2008) divide this transition era into three main stages.

The primary goal of the first period (1991–1996) was to ensure the survival of the Russian science in crisis and initiate a number of structural reforms that would make the country’s S&T system more efficient. The government provided selective support to the high priority projects and laid the foundation for the individual-oriented science structure in a hope to create a competitive and transparent environment that would allow the country to join successfully the world scientific community.

In the meantime, there was some debate in the literature of this period about what sectors had most chances to survive the hardship of the 1990s. Kontorovich (1994) predicted that the Russian Academy of Sciences and the military sector were found in most favorable conditions since they received the bulk of resources in the Soviet Union and could have more time to adapt to the new conditions. At the same time he continued that these sectors were also most likely to shrink under the new system. The destiny of these sectors is still unclear today although it is notable that the Russian policymakers are trying to create a structure
parallel to the Academy of Science, as mentioned above, while military R&D is getting additional support now. Therefore, Kontorovich’s prediction must have come true only partly.

One of the biggest achievements of the Russian STI policy in the first stage of reforms was the establishment of new mechanisms in government funding. The Russian Foundations for Basic Research and the Humanities have been warmly welcomed by the scientific community: these organizations provide individual-based grants and introduced a previously inexistent transparent peer review procedure. However, recently there were concerns regarding the regional distribution of grants with many ‘provincial’ scientists claiming that the lion share of money was given out to the ‘cliques’ of elitist science centers in Moscow and Saint Petersburg while they were left with much fewer opportunities (Graham and Dezhina, 2008). Furthermore, the young scientists urged to increase the amount of money allocated to the Foundations by the government claiming that the share of RFBR was reduced from 6% before the 2008 crisis to 3.8% in 2009 (Chernyh and Gruzdeva, 2011).

The second round of reforms (1997–2001) was tainted with frequent change of leadership due to the political and financial turmoil. However, during this period the government succeeded in providing tax privileges to the research institutes and allowed them to lease their property for more profit. It also started to build the elements of the nascent innovation system: the Innovation Technology Centers and a Russian Venture Innovation Fund were established, and modest support was provided for small innovative enterprises and venture investing.

The third stage of reforms (2002–present) aimed at preserving the S&T potential of the country and providing an adequate regulation for the results of innovation activity. This period witnessed adoption of a set of long-term development documents and a range of legislation including the new Patent Law, Part IV of the Civil Code on intellectual property, and others.

5.3.1. Recent developments

Policies adopted in the last four-five years would probably signify the beginning of the fourth period of the innovation system transformation. In this period the national elite seems to have found particular consensus about the implications of heavy reliance on oil and gas as the major source of national income. President Medvedev has become the symbol of change and economic diversification. The Concept of Long-Term Socioeconomic Development until
2020 was finally approved by the government in November 2008 and offered guidance on modernizing the national economy and promoting innovation.

A number of policy instruments were adopted to support the system transition. At the commercialization stage of innovative activity, the government has also created a set of organizations that support small and medium-size enterprises as well as university spin-offs. Technology parks, Innovation Technology Centers, Special Economic Zones, Technology Transfer Offices, and the Russian Venture Corporation were established to provide a favorable environment for the risky innovation ventures that can grow into big corporations in future. At the same time a number of experts have expressed concerns about how the policy is actually implemented: many technology parks are underpopulated, funding schemes are non-transparent, legislation is underdeveloped and unclear (e.g. there is no clear norm on how and when the cluster residents will have to leave the favorable incubator environment and go out to the world of tough competition).

A set of federal targeted programs were also initiated to support R&D in priority areas. Aimed to support a variety of social and economic areas, these programs seek to stimulate academia and promote technical, engineering and social science research in key sectors. OECD (2011, p.204) names nine such R&D-related programs that are/were supposed to allocate about 1.437 bn roubles (US$ 47.9 bn) before 2010–2015 (dependent on the program). At the same time several flaws of these initiatives were also mentioned. Among others, individual researchers have to fill in piles of different forms and shape their studies so that bureaucrats can understand them and admit it was worth federal money regardless any scientific significance (Yakutenko, 2011; Borisova, 2011).

In higher education, eight federal and 29 national research universities were established to resolve the problem of separation of teaching and research. The government has already allocated about 24 bn roubles (US$ 0.8 bn) for the development of federal and national research universities since 2007. In spring 2010, the Minister of Education and Science Fursenko also noted that the government will spend a total of 90 bn roubles (US$ 3 bn) in the next three years to support Russia’s leading universities (Agranovich, 2010).

In recent years, Russian universities have gained a particular advantage over the Russian Academy of Sciences in terms of research and innovation. According to recent studies, university productivity is 62% higher than in RAS: 5.73 publications against 3.52 publications for
every 10 mln roubles (US$ 3.3 mln) of internal R&D costs. Universities have a bigger talent pool because they employ younger researchers: 39% of researchers are less than 40 years old compared to 26% in the Academy of Sciences, and 17% of them are older than 60 compared to 31% in the RAS (Guriev et al., 2009).

In 2009, Russia also approved Federal Law 217-FZ, an analogue of the US Bayh-Dole Act, which officially allows universities to open new innovation companies and support spin-offs. This initiative is supposed to increase the role of academic institutions in the innovation processes and close the existing gap between business and academia.

The Skolkovo initiative has become an iconic image of Russia’s innovation revival. It was initiated by President Medvedev as the Russian Silicon Valley – “a mighty center for research and development that would promote innovation in all priority areas.” Several multinational corporations have already agreed to open their R&D centers in the cluster where small and medium-sized enterprises can enjoy a good learning environment. The MIT Sloan School of Management supports the Moscow School of Management SKOLKOVO and develops a series of joint programs that are believed to provide the world-level training to the future Russian entrepreneurs and innovators as well as students from other emerging economies. SklTech — another joint project with the Massachusetts Institute of Technology to build a world-class graduate school with western standards — is developing and will likely be ready to welcome its first students in fall 2014.

Yet, several challenges remain. The scientific and innovation community keeps skeptical about the project. Although many scientists hailed it at the start, others disregarded it right away as the one “without prospects”. Among others, the Nobel Prize laureate Andrey Geim, who now resides in the UK, jocosely noted that he doesn’t think that the ‘Silicon Skolkovo’ would ever be a reality. “For me it sounds as if in the 1990s Russia would be building an electrovacuum Skolkovo when the entire world had already shifted from vacuum tubes to transistors”, he said to the Russian News Agency.

Companies have also been quite cautious to move into the cluster. But now, that they are allowed to become Skolkovo residents without relocating their major production and R&D facilities into the technopark, they are more eager to cooperate – probably to use the benefits of tax breaks and government support.
5.3.2. Inheritance and path dependencies

Continuity is not particularly peculiar to the Soviet/Russian public policy given the serious disruption of the early 1990s. Remaining Soviet bureaucracy would have been a major source of inheritance and policy path dependencies, but the ‘cadre ebb and flow’ during Yeltsin era led to a significant renewal of all elite groups at the federal, regional and municipal levels (Kryshtanovkaya, 2005). Hence, there seems to be no ‘personal’ connection of the current leadership to the Soviet past nor there are any constraints on the choice of policy instruments to test in the area of science, technology and innovation policy.

In contrast, the scientific elite have been changing at a much slower pace. Yuri Osipov, President of the Russian Academy of Sciences, has held his position since 1991 together with a large number of other academic leaders including Rector of the Lomonosov University Anton Sadovnichiy, Rector of the elite MGIMO-University Anatoly Torkunov as well as a number of other rectors in Moscow, St. Petersburg, and at regional universities.

This divergence of personal backgrounds and experiences (as well as ages) of the political and scientific elites have led to a paradox situation when politicians are uneager to return to the effective policy solutions adopted in the Soviet Union (or learn from history in Rose’s (2005) terms) while some academic leaders refer to the successes of the previous system and often impose the linear view of the innovation process to justify the special status of science in national economy. So, the recent report by the Russian Association for the Advancement of Science comprising many well-known scientists lamented that “in the Soviet times multiple ministries, the Academy of Sciences and branch institutes were working together to develop a complex program of S&T development. Such program would be also quite useful today. However, the current political elite – primarily consisting of managers, civil servants, lawyers and economists – should have to pay more attention to technology policy and let a number of technocrats in the policymaking process” (RAAS, 2012, p. 75).

This ongoing struggle between scientists and bureaucracy is aggravated by a growing number of editorials and journal articles comparing the situation in contemporary Russia with the Soviet crisis of late 1980s both politically and economically (Klochikhin, 2012d; Petrov, 2011). Moreover, it has been argued that history may not only limit the current choices but also provide opportunities for learning across time (Klochikhin, 2012e). This sentiment may be a sign
of an overall aspiration to return Russia to a more gradual China-type transition trajectory taking off from an arguably more effective Soviet S&T system (especially in times of hardship).

So, in the current situation, it seems that other factors beside inheritance play bigger role in policy planning and implementation but a growing struggle between various approaches might prod Russia to think historically and restore some former strengths to start off again.

In political terms, such change may prove to be quite difficult to implement in contemporary Russia. As Pierson (2004) would suggest, systems with fewer veto points, like the one in Russia today, are more likely to re-evaluate existing commitments while may be uneager to push new agendas. Since the current elite have been formed in an environment quite remotely connected to the Soviet context, their agendas may be very rigid to any drastic change, especially in a highly unstable political environment where mass protests seem to be on the rise and society questions the legitimacy of incumbent leaders. Similarly, the federal constitution implies difficult negotiations with regional elites before carrying out serious reforms (Kleiman and Teles, 2006).

5.3.3. System-evolutionary analysis

Various rationales and approaches can be found in Russia’s science, technology and innovation policies today. So, the first-generation perspective is still widely pursued by the scientific community and some interest groups including in the military (RAAS, 2012; Sinitsyna, 2012). In their view, the linear model is associated with the impressive achievements of the Soviet S&T system and hence should be restored in contemporary Russia if the nation wants to see similar successes. This vision is primarily supported by the groups and organizations that were particularly favored in the USSR, i.e. the Russian Academy of Sciences and military and space technology. However, this sentiment may be dangerous since Berliner (1976) noted that these priority areas achieved particular success not because but despite the state planning S&T system because they were basically taken out of the difficulties and challenges in national economy and could enjoy best manpower and massive funding. Therefore, any setback to this former model would mean a serious imbalance of the Russian economy that seems inappropriate in modern times.

In the meantime, the majority of the political elite seems to be somewhere in transition from second- to third-generation policy thinking. Several official reports and influential
organizations are promoting systems thinking in Russia (Gokhberg, 2003; Gokhberg and Kuznetsova, 2011; Gokhberg and Roud, 2012; OECD, 2011). At the same time Graham and Dezhina (2008) noted that the system-of-innovation approach is still quite formally applied in Russia where most policymakers and researchers see it as a formal set of institutions and public measures that are supposed to push forward innovative development.

These differences in views of various groups in the Russian elite lead to a choice of a rather medley set of STI policies that are adopted from history as well as from a wide variety of other nations including European states, United States, China, and some others. As a result, the policy instruments have quite diverse ideological and theoretical backgrounds ranging from neoliberal measures to provide more freedom to market and promote private sector growth to paternalist strategies of establishing state corporations and imposing tighter control on businesses. Moreover, new programs and initiatives are introduced almost every year, which may be a sign of increasing political competition between various interest groups and limited understanding and experience of what instruments could best serve the objective of rapid innovation system transformation.

This lack of political consensus may be harmful to various attempts to adopt systemic instruments and ensure smooth transition to a market-oriented dynamic innovation system. A sign of this situation is the slow pace of approval of long-term strategies and adoption of various decisions that have not been coordinated with the expert community. For example, the Concept for Long-Term Socioeconomic Development until 2020 was drafted in 2003 but approved by the government only in November 2008. Similarly, the Ministry of Economic Development (2010) stated that only about 40% of objectives set by the Strategy for Innovation and Science Development until 2015 were met in the first period of its implementation. In other aspects, one expert noted that five priority areas of economic modernization announced by President Medvedev in 2009 were never discussed in a wider expert community. As a result, Russia has three different sets of S&T and innovation development today, which may lead to a particular confusion in policymaking.

So, ‘strategic policies’ are rather low-profile in Russia’s STI agenda with more operational instruments adopted to decrease social tension by re-distributing the income gained through natural resource exports. As one policymaker would suggest, science and technology are considered as a critical social policy issue rather than an important economic
area since the Russian Academy of Sciences, universities and enterprises employ millions of people who had very limited funding in the 1990s and should now enjoy better living conditions despite their output to keep things the way they are going.\(^{50}\)

Yet, some initiatives can still be understood as those addressing the four functions of ‘strategic policies’: “reshaping of innovation systems, building platforms for learning and experimenting, stimulating demand articulation and vision development, and providing a tailor-made strategic intelligence infrastructure” (Smits et al., 2010b, p. 442). Among others, these include the Skolkovo project that is supposed to provide a good platform for learning and experimenting and is devised as a ‘locomotive for the entire Russian knowledge-based economy.’ Technology Foresight is also becoming a widely disseminated tool of strategic intelligence in contemporary Russia with several groups applying it in their activities, e.g. Higher School of Economics and Agency of Strategic Initiatives (cf. Sokolov and Chulok, 2012).

The topic of stimulating demand articulation also takes much part of the political agenda. At this point the solution is found in the support of supply-side of innovation, i.e. risky innovative enterprises and venture capitalists who “will not invest money in the projects that are not expected to have a reasonable rate of return on investment”. That said, the government prefers to support a ‘technology push’ strategy at this point of technological development with the further involvement of broader public in the innovation process (Press Office of the Russian President, 2011).

5.3.4. Government failures

Where state plays such significant role in economy and society, like in Russia, government failures are a common problem that often hinders quick recovery and growth. Of all reasons, Russia seems to be suffering most from inadequate penetrative capacity, institutional overhead, inadequate voluntary cooperation and weak administrative culture, most of which are the result of radical reforms of the 1990s when the society has lost much of its political culture and governance, and public agencies were quickly restructured to respond to the needs of economic and political transition while bureaucracy has not been replaced (or retrained) correspondingly.

\(^{50}\) President Putin also indirectly confirmed this point in his 2012 Annual Address to the Federal Assembly saying that “medical doctors, teachers, lecturers, researchers, [and] cultural workers” must get more financial support now after the earlier hardships when “the state underpaid these specialists.”
In today’s Russia there is a limited set of feedback loops that would ensure adequate policy formulation and evaluation. The electoral system has undergone serious changes in the recent years when most elections at the regional and municipal levels were cancelled and most regional governors and mayors were appointed from above. The majority system was introduced at the parliamentary elections where the pro-Kremlin party “United Russia” could enjoy special status and pass only necessary laws. In those few instances where democratic procedures were still preserved, elections were often reported as massively rigged. In December 2011, the mass falsifications were among the major causes of political protests that were organized across entire Russia. As a reaction to this unrest, the leaders started a slow return to democratic elections in some spheres, although these attempts were widely recognized as fictitious.

So, in the current political system, there is a serious lack of information channels to inform the policymakers about the major challenges facing Russia’s economy and society as well as allowing them to change the design and implementation mechanisms accordingly. Moreover, the reliability of national statistics has been questioned on several occasions including the 2010 National Census when many people reported to have never been asked to provide any data regarding their social or ethnical status, especially in big cities like Moscow (temporary internal migration may also have been a difficult datum to capture since many people in central Russia are used to going to work in Moscow from quite remote regions and return home only at week-ends).

Inadequate voluntary sharing of information is also a big problem since many people lost trust in local authorities due to corruption and turbulence of the 1990s when some high-level politicians and bureaucrats were allegedly linked with the criminal gangs hijacking the property through the unfair privatization process (as also confirmed by President Putin on several occasions). Following Soviet cultural inertia, some enterprises would also prefer to conceal particular losses and deficiencies from the central authorities not to ‘upset’ their federal bosses and ensure continuous support of the government. Institutional overhead seems to be a natural consequence of such behavior.

Weak links between state bureaucracy and society do not only have political effects (such as the mass protests in 2011-2012) but also limit the penetrative capacity of the government. Civil servants do not only have limited access to information about the real state
of affairs but also seem to lack proper educational background since MPA (Master of Public Administration) programs continue to be a rarity in contemporary Russia. In the situation when about 60 per cent of university graduates work in sectors quite remote from their primary area of specialization, it would be reasonable to assume that these negative trends also have significant impact on public sector. Weak administrative culture is a factor that is also tightly linked to these circumstances.

All these issues seriously reduce the effectiveness of policy interventions or even slow down the system transformation. So, improved governance must be one of the major priorities of Russia’s national development strategy today.

5.4. Summary

This chapter analyzed the main characteristics of the contemporary innovation system of Russia from the point of view of remaining path dependencies and system features that can be traced back to the state planning past. Innovation policies are discussed from the point of view of their contribution to the strategic transformation of the national innovation system and effective resolution of remaining weaknesses or support of particular strengths coming from the former state planning S&T system. Some problems including policy path dependencies and government failures have been mentioned as important challenges hindering rapid progress.

Despite the visible stabilization of the Russian economy and political environment in the 2000s, the country continues to face immense difficulties in transition to an effective innovation model. Multiple institutional and organizational problems remain on the agenda and prevent the nation from undergoing a serious system transformation. Many of these issues have their roots in the Soviet S&T system where science, R&D and production were clearly separated and mediated by the government. Corruption and nepotism, fragmentation of science, administrative centralization, weak technology diffusion and poor technology transfer are some negative features that prevail in contemporary Russia.

Political leadership have set course on reforming the S&T sector and providing more opportunities for innovative enterprises to attract investment and pursue difficult R&D tasks. However, results have been quite modest so far: only 0.17% of the Russian exports were produced by R&D intensive industries in 2008 (Fu et al., 2011). Private sector has also been growing quite slowly with every sixth entrepreneur put to jail for their economic activity. ‘Brain
drain’ and poor quality of education system are also contributing into the serious lack of qualified manpower.

Importantly, policymakers have been quite free to choose the ways of reform and establish new programs after modern Russia openly detached from its Soviet past in the 1990s. However, limited attention to science and technology has been one of the major reasons of ongoing challenges in system transformation. As President Putin lamented in his 2012 Annual Address to the Federal Assembly, “for long years the state underpaid [medical doctors, teachers, lecturers, researchers, [and] cultural workers] because it didn’t have an opportunity to do so since we had to resolve other serious, burning issues such as increase of pensions because the elderly were even in a worse condition, often below the poverty line.”

As a result, Russia’s STI policies present a medley set of various instruments that come from first-, second- and third-generation approaches. System failure rationale is gaining more weight but is still understood quite formally with limited number of systemic instruments implemented in Russia today. Several other reasons including inadequate penetrative capacity, institutional overhead, inadequate voluntary cooperation and weak administrative culture aggravate the policy shortcomings and lead to tangible government failures. Besides, bad policy governance prevents the incumbent leadership from adopting a number of long-term strategies and effectively realizing them over time.
Chapter 6. Nanotechnology in Russia

This chapter pays particular attention to nanotechnology development of the Russian Federation. This subject relates directly to the fourth research question that seeks to understand whether this novel technology can help transition economies to resolve existing problems and eliminate system path dependencies dating back to the socialist times. Here, I seek to evaluate the transformative capacity of nanotechnology as is observed in Russia and also see whether this new technological field has significant effects in the six key areas as identified by the theoretical discussion presented in sections 2.3 and 2.4.

6.1. The context

Nanotechnology has been considered one of the priority areas in Russia’s STI policies since mid-2000s. According to a brief content analysis, the area has been mentioned 113 times in presidential speeches and public remarks in the period from 1 January 2000 to 30 November 2010. The first usage of the word ‘nanotechnology’ by the Russian President was registered in 2003 in the context of international cooperation (see Figure 8). Given the fact that the United States President launched the National Nanotechnology Initiative in 2000, this may be a sign of Russia’s late start and relative backwardness in the nano field.

Figure 8. Role of nanotechnology in innovation discourse in Russia (by total amount of references in presidential speeches and public remarks).

Source: own calculations based on data from the official website of the Russian President www.kremlin.ru.
For a long time nanotechnology was seen as a separate industry in Russia capable of developing its own manufacturing facilities and products. Only in 2008 it was first used as a useful application for the spheres of medicine and military arms development. So, the Russian leaders seem not to have clear understanding of what nanotechnology is and how to properly support it, which is further proven by policy analysis. This is vividly exemplified by erratic usage of the word almost entirely independent of the context like any 'buzz-word'. Figure 9 presents an overview of major contexts where nano applications were mentioned in presidential speeches and public remarks.

The peak of nanotechnology discourse in the overall economic and industrial development context was reached in 2007 when the state corporation Rosnanotekh (now Rusnano) was founded to support the country’s nanotechnology industry. After that the number of references in the general economic context has been degrading with increasing attention paid to the issues of international cooperation.

The recent fall in the number of references to nanotechnology points that the interest to the area is diminishing with many policy shortcomings evidenced during the last two years. This may be an indicator that nanotechnology has become an unpopular and unpleasant topic in contemporary Russia. Among others, it was not included in the five priority areas of economic modernization identified by President Medvedev in 2009 (see p. 120).

Figure 9. Role of nanotechnology in innovation discourse in Russia (by subject area).

Source: own calculations based on data from the official website of the Russian President [www.kremlin.ru](http://www.kremlin.ru).
Overall, the role of nanotechnology in the innovation discourse in Russia remains insignificant with only about 5.7% of all presidential speeches and remarks in 2000-2010 referring to this area. The possible conclusions may be that either the Russian leadership does not clearly see the advantages of the field or it focuses on other technology areas to achieve its strategic goals (e.g. information and communication technologies or biotechnologies).

6.2. Nanotechnology policy

The nanotechnology policy making process in Russia took about four years before it was established as an official government strategy in the form of federal programs and new institutional mechanisms. The first reaction to the U.S. National Nanotechnology Initiative launched in 2000 was inclusion of the nanotechnology-related research and development into the List of Critical Technologies of the Russian Federation (President of the Russian Federation, 2002). According to the content analysis of presidential speeches presented above, 2003 was the first year when the country’s leader used the very term ‘nanotechnology’ in public relating to the broadening economic cooperation with France. Later on, in 2006 all the relevant technologies were included in the special section of the List of Critical Technologies under the title “Nanotechnology and nanomaterials” (President of the Russian Federation, 2006). In 2004, the Russian government adopted the Concept of Nanotechnology Development until 2010.

In 2006, a special Program on Coordination of Nanotechnology and Nanomaterials Development was developed and adopted. The Program distributed responsibility for nanotechnology development among a group of key government agencies. The Russian Ministry of Education and Science was put in charge of leading, coordinating and implementing the program. The Russian Science Center ‘Kurchatov Institute of Nuclear Physics’ became the head scientific coordinator of the program.

Nevertheless, the real work on nano development began only in April 2007 when President Putin signed an initiative on the Strategy for Nanoindustry Development. The document ordained the government to develop a federal program to support nanoscience and nanotechnology development. It also envisaged establishment of the new state corporation to facilitate the commercialization of nano applications. As a result, in 2007 and 2008 the Russian government adopted the Federal Program “Development of Nanoindustry Infrastructure for the period of 2008-2010” (later prolonged until 2011) and the Program of Nanoindustry Development until 2015. In July 2007, the new state corporation Rosnanotekh (now Rusnano)
was finally established to support “the expansion of companies at the commercialization or close to commercialization phase” (Kiselev, 2010). According to its founding documents, the corporation was able to invest only up to 50% of the project and was meant to become an efficient mechanism of public-private partnership in the field of nanoscience and nanotechnology.

Lately, the Rusnano corporation has been transformed into a joint stock company and now includes a main business company and the Foundation for Infrastructure and Education Programs, which is a not-for-profit organization whose primary objective is to increase public awareness of nanotechnology and support research and education initiatives (Federal Law 211-FZ from 27 July 2010; Government of the Russian Federation, 2011).

In April 2010, the Russian Prime Minister Putin signed the resolution to create the National Nanotechnology Network (Government of the Russian Federation, 2010a). This decision is aimed at constructing a viable infrastructure and network connections among its participants in Russia.

The main public platform to discuss the achievements and problems of Russia’s nanotechnology development was launched in 2008 in the form of an annual Nanotechnology International Forum. The Third Forum took place on 1-3 November 2010, and was traditionally addressed by the President of the Russian Federation Dmitry Medvedev. In his concluding speech, Rusnano President Anatoly Chubais told about success stories and future plans of the corporation and overall nanoindustry development in Russia. Basically, the country is now focused on four main sectors of nanotech development: green, alternative and renewable energy; pharmaceuticals; biotechnology; new materials and technologies (Kiselev, 2010).

In his speech on 3 November 2010, Chubais also talked in more detail about these four sectors concentrating on successes in energy efficiency, nanoelectronics, solar energy, nanocoating, nanomedicine, laser-construction and carbon nanotubes. In these fields, he argued, Russia is undergoing a transition from laboratory research to industrial production.

Strikingly, Chubais was mostly talking about cooperation with foreign companies rather than domestic corporations like PG Photonics or Plastic Logic. The only big project that involves the Russian companies Sitronics and X5 Retail Group is aimed at producing RFID cards for retailing purposes, which does not seem a real innovation in terms of global nanotechnology.
development. Chubais promised to establish production of such chips at the scale of 90 nm only by 2012, when Russia will be already lagging behind given that most advanced countries are already manufacturing products at 32 and 65 nm (Chubais, 2010).

Thus, despite these bright speeches and optimistic prognosis there are some vivid shortcomings of Russia's nanotechnology development that have surfaced recently and have great impact on its future advancement.

To begin with, Russia was considered a country with the second-largest investment in the nano field when it decided to put about 130 bn roubles (US$ 4.3 bn) into the newly-established Rosnanotekh corporation. Nevertheless, in two years of its existence the company succeeded to spend only 10 bn roubles (US$ 0.33 bn) on nanotechnology projects of which 5 bn roubles (US$ 0.165 bn) were wasted on its operational costs (Rosbalt News Agency, 2009). As a result, today the Russian government aims to increase efficiency of Rusnano by reforming it into a joint stock company with a separate non-profit Foundation for infrastructure projects.

Another setback could be traced in the reshaping of the Government Council for Nanotechnology, which was created in 2007 to oversee the federal programs, planning and policy implementation in the nano field. In September 2008, because of the difficulties in defining the term 'nanotechnology', the Russian Prime Minister renamed the Council into the Commission for High Technology and Innovation returning nanotechnology onto the general innovation development agenda and depriving the field of its former privileged status (Kommersant, 2010).

6.3. Impacts

So far, there have been few evaluations of nanotechnology development in Russia (cf. Terekhov, 2012; Klochikhin, 2011a; Westerlund, 2011). Together with Rusnano, the Institute for Statistical Studies and Economics of Knowledge at the Higher School of Economics has developed a wide set of indicators to capture the dynamics of nano development in Russia. These indicators reflect the institutional structure of nano R&D; major inputs and outputs; commercialization; technology transfer, etc. (Gokhberg et al., 2011).

According to the latest statistical book *Indicators of Science 2012* (HSE, 2012), 13.7 per cent of all Russian R&D organizations employing about 18,000 researchers are involved in nano
scale research and development and 4.1 per cent of gross R&D expenditure is allocated to the
tasks related to the area.

Terekhov (2012) noted that Russia occupied tenth position in the world among the top
producing countries in 2010 falling from sixth place registered in 1990 for the USSR. The
number of nano publications having Russian address in Thomson Reuters Web of Science (SCI-
Expanded) has been growing rather slowly since 1996: 1,031 of Russian nano articles were
registered in 1996 compared to 3,229 in 2011 with an average growth of about 8 per cent per
year. Interestingly, the massive effort to support nano scale research and development realized
by the Russian government since mid-2000s has had marginal effect on the growth of the
Russian publication output with an average annual growth of about 7 per cent in 2007-2011.

In the meantime, it has been widely recognized that it is quite difficult to calculate direct
effects of nanotechnology on economic growth and social development (Sargent, 2008).
Therefore, this study presents an analysis of six key areas where impacts of nanotechnology
may be assessed in broader terms.

6.3.1. Institutional development, knowledge flows, and network efficiency

Since the presidential initiative on nanoindustry development was launched in 2007,
Russia has created several institutions that do not only contribute to the national nanotech
growth but also have some positive effects on the overall innovation transition and emergence
of new knowledge networks. These institutions include:

1) Federal targeted programs “Development of Nanoindustry Infrastructure for the period of
2008-2011” and “Nanoindustry Development until 2015” as well as other national programs
with wider objectives including federal programs “Research and Teaching Staff of Innovative
Russia for the period 2009-2013”, “Research and Development of the Priority Areas of
Science and Technological Development of Russia for the period 2007-2012”, etc. These
programs have created a new kind of relationship between innovation stakeholders and
dramatically increased investment into the field. They also pushed forward creation of new
standards and regulations for nanotechnology in Russia and enabled statistical observation of
this technological area. In 2008, gross R&D expenditure in the “nanosystem and nanomaterials
industry” totaled 11.03 bn roubles (US$ 368 mln), in 2009 – 15.11 bn roubles (US$ 504 mln),
and in 2010 – 21.28 bn roubles, or US$ 709 mln (HSE, 2012).
Federal programs also drastically increased the number of actors involved in nano scale research and development and led to substantial reorganization of existing ministries, government agencies, universities and research institutions. However positive this reorganization has been, it still seems to be oriented on imported technologies and new knowledge creation rather than full usage of existing resources. Notably, Rusnano amply invests in projects abroad while domestic start-ups and nanotech ventures seem to be underdeveloped (cf. Chubais, 2010).

2) **Rusnano corporation, a facilitator in the commercialization phase of nanotechnology development.** The corporation became one of the most efficient nanotechnology developers and promoted understanding of the field among ordinary citizens. Rusnano also contributed to developing the nanotechnology infrastructure by supporting new research centers and production facilities. Successes of the corporation may be evidenced by private sector investment totaling 50.6% of total R&D expenditure in the field in 2007. Importantly though, 81.4% of these were subsidized by Russia’s federal budget (HSE, 2009).

3) **Annual Nanotechnology International Forums (RUSNANOTECH)** that serve as a communication platform for nano researchers, policymakers and social scientists and promote international collaboration with foreign colleagues. The Forums are traditionally addressed by the Russian President and are considered to be an important conference both for national and international research institutions and individual scientists. They also serve as a crucial instrument of knowledge dissemination and broader public engagement. The latest RUSNANOTECH 2012 was integrated into a larger Moscow International Forum for Innovation Development “Open Innovations” that may be a sign of a decreasing importance of nanotechnology as a priority area with special status (together with the reform of the former Government Council for Nanotechnology in 2008).

4) In 2008, the **Russian Nanotechnology Society** was established by a group of academics and business representatives as a non-profit organization to promote the emergence of nanoindustry in Russia and provide a platform for effective cooperation between its members and organizations involved in nano scale research and development. Joint Stock Company “NT-
MDT is an official partner of the Society and its CEO Victor Bykov has been elected President of the Society until 2012.

As a result of these institutional developments, nanotechnology has been one of the areas where international and cross-regional knowledge networks have been developing quite rapidly.

Expectedly, Germany, United States and France are the most active international collaborators working with Russian nano scientists on joint papers and projects (see Figure 10). These three countries have been strategic business and S&T partners for quite some time now and in this sense nanotechnology is path dependent and does not present any unique characteristics compared to other S&T and economic areas developed in Russia. According to Ernst & Young (2011), the United States ranked first in the number of FDI projects making 16% of total number of projects in Russia, Germany followed with 13%, and France ranked fourth with 6% of total number of projects on par with Finland.

Figure 10. Russia’s top five international collaborators in nanotechnology, 1996-2011.

![Figure 10](image.png)

Source: own calculations based on Thomson Reuters Web of Science SCI-Expanded.

In intra-country collaboration, the picture also looks particularly path dependent due to the concentration of major S&T resources and organizations in Moscow, St. Petersburg and Novosibirsk. However, nanotechnology seems to be making a significant contribution in

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increasing knowledge spill-overs from these three scientific clusters, as evidenced by the share of collaborative papers between Russian regions presented in Table 11.

6.3.2. Research and education capabilities

The recent actions undertaken under the umbrella of nanotechnology policies seem to have contributed to improved research and education capabilities in Russia. Several centers of excellence in the area of nanoscience and nanotechnology were created across the country with most recent ones opened in Belgorod and Tomsk. Many established research institutions, including the Russian Academy of Sciences, actively participate in the new programs with an aim to build up their research capacity. All in all, 3.9% of all country’s researchers were working in the nano field in 2009 and 338 nano-related patents were issued in 2009 (Rosstat, 2010; Kachak et al., 2010).

The non-profit Foundation for Infrastructure and Education Programs supports a number of education projects that increase the level of university graduates so that they fit into the research environment and improve public awareness. The Foundation organizes different initiatives for all ages starting with young kids and school children (e.g. contests, public lectures and exhibitions) to university students, scientists and engineers (e.g. conferences, internships and executive training) (Klochikhin, 2012a).
Table 11. Share of cross-regional collaborative papers in the overall nanotechnology publication output by top-20 Russian regions, 2001-2011.

<table>
<thead>
<tr>
<th>Region</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Average annual growth by region</th>
<th>Total number of publications by region (2001-2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moscow</td>
<td>15.1</td>
<td>16.4</td>
<td>15.5</td>
<td>17.7</td>
<td>17.2</td>
<td>22.5</td>
<td>20.1</td>
<td>21.3</td>
<td>22.4</td>
<td>23.6</td>
<td>22.6</td>
<td>4.7</td>
<td>10,386</td>
</tr>
<tr>
<td>St Petersburg</td>
<td>9.9</td>
<td>9.8</td>
<td>9.6</td>
<td>11.3</td>
<td>13.6</td>
<td>13.4</td>
<td>10.7</td>
<td>12.9</td>
<td>18.0</td>
<td>19.4</td>
<td>16.2</td>
<td>6.5</td>
<td>6,203</td>
</tr>
<tr>
<td>Moscow Oblast</td>
<td>31.2</td>
<td>31.0</td>
<td>29.4</td>
<td>30.6</td>
<td>28.2</td>
<td>36.5</td>
<td>31.7</td>
<td>34.6</td>
<td>45.0</td>
<td>40.8</td>
<td>43.3</td>
<td>4.3</td>
<td>3,000</td>
</tr>
<tr>
<td>Novosibirsk Oblast</td>
<td>15.5</td>
<td>12.8</td>
<td>14.1</td>
<td>12.4</td>
<td>21.4</td>
<td>18.3</td>
<td>20.6</td>
<td>16.0</td>
<td>16.9</td>
<td>20.9</td>
<td>20.5</td>
<td>5.6</td>
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<td>33.8</td>
<td>28.6</td>
<td>25.8</td>
<td>26.4</td>
<td>27.7</td>
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<td>18.7</td>
<td>-2.4</td>
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<td>21.3</td>
<td>24.4</td>
<td>18.2</td>
<td>38.2</td>
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<td>30.2</td>
<td>28.9</td>
<td>23.5</td>
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<tr>
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<td>22.6</td>
<td>27.5</td>
<td>12.1</td>
<td>9.1</td>
<td>20.4</td>
<td>20.0</td>
<td>21.6</td>
<td>28.4</td>
<td>9.6</td>
<td>684</td>
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<td>Tatarstan</td>
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<td>15.2</td>
<td>11.7</td>
<td>24.1</td>
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<td>20.0</td>
<td>20.0</td>
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<td>27.5</td>
<td>29.5</td>
<td>46.5</td>
<td>29.3</td>
<td>28.2</td>
<td>28.4</td>
<td>36.8</td>
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<td>17.6</td>
<td>3.0</td>
<td>587</td>
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<td>0.0</td>
<td>10.5</td>
<td>9.4</td>
<td>13.6</td>
<td>10.6</td>
<td>17.3</td>
<td>35.3</td>
<td>25.0</td>
<td>16.7</td>
<td>-15.1</td>
<td>388</td>
</tr>
<tr>
<td>Krasnoyarsk Krai</td>
<td>30.4</td>
<td>14.3</td>
<td>23.1</td>
<td>14.3</td>
<td>25.8</td>
<td>32.3</td>
<td>22.5</td>
<td>31.4</td>
<td>20.5</td>
<td>50.0</td>
<td>18.4</td>
<td>13.1</td>
<td>377</td>
</tr>
<tr>
<td>Primorsky Krai</td>
<td>0.0</td>
<td>7.7</td>
<td>21.4</td>
<td>23.1</td>
<td>32.0</td>
<td>14.3</td>
<td>16.7</td>
<td>29.0</td>
<td>7.1</td>
<td>18.2</td>
<td>19.0</td>
<td>25.2</td>
<td>288</td>
</tr>
<tr>
<td>Voronezh Oblast</td>
<td>0.0</td>
<td>28.6</td>
<td>63.6</td>
<td>42.9</td>
<td>55.6</td>
<td>40.7</td>
<td>33.3</td>
<td>26.5</td>
<td>31.3</td>
<td>39.5</td>
<td>20.0</td>
<td>-2.2</td>
<td>252</td>
</tr>
<tr>
<td>Udmurtiya</td>
<td>16.7</td>
<td>36.4</td>
<td>30.0</td>
<td>50.0</td>
<td>46.7</td>
<td>55.0</td>
<td>26.3</td>
<td>60.0</td>
<td>51.7</td>
<td>50.0</td>
<td>12.5</td>
<td>16.2</td>
<td>224</td>
</tr>
<tr>
<td>Rostov Oblast</td>
<td>44.4</td>
<td>25.0</td>
<td>33.3</td>
<td>21.4</td>
<td>60.0</td>
<td>25.0</td>
<td>28.1</td>
<td>21.4</td>
<td>23.3</td>
<td>36.7</td>
<td>14.7</td>
<td>7.0</td>
<td>216</td>
</tr>
<tr>
<td>Perm Krai</td>
<td>14.3</td>
<td>9.1</td>
<td>30.0</td>
<td>8.3</td>
<td>23.1</td>
<td>7.7</td>
<td>40.0</td>
<td>35.7</td>
<td>42.1</td>
<td>42.9</td>
<td>14.3</td>
<td>59.4</td>
<td>151</td>
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<tr>
<td>Ivanovo Oblast</td>
<td>50.0</td>
<td>14.3</td>
<td>11.1</td>
<td>12.5</td>
<td>40.0</td>
<td>28.6</td>
<td>16.7</td>
<td>15.0</td>
<td>25.0</td>
<td>13.0</td>
<td>23.5</td>
<td>15.8</td>
<td>127</td>
</tr>
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<td>Irkutsk Oblast</td>
<td>0.0</td>
<td>0.0</td>
<td>25.0</td>
<td>0.0</td>
<td>25.0</td>
<td>11.1</td>
<td>27.8</td>
<td>6.7</td>
<td>38.1</td>
<td>33.3</td>
<td>38.5</td>
<td>27.0</td>
<td>124</td>
</tr>
<tr>
<td>Leningrad Oblast</td>
<td>87.5</td>
<td>66.7</td>
<td>66.7</td>
<td>50.0</td>
<td>33.3</td>
<td>80.0</td>
<td>71.4</td>
<td>60.0</td>
<td>95.7</td>
<td>100.0</td>
<td>89.5</td>
<td>8.5</td>
<td>124</td>
</tr>
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<td>Ulyanovsk Oblast</td>
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<td>37.5</td>
<td>11.1</td>
<td>50.0</td>
<td>50.0</td>
<td>33.3</td>
<td>33.3</td>
<td>50.0</td>
<td>20.0</td>
<td>12.5</td>
<td>29.6</td>
<td>112</td>
</tr>
</tbody>
</table>

Source: own calculations based on Thomson Reuters Web of Science SCI-Expanded.
The ongoing campaign in favor of nanotechnology led to increased awareness about nano among ordinary citizens. According to the polls of the All-Russian Public Opinion Research Center, 43% of Russians heard about nanotechnology and its applications and 81% of citizens believed that they will be useful for the human development (All-Russian Public Opinion Research Center, 2008). In 2009, Russians put nanotechnology at the 9th place out of 23 in the list of most important scientific discoveries of the 20th century with 4% of citizens pointing at this technological area (All-Russian Public Opinion Research Center, 2009).

Despite this massive effort, serious problems have been evidenced in the field of nano education. Some reports mentioned that there is practically no demand in the domestic labor market for university graduates with nanotechnology degrees (Sokolova, 2011). Until now, there is no formal academic union (or Education and Methodics Association, as it is commonly called in Russia) in the area of nanotechnology that would be establishing standards and curricula for this new research and education area so that universities can use similar books and share best teaching practices.

Cross-disciplinary links in nano scale research and development are very much in line with the situation observed in former Soviet Union in 1991 (cf. Figure 5). Physics, mechanics and materials science continue to play significant role in nanotechnology research today supporting the idea that this area is largely path dependent in Russia in terms of disciplinary bias. Engineering is also tightly linked to basic research suggesting that this area is more theory-laden rather than practice-based in Russia (see Figure 11). Terekhov (2012) also confirms that the most productive and influential Russian scientists publish in the areas of physics of nanostructures, nanooptics, mechanics of nanomaterials, functional nanomaterials, carbon nanostructures, etc.

6.3.3. Industrial and enterprise development

According to HSE (2012), the Russian nano market reached 70,702.3 mln roubles (US$ 2.36 bn) in January-June 2011 increasing 28.3 per cent compared to the same period of 2010. Kachak et al. (2010) also mentioned that the Russian nano market already accounted for 81 bn

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52 It is mentioned in HSE (2012, p. 295) that these are preliminary results of a pilot project involving enterprises employing 15 people on average and excluding military sector and small-sized enterprises. Moreover, Sargent (2008) mentioned it extremely difficult to calculate the exact output of nanotech research and development, and thus any estimates of the size of the Russian nano market as well as other available assessments in other countries should be considered largely speculative. For example, other estimates suggest that the US nanotechnology market reached US$ 80 bn in 2008 (Roco, 2011).
roubles (US$ 2.7 bn) in 2009 and the amount of nano product exports equaled 11.3 bn roubles (US$ 377 mln). In 2009, President Dmitry Medvedev expected the nanotechnology market in Russia to reach 900 bn roubles (US$ 30 bn) by 2015, and 25% of the Russian nano products to be exported abroad (President of the Russian Federation, 2009).

At the same time the bulk of new nanotechnologies have been created in the service sector and by higher education establishments: 104 and 91 respectively out of 222 in total in 2010. Strikingly, only about 2.5 per cent of nano-related R&D is spent by manufacturing organizations while an impressive 72.9 per cent is provided by the real estate firms and related services. As a result, industrial enterprises continue to play a rather marginal role in nanotech development spending just about 3.5 per cent of total nano-related R&D expenditure including about 2 per cent spent by privately-owned companies (HSE, 2012).

Rusnano is supposed to serve as an important platform to facilitate nano market formation in Russia and promote research-intensive enterprises. However, it was reported lately that the corporation is starting to close some projects. In March 2012, thirteen of 145 earlier approved projects with a budget of 17.9 bn roubles (US$ 600 mln) had to be closed because “private co-investors did not fulfill their obligations,” and further seven projects were left out by Rusnano in October 2012 (Gazeta.ru, 2012).

Other negative developments were also reported by a manager in a leading Russian nanotechnology company who shared that his firm participated in a government grant competition but ended up losing large sums of money despite winning it because the government kept changing the terms of the grant throughout the entire year after the competition was officially closed and the grant agreement was signed by both parties.\footnote{Private sector also complains that the domestic demand for nano applications is very low with most enterprises preferring to buy imported technologies rather than trust Russian products (Zykova, 2011).}

\[53\] It should be noted, though, that such situations do not only happen in catching up countries like Russia – a British businessman shared in a private interview that he encountered similar problems in the UK losing over 100,000 pounds in a program established by the government ‘to support business growth.’
Figure 11. Cross-disciplinary collaborations in nanotechnology publications in Russia, 1996-2011.
Patenting activity by Russian enterprises has also been quite low. Alexander Kuznetsov, managing director of National Electronic Information Consortium (NEICON) – a non-profit association of Russia’s libraries carrying out bibliometric and patent analysis, lamented that Russians patented only 160 nano patents in 2009 while the following year the number of patents plummeted to less than 40. Meanwhile, the federal Program of Nanoindustry Development until 2015 set an objective of 650 patents granted by 2010 that had not been achieved and the trend remains “dead-alive” (RIA Novosti, 2012).

Besides, Russia experiences poor science-industry links in nanotechnology with no clear trends for improvement, as evidenced by the number of co-inventorships in Thomson Reuters Derwent Innovations Index (see Figure 12).

Figure 12. Science-industry co-inventorships, as percentage of total patents by companies and RAS, research institutes and universities in 2001-2011.

Source: own calculations based on Thomson Reuters Derwent Innovations Index.

6.3.4. Cluster and network development

By 2010, the Russian government sponsored the creation of 38 research and education nanotechnology centers in major country’s universities (Government of the Russian Federation, 2010b, Appendix 5). These centers serve as important hubs for knowledge sharing and experimentation creating nano-related networks across the entire country.
Major clusters also make significant effort to support this priority area and provide most favorable conditions for growing research-intensive companies. Among others, the Ministry of Economic Development overlooks the establishment of 25 territorial clusters in various parts of the country to support innovation growth. Skolkovo, near Moscow, is also developing a number of nanotechnology projects. Large-scale nanotechnology projects in Biysk, Kazan, Khabarovsk, Kaliningrad, and other cities.

Since 2010, the Russian government is also aiming to create a National Nanotechnology Network. The network is managed by the Russian Ministry of Science and Education together with other relevant organizations including Rusnano, Kurchatov Institute, and others. Today, the network unites 794 entities including 384 industrial enterprises, 112 universities, and 94 research institutes.\(^5^4\)

6.3.5. Regional spread

Russia seems to have achieved particular success in improving the distribution of S&T effort across regions through its nanotechnology program. Compared to 2001 when St. Petersburg produced 28.3 per cent of all nano publications, the region published only 16.5 per cent of nano-related papers in 2011 redistributing the balance among other regions (see Figure 13).

Figure 13. Distribution of nanotechnology publication output across Russian regions, 2001-2011.

Source: own calculations based on Thomson Reuters Web of Science SCI-Expanded.

\(^5^4\) See more at the official website of the National Nanotechnology Network of Russia – www.rusnanonet.ru.
In the last decade, the most impressive growth of nano publication output was observed in Tomsk Oblast (increased from 1.26% of total publications in 2001 to 2.94% in 2011), Tatarstan (from 1.48% in 2001 to 2.59% in 2011), Saratov Oblast (from 0.77% in 2001 to 1.45% in 2011), and Primorsky Krai (from 0.66% in 2001 to 1.7% in 2011).

6.3.6. Product innovation

The aggregate effects of nano-related product innovation on economic growth and social development are quite hard to capture (Klochikhin and Shapira, 2012a). One of the challenges consists in the difficulties of calculating the share of nano scale components even if they are part of larger products (Sargent, 2008; Klochikhin, 2011a). Yet, HSE (2012, p. 296) was able to provide rough statistics on nano product development in Russia: nano products accounted for 1.2 per cent of the Russian nano market in January-June 2011 totaling 862.7 mln roubles (US$ 28.75 mln) which was 3.65 times more than in the same period of 2010. The bulk of the market was occupied by the goods and services produced by the use of nano applications – 90.3 per cent of the nano market in January-June 2011 while the production of goods comprising at least some nano components grew more than three times in the first half of 2011 accounting for 8.4 per cent of the total market.

6.4. Summary

This chapter provided an evaluation of the early impacts of nanotechnology on the national innovation system and broader society and economy of Russia. It is argued that the impacts are traceable and significant in some areas including regional spread, institutional development, and research capabilities. These effects can have a potentially strong influence on the innovation system transformation by promoting infrastructure development and building up networks that would contribute to the ‘distributed innovation processes’ and spread of scientific and technological knowledge. Moreover, these impacts seem to have particular significance for the wider development objectives that include a set of economic, social and political objectives and were discussed in more detail in section 2.3.
Chapter 7. China: innovation system and policies

This chapter follows the pattern established by the preceding empirical chapters and seeks to evaluate the impact of individual factors dating back to the state planning S&T system on the contemporary development of China. This evaluation permits to further identify the common problems shared by China and Russia that would prove the complementarity of their systems and allow them to learn effectively from each other. Innovation policies are analyzed from the point of view of their effectiveness and with an implicit evaluation of the best practices that can be potentially transferred to Russia.

7.1. The context

China has undergone impressive transformation in the last decade. In 2011, the nation surpassed Japan to become the second largest economy in the world, and the Global Trends 2030 report by the U.S. National Intelligence Council (2012) predicts that the country will outperform the United States by 2030 (twenty years earlier than previously expected in the BRICs forecast by Goldman Sachs, 2001).

Indeed, China’s growth has been fascinating in all extents. The length of highways alone has soared from 147 km in 1989 to 30,000 km in 2004 and further 85,000 km in 2012. Today, one can make a 1,500-km trip from Beijing to Shanghai in about five hours at an average speed of 300 km per hour while just twelve-fifteen years ago such journey would take no less than a day at an average speed of 60 km per hour (Baunov, 2012).


Unlike in Russia, the last major disruptions in Chinese development happened in the mid-20th century. The current period starting with 1978 when Deng Xiaoping launched the Four Modernizations and Open Door Policy may be considered quite consistent in reforms and effort made by the Chinese government to ensure smooth transition to market economy. The 1989 events in Tiananmen Square had significant impact on political modernization and international trade relations but may be considered as a minor distortion compared to the periods of the Great Leap Forward and the Cultural Revolution.
7.2. Innovation system

China’s innovation system has gone through a number of serious changes in the recent decades. Since 1978 when science and technology were officially announced as the ‘first production power’, several large-scale efforts have been made by the government to create an effective platform for indigenous innovation-driven growth. Yet, the nation continues to face multiple challenges and some policy instruments have been found quite inefficient in resolving existing problems and promoting system transformation. Many issues deal with the legacies of the state planning past and continuing dominance of the Communist Party in the political system.

7.2.1. Social and political status of science and technology

After the massive reforms were launched in 1978 and reinforced during Deng Xiaoping’s 1992 Southern Tour, China’s science and technology have witnessed a rapid rise in social and political prestige of scientific labor and innovation activity. Like in Russia, members of the Chinese Academy of Sciences remain on board of many public sector organizations and influence the policymaking process to much extent. Among others, the CAS Institute for Policy and Management provides regular advice to the government in the direction of S&T reform and long-term planning.

Similar to Russia, one may expect serious corruption and nepotism that would be linked to the high status of academic and industrial leaders in contemporary China. Indeed, several interviewees mentioned that mid-level researchers and managers have little impact on the policymaking process and funding allocation while CAS members and institute directors sit on multiple committees in the government agencies and foundations.

However, the majority of the interviewed scientists, many of whom are recent returnees, emphasized that their careers are primarily dependent on their personal achievements and merit rather than connections with more powerful colleagues (guanxi). One proof is the recognized prestige of publishing articles in peer-reviewed journals abroad as well as establishment of own English-language outlets in the best Chinese universities including Zhejiang, Peking, and Tsinghua Universities.\(^5^5\) Another proof is the growing budget of the

\(^{55}\) The interviewees reported that many universities have established links with foreign publishing houses, most popular one being Springer. Zhejiang University was said to be one of the most successful in this movement with
National Natural Science Foundation of China (NSFC) that allocates about 70% of funding to individual scientists and research groups: the budget has soared from RMB 6.43 bn in 2009 to about RMB 12 bn in 2011 and further RMB 15 bn in 2012.

In recent decades, China has been also successfully ‘utilizing’ the training potential of technologically advanced countries. 620,000 Chinese students have chosen to study abroad in the past two years – more than a quarter of the total number of students overseas since 1978 (Hille, 2012). In the Global Competitiveness Report 2012-2013 (WEF, 2012), China was ranked at the 39th position in brain drain with an indicator much higher than the mean, which demonstrates that the country has been quite successful in retaining talent and supporting effective brain circulation. Furthermore, China Scholarship Council (CSC) provides stipends for Chinese students to go work with the best research groups abroad, and the One Thousand Talents Program provides exceptional support to returnee scholars who do not only get high salaries but are also provided with world-class S&T equipment and support personnel. As a result, the country is becoming increasingly attractive to the returned students: about a third of Chinese students studying abroad returned home in 1991-2009 (see Table 12).

Returning scholars sustain their links with academics in developed countries and improve international exchange and knowledge flows between the two worlds (Jonkers and Tijssen, 2008). They also contribute to the development of science parks and market culture, e.g. returned students from overseas set up over 2,100 firms in the Zhongguancun Science Park (Cao, 2004).


<table>
<thead>
<tr>
<th>Year</th>
<th>Number of students studying abroad</th>
<th>Number of returned students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>2,900</td>
<td>2,069</td>
</tr>
<tr>
<td>1992</td>
<td>6,540</td>
<td>3,611</td>
</tr>
<tr>
<td>1993</td>
<td>10,742</td>
<td>5,128</td>
</tr>
<tr>
<td>1994</td>
<td>19,071</td>
<td>4,230</td>
</tr>
<tr>
<td>1995</td>
<td>20,381</td>
<td>5,750</td>
</tr>
<tr>
<td>1996</td>
<td>20,905</td>
<td>6,570</td>
</tr>
<tr>
<td>1997</td>
<td>22,410</td>
<td>7,130</td>
</tr>
<tr>
<td>1998</td>
<td>17,622</td>
<td>7,379</td>
</tr>
<tr>
<td>1999</td>
<td>23,749</td>
<td>7,748</td>
</tr>
<tr>
<td>2000</td>
<td>38,989</td>
<td>9,121</td>
</tr>
</tbody>
</table>

about a dozen English-language journals edited by the Chinese professors. Meanwhile, Tsinghua University has got at least two journals: Nano Research and Journal of Advanced Ceramics.
To sum up, Suttmeier (2008, p. 2) named it ‘one of the most striking features of today’s science and technology trends in China’ that the political elite and society in general demonstrate so high level of commitment and enthusiasm toward S&T development.

7.2.2. **Quality of science, technology and innovation and technology transfer**

The growth of S&T sector in China has been most remarkable. The publication output increased about 16 times in the period between 1994 and 2011 (see Figure 14).

Figure 14. Number of scientific publications by the Chinese scientists, 1994-2011.\(^\text{56}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Publications</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>83,973</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>125,179</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>117,307</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>114,682</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>118,515</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>134,000</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>144,000</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>179,800</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>229,300</td>
<td></td>
</tr>
</tbody>
</table>


\(^\text{56}\) Hong Kong is excluded from searches until 30 June 1997 and Macau until 19 December 1999, when People’s Republic China assumed official sovereignty over these territories. Taiwan is excluded from the entire search.
The progress of the education system has also been quite illustrious. The quality of the Chinese system is now estimated at the levels close to Israel, Czech Republic, and Lithuania (WEF, 2012). Enrollments in tertiary education rose from 2.04 mln students in 1991 to 21.45 mln students in 2009 (see Figure 15).

In 2009, nine elite Chinese universities established a C9 League that is a self-organized alliance seeking to promote China’s best schools that employ 3 per cent of scientific manpower and receive 10 per cent of national R&D expenditure. The C9 League universities produce over 20 per cent of China’s output of journal articles indexed by Thomson Reuters that generated about 30 per cent of the nation’s total citations (Times Higher Education, 2011). Two best universities – Peking and Tsinghua – have already gained high positions in the World University Ranking 2012-2013: 46th and 52nd places respectively (Times Higher Education, 2012).

As a result of these recent developments, the number of researchers in R&D per million people in China increased from 548 in 2000 to 1,199 in 2008 (World Bank, 2012).

Figure 15. Number of students enrollment in regular institutions of higher education in China, 1991-2009.

Several interviewees also confirmed that China is overcoming a serious weakness of the former state planning S&T system that is separation of research and teaching. Universities got
7.9 per cent of the nation’s gross R&D expenditure and employed 12 per cent of the national full-time equivalent of R&D personnel in 2009 (China Statistical Yearbook 2010). A number of large-scale programs, e.g. 985 and 211 project, are aimed at improving the quality of education and take Chinese schools to the top positions of world university rankings. Businesses also choose to establish closer links with top universities: for example, Foxconn, a Taiwan-based IT giant, have already invested RMB 300 million with further RMB 1 billion promised over the next ten years (People’s Daily Online, 2011).

At the same time the problem of poor training of researchers does not seem to be completely resolved: some professors have up to thirty PhD students at a time and do not have an opportunity to supervise all of them effectively. However, the flaws of domestic education system are largely compensated by the CSC stipends allowing junior researchers to gain experience at top universities abroad.

In the meantime, despite these massive achievements, the quality of scientific output in China has been questioned on several occasions. Among others, Zhou and Leydesdorff (2006) mentioned that the nation is emerging as a new technological superpower but still has to improve the level of its S&T to match with other S&T leaders. Suttmeier (2008) noted that basic research in China is more derivative than original. And New Scientist (2006) reported a scandal dealing with unethical behavior of a Chinese scientist who published falsified data.

Serious challenges also remain in the area of technology transfer. The World Economic Forum (2012) continuously classifies China as an efficiency-driven economy emphasizing that manufacturing based on cheap labor and extensive growth capacity plays major role in the country’s success. To support this position, WEF ranked China quite low in availability of latest technology and firm-level technology absorption – at the 107th and 71st positions respectively.

One of the major reasons for such situation is lack of enterprise autonomy and imperfect market mechanisms. Until October 2007, property rights were not explicitly guaranteed to private entrepreneurs, businesses, and homeowners, leading to ambiguous ownership structures presenting joint foreign ventures and odd public-private partnerships (cf. Breznitz and Murphree, 2011; Huang, 2008).

Several entrepreneurs and investors whom I interviewed in China also pointed that guanxi continue to have a decisive impact on business success while policies play quite
marginal role in identifying opportunities and promoting quality research and development, although Kennedy (2009) mentioned that the situation is getting better now that business proposals are increasingly weighed on the basis of their merit rather than the status of their supporters. The developments in industrial parks and other national- and regional-level clusters may present a somewhat contrasting view. However, the major impression is that these locations create somewhat isolated environments for start-ups who may prove to be incapable of entering the competitive market once they have to leave the cluster. Moreover, no particular legislature seems to have been developed to explain the mechanism when companies have to exit the industrial park whether when they reach a certain level of revenue or experience obvious failures.

A number of extensive reforms have been realized to promote private-sector growth and competition in China. In early 1990s, China launched a program to privatize and corporatize state-owned enterprises (SOEs) and industrial institutes. As a result, the economic performance of transformed research institutes increased significantly with the revenues reaching RMB 19.91 billion in 2001, which was 50% bigger than in 1999 (Sigurdson, 2005).

Gu et al. (2006) also showed that growing competition and corporatization reform had important effect on the firm dynamics in the Zhongguancun Science Park where productivity and financial performance are crucial for the survival of firms.

In the meantime, Benner et al. (2012) mentioned that the progress has been slowed down by the institutional shortcomings and weaknesses, especially in bank landing and venture capital funding, which creates lack of finance for innovation projects and accentuates the bias against diffusion in STI policies.

Rules for venture capital, mergers and acquisitions, and initial public offerings are generally quite vague. This legal ambiguity makes venture capitalists behave more like private-equity firms and prevents them from investing into high-risk R&D-based start-ups. Banks remain state-owned and prefer to support their “primary charges” – state-owned enterprises (Breznitz and Murphree, 2011, pp. 31-32).

Moreover, it has been noted that domestic private firms have less advantages in China as compared to both state-owned enterprises and foreign companies. This paradox was dubbed by Huang (2008) who suggested that the real advantage of the Chinese innovation model
consists in its ability to retain the free economy zone in Hong Kong and effective policies to attract foreign direct investment (FDI). Several striking examples of practically foreign-invested enterprises with roots in Hong Kong include Lenovo, Sina, UTStarcom, Haier, and others.

China’s household registration system, or *hukou*, is another important constraint that limits the freedom of movement and residence impeding free flow of talent and knowledge within the country. As mentioned by Breznitz and Murphree (2011, p. 30), “the hukou system organizes all Chinese citizens on the basis of their ancestral hometowns,” which seriously effects the employability, access to education, social services, and permission to travel. Various regions are using the difficulty of changing one’s hukou as part of their innovation and industrial policy to attract most talented individuals.

In a more comprehensive study of China’s productivity growth, Chen et al. (2011) pointed that the structural shift from the heavy-industry-oriented policy to a balance between light and heavy industry after 1978 had significant effect on the efficiency of the Chinese economy: the productivity has been growing between 2.7% and 4.1% annually, according to various estimates. Chen et al. (2011, p. 137) also supported the notion of the inefficiency of state-owned enterprises and noted that in 1995, “roughly half of the SOEs were unprofitable and required large subsidies for continuing operations” with the entire public sector report stating its first net loss the following year.

In general, China employs three ways of resolving these challenges: through large-scale national programs (e.g. Key Technologies R&D Program, High-Tech R&D (863) Program, Torch Program, and others); through internationalization of new technology ventures that gain knowledge by interactive learning in the developed markets (Chen and Holmes, 2006); and through knowledge spillovers from R&D centers of big western corporations (e.g. IBM, Microsoft, Intel, Motorola, etc. – see Cao, 2004).

The latter strategy of collaboration with western corporations on the Chinese soil seemed to be especially promising but has caused some disappointment lately. Fu et al. (2011) suggested that spillovers were not as successful in sharing the knowledge with their Chinese partners as it was expected due to the fact that foreign technologies do not always ‘fit the local socioeconomic and technical context’ (p. 1210). Among others, the spillover strategy did not bring the expected results due to the lack of absorptive capacity of the Chinese firms and the inability to imitate foreign practices in the unique institutional and cultural context of China.
7.2.3. **STI policy system**

Since 1978, China has been implementing quite a consistent series of reforms that have also been reflected in the STI policy system. Like in the previous periods, the overall S&T development is guided by the long-term programs that are adopted roughly every 7-10 years (Sigurdson, 2005).

In different periods, these programs served various objectives. Huang et al. (2004, p. 8) divided them into four major stages:

- **Reformation of planning practice (1978-1984):** recover and improve China’s R&D system and integrate it in the planned economic practices through rehabilitation and improvements of R&D institutions that had survived the damage of the Cultural Revolution as well as inclusion of R&D objectives in the Sixth National Five-Year Plan (1980-1985);

- **Performing S&T activities in the ‘Market’ (1985-1991):** establish innovation networks and promote science-industry collaboration through encouraging project-based and mission-oriented funding schemes, merging research institutes and enterprises, supporting spin-off strategies, legitimating a technology market with paid transactions for the use of intellectual property;

- **Bridging S&T activities closely to ‘Socialist Market Economy’ (1992-1998):** increase efficiency of applied R&D institutions to bring them closer to the market through providing them with more autonomy and encouraging spin-off and merging strategies;

- **Large-scale transformation of R&D institutions (1999 until now):** transform almost all state-owned R&D institutions by turning them into enterprises, non-profit organizations, intermediaries or merging them with universities.

The latest National Medium- and Long-Term Program for Science and Technology Development (2006-2020), also called MLP 2020, set forth the objective of overcoming dependence on foreign technology and creating a favorable environment for indigenous innovation (zhizhu chuangxin) supporting local efforts in research and development and establishing better networks between all components of the innovation system.

The resource allocation to science and technology is rapidly catching up with the levels common in technologically advanced countries. Gross R&D expenditure increased from 0.9 per
cent of GDP in 2000 to 1.7 per cent of GDP in 2009. The full-time equivalent of R&D personnel also surged from 675,000 person-years in 2000 to 2.3 mln person-years in 2009 (see Table 13).

In recent decades, China has been particularly effective in applying one of the major strength of the state planning system that is massive resource mobilization for a limited number of priority S&T projects. A number of programs serve specific missions that set priorities in several S&T areas, e.g. 16 mega-engineering projects, Key Technologies Program, and the 863 program.


<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2005</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP (billions, constant 2000 US$)</td>
<td>1,198.5</td>
<td>1,908.8</td>
<td>2,937.55</td>
</tr>
<tr>
<td>GDP per capita (constant 2000 US$)</td>
<td>949</td>
<td>1,464</td>
<td>2,206</td>
</tr>
<tr>
<td>Gross R&amp;D expenditure (as % of GDP)</td>
<td>0.9</td>
<td>1.32</td>
<td>1.7</td>
</tr>
<tr>
<td>- Including private sector R&amp;D expenditure (as % of GDP)</td>
<td>0.56</td>
<td>0.88</td>
<td>1.21</td>
</tr>
<tr>
<td>High-technology exports (billions, current US$)</td>
<td>41.7</td>
<td>215.93</td>
<td>348.3</td>
</tr>
<tr>
<td>Export market share of R&amp;D intensive industries (%)</td>
<td></td>
<td></td>
<td>13.09*</td>
</tr>
<tr>
<td>Patent applications (residents)</td>
<td>25,346</td>
<td>93,485</td>
<td>229,096</td>
</tr>
<tr>
<td>Researchers in R&amp;D (per million people)</td>
<td>548</td>
<td>856</td>
<td>1,199*</td>
</tr>
<tr>
<td>Full-time equivalent of R&amp;D personnel (person-years)</td>
<td>675,000</td>
<td>1,365,000</td>
<td>2,290,000</td>
</tr>
</tbody>
</table>


* Data available for 2008.

Although the mission-oriented approach seems to have been widely adopted in China’s S&T sector, a senior researcher in a leading Chinese university noted that his institution still prefers to make more programmatic planning and state its development goals in a declarative manner without specifying particular tasks and solutions that would help achieve these high targets. The language of strategic documents remains quite vague and is probably oriented more on improving the current image of a university rather than elaborate specific plans of development.

At the same time government agencies involved in the implementation of S&T policy aim to combine both mission-oriented and programmatic approaches. For example, as mentioned by a high-level policymaker, the National Natural Science Foundation of China declares its strategic goals in a programmatic form in long-term documents while it also supports a group of well-known scientists who elaborate five-year plans where they identify the
major priorities of science and technology for this term and present a specific mechanism to implement them including particular calls for projects to be announced by the Foundation.

In other aspects of the STI policy system, China was quite lucky not to inherit a particular bias between military and civilian sectors peculiar to the Soviet S&T system. As a result, the nation has been following the western model in its military reform that combines military and civilian R&D at the same enterprises and research institutes to ensure better learning environments and cross-sectoral knowledge spill-overs.

In this context, a RAND report suggested that China had not been particularly productive in this area before late 1990s but the effort for military modernization has been most impressive in the last decade (Medeiros, 2004). Nevertheless, the report also mentioned that many companies and research institutes continue to be isolated from each other given the weaknesses of the Soviet-type hierarchical system that impedes horizontal knowledge flows and effective technology transfer.

Some interviewees in China also noted that most universities that primarily developed military and dual-use technologies in the past are now engaged in a wide range of civil programs, which serves the goals of overall science and technology development of China. Surely, there remain a number of military-oriented universities such as the National University of Defense Technology sponsored by a special program under the 985 Project but civil research seems to be regaining its importance in China’s S&T quite quickly today.

In 2011, China allocated US$ 143 bn to its military programs, the second largest military budget in the world (SIPRI, 2012). However, compared to other countries by the ratio to GDP, China’s defense expenditure is smaller than that of developed countries: 2% of GDP in China in 2010 as opposed to, say, 4.8% in the United States and 2.6% in Britain (World Bank, 2012).

Despite many recent successes in science and technology, China’s policy system remains quite non-transparent with underdeveloped policy evaluation mechanisms. However, unlike in Russia, most policymakers, whom I interviewed in China, are well aware of the problem and seek to introduce new mechanisms that would allow them to absorb expert knowledge more effectively into the policy process. Among others, NSFC invites domestic and foreign experts to review its activities and give recommendations; its first international evaluation report was issued in 2011.
Meanwhile, a serious weakness of the state planning system is still present in Chinese policies – rampant departmentalism. According to many interviewees, inter-agency struggles are a norm in contemporary politics and sometimes taint the noble goals of the government. At the same time a further move towards political modernization and liberalization is expected after the change of country’s leadership happened in November 2012, and some structural adjustments will probably resolve these challenges at least partly.

7.2.4. System of intellectual property rights protection

As mentioned in chapter 4, China launched a large-scale reform to improve its patent system in 1985. The legislature reviews in 1992 and 2000 as well as accession to World Trade Organization (WTO) in 2001 significantly improved the national system of IPR protection and stimulated patenting activity in the private and research sectors. Although some developed countries continue to issue regular warnings and open disputes against Chinese enterprises through WTO procedures for the breach of patents and copyright, it has been noted that the country is generally on the right track despite occasional violations of IPR law supported by the central government.

As a result, China has been producing a rapidly growing amount of patents: 25,346 patent applications by Chinese residents in 2000 versus 229,096 applications in 2009 (see Figure 16). Such surge of patenting activity has been explained primarily by the need to promote indigenous innovation and avoid paying huge license fees to western corporations. Furthermore, after the accession to the WTO China has become number one choice of R&D outsourcing for the largest companies who prefer to protect their intellectual property in China as well (Lu and Hu, 2008). A special National Patent Development Strategy (2011-2020) was also adopted in 2010 to promote a more effective integration of patent work with the economic and social development (Lohr, 2011).

Meanwhile, concerns have been raised regarding the quality of the Chinese patents since the rules of patent examination at the State Intellectual Property Office of China were recognized to be quite vague. A detailed study by Kroll (2011) addressed these issues and found that the patterns of patenting activity in China are very much in line with the patterns adopted in technologically advanced countries, although certain persistent particularities remain in place including the policy-driven logic prevalent in domestic patent applications. China’s patent data should be generally considered valid as an indicator of the country’s competitiveness and
market structure, and “even though the Chinese IPR system may not be functioning very well yet, it does already reflect the main features of the Chinese innovation system” (Kroll, 2011, p. 33).

Figure 16. Number of patent applications by Chinese residents, 2000-2010.


7.3. Science, technology and innovation policies

Today, China utilizes a wide variety of instruments and programs in its STI policies (see Table 14). Benner et al. (2012) divided these programs into four major groups: diffusion-oriented, mission-oriented, excellence-oriented and oriented toward capability building. While the former two are better funded by the grant individual-based systems, the latter two tasks of improving the excellence and capabilities of national S&T require consistent and massive resource allocation through the block system of funding. In this respect China has been reasonably successful in combining the two approaches, and the Programs 973, 985 and 211 have delivered vast amounts of money to develop China’s universities and research institutes. The government provided 66.5% of funding for the 6,901 public research institutes in 2005 with the bulk of this finance going to the Chinese Academy of Sciences (Schaaper, 2009). At the same time a major problem has been seen in applying quite an elitist approach to support only 0.5% of all universities with these programs (Benner et al., 2012).

In the university reform, China is realizing the Project 211 and 985 Program. The former was launched in 1995 under the auspices of the Ministry of Education to promote research activities in the nation’s top universities and improve their contribution to the overall socioeconomic development of China. In 1996-2000, about US$ 2.2 bn were allocated to the
project with 113 universities participating in the program, as of today (Lixu, 2004). According to People’s Daily Online (2008), these universities train 80% of Chinese doctoral students, two-thirds of graduate students, half of students of abroad and one-third of undergraduates. They also hold 96% of the state’s key laboratories and are allocated 70% of scientific research funding.

The 985 Program takes a more elitist approach. At first, it was only meant for two major universities – Peking and Tsinghua – that are supposed to join the group of top world universities. The list of 985 schools was subsequently supplemented by a number of other universities totaling 39 universities that are split into 4 tiers with respective objectives of becoming: 1) top universities in the world; 2) world-class universities; 3) top universities in China and well known in the world; and 4) special goals assigned to the National University of Defense Technology.

The State Key Laboratories Program and 873 Program also contributed to the significant improvement of R&D facilities at universities and provided them with additional funding to improve their scientific capabilities.
Table 14. Major S&T programs of China.

<table>
<thead>
<tr>
<th>Program</th>
<th>Initiating Year</th>
<th>Objective</th>
<th>Program Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Technology R&amp;D Program <em>(Gong Guan Ji Hua)</em></td>
<td>1983</td>
<td>Concentrate resources on key and common technologies that direly needed by industrial upgrading and social sustainable development.</td>
<td>The program target set in 10th five-year plan from 2001 to 2005 is: 1) By 2005 the general agriculture technology is increased to the level that lags behind international advanced level 5 years; 2) The technology and equipment level in several key industry sectors like ICT and manufacturing sector matches the level of developed countries in the mid-1990s; 3) Develop the technology related to environment protection and sustainable development; 4) Support the enterprises to be the major technological innovators.</td>
</tr>
<tr>
<td>State Key Laboratories Program <em>(Guo Jia Zhong Dian Shi Yan Shi Ji Hua)</em></td>
<td>1984</td>
<td>Support selected laboratories at public or private facilities.</td>
<td>This program is intended to promote the research and advanced training in the 159 laboratories (2002 data) belonging to universities and R&amp;D institutions and establish a string of national engineering research centers.</td>
</tr>
<tr>
<td>Spark Program <em>(Huo Ju Ji Hua)</em></td>
<td>1986</td>
<td>Support technology transfer to rural area to promote the rural area development.</td>
<td>In 1990s the government appropriation for this program hardly surpassed 5%. The bank loan and enterprises own capital occupied the majority investment of the projects. In fact, the projects sponsored by this program attain the government credit for the bank loan application. In 2000, 16.8% of total investment of this program came from bank loans.</td>
</tr>
<tr>
<td>National Natural Science Foundation of China <em>(Guo Jia Zi Ran Ke Xue Ji Jin)</em></td>
<td>1986</td>
<td>Support basic research through directly funding the projects.</td>
<td>From its establishment of 1986 to 2000, the NSFC has funded over 52,000 research projects of various categories by investing a total sum of RMB 6.6 billion. More than 60,000 scientists are supported by NSFC to conduct basic research. In 2004, the NSFC received over 40,000 funding applications.</td>
</tr>
<tr>
<td>High Technology R&amp;D Program *(863 Program) <em>(863 Ji Hua)</em></td>
<td>1986</td>
<td>Enhance China’s international competitiveness and improve China’s overall capability of R&amp;D in high technology.</td>
<td>The Program is concentrating on mid to long-term development in both civilian and military areas. This Program is co-managed by MOST and the Commission of S&amp;T and Industry for National Defense. The Program covers 20 subject topics selected from</td>
</tr>
</tbody>
</table>
Recent years 863 program continuously increased the funding for R&D projects undertaken by enterprise.

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Year</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>National New Product Program</td>
<td>1988</td>
<td>Compile the annual list of new and high technology product and fund those products selectively through the grants and interest subsidiary.</td>
<td></td>
</tr>
<tr>
<td>(Guo Jia Zhong Dian Xin Chan Pin Ji Hua)</td>
<td></td>
<td>In 2002, 71.86% of the program’s funding is by the means of grants and 28.14% is through interest subsidiary.</td>
<td></td>
</tr>
<tr>
<td>Torch Program</td>
<td>1988</td>
<td>Support high technology industry sector development through setting up science park and incubator, funding projects, and human resource training etc.</td>
<td></td>
</tr>
<tr>
<td>(Huo Ju Ji Hua)</td>
<td></td>
<td>By the end of 2003, through Torch Program the governments have established the structure such as science park, incubator, software park, university science park etc. Inside these science parks and incubators, 28,504 high technology enterprises had been founded and created 3.49 million jobs. The program had funded 10,261 projects.</td>
<td></td>
</tr>
<tr>
<td>Key Basic Science R&amp;D Program</td>
<td>1997</td>
<td>Support basic science research. The 973 Program’ s specific tasks are to support the implementation of key basic research in important scientific areas related to agriculture, energy resources, information, resources &amp; environment, and population &amp; health; to provide a theoretical basis and scientific foundation for innovation; to foster human resource; and to establish a number of high level scientific research units.</td>
<td></td>
</tr>
<tr>
<td>(973 Ji Hua)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>The Innovation Fund for Small Technology Based Firms</td>
<td>1999</td>
<td>Support the establishment of Newly Technology Based Firms. The financial support includes interest subsidiary, grants and capital investment. The fund connects to Key Technology R&amp;D Program, 863 program and Torch Program to facilitate the technology transfer from the R&amp;D projects funded by them.</td>
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7.3.1. **Recent developments**

Two particular changes have been widely discussed with regard to China’s STI policies lately: the new approach to standardization and the mega-projects policy.

Since early 2000s, seeking not to pay huge license fees for the use of foreign platforms and create more stable markets for its own products, China’s leadership decided to elaborate a number of national and international standards where it can compete with other technologically advanced nations.

Suttmeier and Yao (2008, p. 79) see the new policy as a “middle ground between adherence to WTO norms and the introduction of measures to enhance Chinese competitiveness and ability to move up the international value chain.”

In November 2003, China made the first attempt to adopt a ‘national standard’ in telecommunications. All wireless devices sold in China in the next few years were expected to adhere to the WLAN Authentication and Privacy Infrastructure (WAPI) standard. This new specification was supposed to overcome certain security flaws found in the widely spread 802.11x ‘wi-fi’ standard developed by the Institute of Electrical and Electronics Engineers (IEEE). The friction with other countries arose when Beijing announced that access to new technology would be given to a limited number of Chinese companies, which was perceived as a breach of Technical Barriers to Trade provisions of the WTO. The conflict ended up officially in 2005 when members of the Joint Technical Committee, Subcommittee 6, of the International Organization for Standardization (ISO) and the International Electrochemical Commission (IEC) voted against the WAPI standard in favor of the new IEEE 802.11i specification (Suttmeier and Yao, 2008).

Other stories happened around TD-SCDMA, a standard developed by China together with Siemens in the field of 3G telecom; EVD, a digital video standard; AVS, an Audio Video Coding specification; digital home networking; and RFID, ratio frequency identification technology. Unlike in the WAPI case, China established international partnerships in most of these other stories involving major multinational corporations in its standard-setting endeavors. Motivation has been different in these cases: sometimes the country seeks to avoid paying hefty license fees while in other instances China was looking to address particular security concerns and promote competitiveness in particular industries (e.g. with WAPI and RFID).
In accordance with the MLP 2020, China has established a multi-level national standardization system to ensure a better transition in the post-WTO accession period and serve the major objective of promoting indigenous innovation. The Standardization Administration of China oversees the implementation of the national standards strategy and serves as the major national body representing the country in ISO and IEC. Specialized industry standards are developed and propagated by relevant government agencies and trade associations. Local governments are responsible for local standards that are supposed to be harmonized with the national and industry standards. At the bottom of the hierarchy are the enterprise standards. Suttmeier and Yao (2008) mentioned that the operation of China’s standards system involves 264 technical committees and 386 subcommittees engaging some 30,000 technical experts. 25 standardization research institutes at the national level and 158 local institutes are also subscribed to the task of developing new standards to promote indigenous innovation in China and the country’s international competitiveness.

Overall, it is still unclear whether the standards policy will be successful in promoting China’s high-tech goods and services and whether the frictions with western powers, especially the United States, around the issues of IPR protection and international compatibility and interoperability of new Chinese-based technical standards will be eventually resolved in the nearest future.

Suttmeier and Yao (2008) noted that the state has been playing an ambiguous role in these developments so far: on the one hand, China has established a multi-level national standards hierarchy to oversee the behavior of individual companies and promote national interests in the most sensitive areas (e.g. in the WAPI case); on the other hand, ministries and agencies had to play a more neutral role where market-driven standardization should have been given priority as a more effective mechanism to support domestic industry (e.g. in digital home network case).

Breznitz and Murphree (2011) suggested that the uncertainty of regulatory framework may have negative effects on innovation activity of Chinese enterprises. As rational economic actors afraid of wasting their time and resources on developing novel products that may be potentially excluded from the new standards, they may “refrain from committing to extensive, cutting-edge R&D, which is deemed both high risk and long term” (p. 30).
Since 2006, China has also adopted another instrument of building up the national innovation capabilities. The country launched 16 mega-projects in the most promising technological areas including nuclear reactors, large-airplane construction, new drugs and medicine, lunar exploration, etc. The government plans to invest US$ 100 bn in these projects by 2020 and allocates the best human resources to their implementation. Meanwhile, some projects may be lagging behind due to the lack of finance caused by the 2008 world crisis. In this context, some endeavors may prove to be more promising than the others with large-airplane construction being of the more successful examples (Liu and Cheng 2011).

7.3.2. \textit{Inheritance and path dependencies}

Since 1978, the degree of continuity in China’s STI policies has been quite high. Despite the serious political setback after the 1989 Tiananmen Square events, the country has been supporting its S&T sector quite consistently. Major programs were realized in subsequent stages and planning was implemented effectively at all levels in short, medium, and long terms.

The characteristics of the state planning system have been both an advantage and a disadvantage. On the one hand, the Chinese leadership could support high level of continuity and stability in its S&T reform and mobilize massive resources to the objectives of system transformation. On the other hand, particular political and ideological features have been holding the country back especially in the promotion of private sector and market mechanisms in the research-intensive sector. These policy path dependencies seem to prevent the incumbent leadership from introducing any drastic changes that would undermine its ideological commitments. Among others, Ahlstrom et al. (2006) noted that successful firms in China face hostility from policymakers who think they may undermine communist ideology and increase competition for the state-owned enterprises. Reluctance to dissolve unsuccessful SOEs adds up to this problem.

Theory confirms that the Chinese leadership may face serious difficulties in an attempt to launch a disruptive reform since the nation’s political system has few veto points (Pierson, 2004). Similarly, the corporatist structure of the country’s decision making process, where few large organizations dominate the agenda, may allow China to introduce incremental changes to existing commitments while making it particularly difficult to make any dramatic move (Kleiman and Teles, 2008). Also, the federal-type relations between the center and the regions make it
quite challenging to convince diverse elite groups at all levels to launch a major reform (cf. Breznitz and Murphree, 2011; Thun, 2004).

In the international arena, the bad image of China as a rule-breaker has also presented particular problems. International Intellectual Property Alliance (2012) estimated the piracy rate in records and music to be over 90% in China and in PC software the trade losses reached US$ 7.8 bn in 2010 with a piracy rate of 78%. The WAPI case is also illustrative of the challenges that China has on the world stage due to regular violations of IPR law.

Meanwhile, a lively discussion at the S.NET 2012 conference57 involving a number of senior researchers from US and European universities suggests that China’s role as a rule-breaker may eventually help the country to surpass the world leaders in future like it happened with other major empires (Great Britain, United States), who had basically to change the world system before assuming their hegemonic role.

7.3.3. System-evolutionary analysis

When interviewing Chinese policymakers, one of the most striking impressions is that they are using the same sort of terminology as western academics. This means that they are well aware of the systems thinking and are doing their best to transfer to the third-generation STI policies as soon as possible. Governments at various levels open special units on system reform where experienced bureaucrats are trying to build knowledge networks and improve innovation capabilities. Together with Chinese colleagues, the OECD delivered it Review of China’s Innovation Policy already in 2008. Many high-level researchers and policymakers have visited the US and European institutions on a scholarship program where they also absorbed particular knowledge and experience about how to guide an innovation system transformation.

Not every region in China is decisive in its innovation effort, though. Some interviewees would point at a particular imbalance between the interests of the central government that is straightforward in its desire to support indigenous innovation and provincial authorities that are more GDP growth-oriented and choose to make short-term plans with emphasis on manufacturing rather than innovation.58

57 The discussion took place on 24 October 2012 at the panel ‘Will China’s effort to become a high-tech innovator succeed?’ at the S.NET 2012 conference hosted by the University of Twente, Enschede, The Netherlands.
58 This point is also vividly supported in an extensive study of China’s innovation in Breznitz and Murphree (2011), as discussed in more detail below.
Overall, China has been pursuing strategic policies for quite some time now. Basically all seven programs of S&T development adopted at the national level since 1949 had long-term thinking and provided strategic guidelines for more operational reforms. In particular, the massive transformation undertaken after 1978 has resulted in an impressive progress of Chinese science, technology, and innovation (see section 7.2.3 for a more detailed discussion). All three components of strategic policies mentioned by Smits et al. (2010b) – incentives and programs, institutional and regulatory changes, and other actions including setting a long-term innovation agenda and planning strategic institutional transformations – seem to be in place in contemporary China.

It seems obvious that some challenges remain in the areas of science-industry links, technology transfer, demand articulation, platforms for learning and experimenting, and others; but the overall trend is quite positive. To support these developments, China is also utilizing a number of strategic intelligence tools. Among others, the Chinese Academy of Sciences is following S&T development quite closely and releases regular Foresight reviews including the recent Roadmap to 2050 (CAS, 2010a).

7.3.4. Government failures

Among the causes of government failure in China, the challenges of inadequate voluntary cooperation and policy path dependencies are becoming most visible today. Political liberalization is a growing demand amidst cautious market reforms to build up innovation capabilities and international competitiveness of the nation. The ‘Great Firewall’ cuts the general public off many ideas and developments of the western world disseminated through the Internet. The vehicle serves multiple objectives including national security and protection of domestic industry that develops a number of ‘shadow’ services including Chinese Google (Baidu), Chinese Youtube (Youku), and others (see more in Ahlstrom et al., 2006).

However, a growing number of Chinese people go abroad either for tourism or for business or to continue their studies. They absorb many western values and observe the results of technical progress and political liberalization that they may want to bring back to their own country. It is this factor that leads to inadequate voluntary cooperation and increasing discontent that had already caused a serious backlash in 1989.
Besides, continuity in public policy has brought impressive results to the emergence of China as the second largest economy and a promising technological power but path dependencies may be an important constraint in further modernization both in economy and politics.

Breznitz and Murphree (2011) mentioned several other constraints that lead to substantial government failures in Chinese S&T reform. Among others, peculiar center-region relations put at danger the national government’s initiatives to promote indigenous innovation. Judged by the economic output, provincial leaders prefer to shirk away from promoting long-term and risky innovation activity but rather support manufacturing facilities that offer much quicker returns. Oddly, some regional leaders are not accountable to the central government ministries if they occupy an important position in the Politburo, which makes every effort of professional bureaucracy useless in case they do not have enough political support in the Communist Party. Localities are also quite independent economically after Deng Xiaoping permitted them to retain a portion of their revenues in 1980, i.e. take a bigger stake in local state-owned enterprises. Although promoting local accountability and awareness, these reforms also instigated fierce competition between various regional economic blocs that led to a decrease of general policy governance as well as rapid decentralization of the country, beneficial in some ways and pernicious in the others.

In addition, the national STI policy formulation intermingles oddly with the politics of Chinese decision making. The ‘structured uncertainty’, as Breznitz and Murphree (2011) call it to signify a set of institutional and political elements that create particular challenges for the development of private enterprise and effective policy making, plagues multiple efforts to build high-technology industry and promote innovation in China. In essence, the researchers point that the current model of second-generation innovation and continuous production and process improvements, that they call the ‘run of the Red Queen’ model, is “a story of political institutions and spheres of uncertainty shaping and enabling growth, facilitating certain types of innovation and R&D behavior, inhibiting others, and being shaped via a feedback loop by the particular economic changes they initiated” (Breznitz and Murphree, 2011, p. 20). In other words, some of these problems lead to serious government failures while others may in fact

59 In more precise terms, Breznitz and Murphree (2011, p. 38) define structured uncertainty as “an agreement to disagree about the goals and methods of policy, which leads to intrinsic unpredictability and to inherent ambiguity in implementation”, and thus it is “an institutional condition that cements multiplicity of action without legitimizing any specific course or form of behavior as the proper one.”
provide major opportunities for the rapid surge of the Chinese economy in its unique institutional, social and political environment.

7.4. Summary

In this chapter, I looked at the Chinese innovation system and provided an estimate of persistence of the key factors related to the state planning S&T system to find out whether Russia and China share a number of complementarities that would allow them to learn effectively from each other.

The overall progress in innovation system transformation in China is quite impressive. The country has overcome serious flaws of the state planning S&T system and has brought research and development closer to industrial production allowing its companies to build up their innovation capabilities and compete in the world market. The level of competitiveness differs across sectors with information and telecommunications technologies being at the forefront.

At the same time particular challenges remain in some areas including: separation of research and training; uneven distribution of science and technology across regions; poor mechanisms of technology transfer; and challenges for independent science-driven entrepreneurial development. Many of these problems take root in the Soviet-type S&T system that was prevalent in China before the massive reform started in 1978 (Klochikhin and Shapira, 2012a).

Policymakers seem to be well aware of existing problems and prefer to choose policy instruments quite carefully. Sometimes they look at Europe as a source of learning (e.g. in promoting system thinking and using best practices in an environment of strong state), and sometimes they transfer policies from the United States (e.g. in supporting market-driven standards in home digital TV networking).

Third-generation STI policies seem to have taken priority in contemporary China. Policymakers are utilizing the concepts related to the systems-of-innovation approach quite regularly and are eager to learn from their western counterparts to find the best ways to support innovation system transformation.

So far, policy path dependencies have mostly served good to the Chinese government that set the major route for reform in 1978. However, a serious change in the world economy
or any other powerful external factor may prove to have quite negative implications for China
since the country’s political system may be incapable of implementing any drastic policy
transformation. Hence, stability in the world market and international political arena is critical
for success of China’s reform and its rapid catch-up with the world technological leader and the
largest economy – the USA.

An interesting argument was also proposed by Breznitz and Murphree (2011) who
consider that the massive national effort aimed at promoting indigenous innovation may
actually do more harm than good by destroying the already highly successful ‘run of the Red
Queen’ model that puts China in a very beneficial position in the new global system of
fragmented production. Although the authors argue that the model will continue to play a
positive role in national development in the long term, the issue of sustainability of such
approach is still on the agenda and deserves more thorough analysis that has not been a
particular objective of the present study.

Among others, social and political dynamics are important factors that may have
significant impact on China’s progress in the nearest future. Improving quality of life and
growing middle class are important forces pushing the country towards more openness and
liberalization including a serious reduction of ‘structured uncertainty’. The new Communist
Party leader Xi Jinping is expected to support some major political reforms but it is too early to
make any firm predictions.
Chapter 8. Nanotechnology in China

In this chapter, I provide an assessment of the early impacts of nanotechnology on the Chinese economy, society, and innovation system. It follows the structure also used in chapter 6 for Russia. Starting with a discussion of nanotechnology policy, I consider whether this novel technological area has particular transformative capacity to help China accelerate its transition to an effective market-oriented innovation system. Based on this analysis, the next chapter further compares the policies and effects observed in Russia and in China to provide a more generalized assessment of the role of nanotechnology in the transition process and improve the validity of results.

8.1. The context

Nanotechnology in China have attracted increasing attention of the academic community in recent years (cf. Appelbaum and Parker, 2008; Appelbaum et al., 2011; Tang et al., 2010; Tang and Shapira, 2011; Klochikhin and Shapira, 2012a). In recent decades, the rapid rise of China has been largely explained by massive industrialization and urbanization that turned the country into a huge manufacturing base where all major corporations hurried to open their production and, later, R&D facilities. The aspiration of the Chinese government was that multinational companies will share their knowledge and technologies with local businesses allowing the nation to take-off on an innovation-driven economic trajectory. However, these expectations largely failed together with the minor effect of the market-for-technology policy leading China to think more thoroughly about mechanisms to promote indigenous innovation (Fu et al., 2011). Among others, nanotechnology was chosen as one of the most promising areas where China can catch up quickly with the world leaders (primarily the United States) who had not have enough time yet to create a large gap with other countries (Sigurdson, 2005). Lately, this emerging technological area has deserved significant attention of the Chinese policymakers with impressive results observed over the last years. China surpassed the United States in the number of nano publications in 2010 (Arora et al., 2012).

8.2. Nanotechnology policy

China started to support nanoscience and nanotechnology development already in the 1980s and adopted a 'Climbing-up' ten-year program in 1990 to provide necessary public assistance for nano research and development. Since then, Beijing has been very consistent in
its policies aimed to ensure the country's worthy place in the emerging nano race. In 1999, the Ministry of Science and Technology launched a special research project on 'Nanomaterial and Nanostructure' – the spheres where China has already achieved substantive results. A new institutional framework was created to support the nascent nanoindustry with the National Steering Committee for Nanoscience and Nanotechnology to oversee the policy-making and implementation, and National Center for Nanoscience and Nanotechnology co-founded by the Chinese Academy of Sciences in Beijing. Moreover, a large network of research institutions and local agencies was involved into building up the country's innovation capabilities.

Two major programs were established in China after the United States launched its National Nanotechnology Initiative: the ten-year plan of National Development Guideline for Nanoscience and Nanotechnology (2001-2010) and the National Development Framework for Nanoscience and Nanotechnology. These programs were further supplemented by specific strategies adopted by the concerned government agencies and research institutions. Furthermore, they were enhanced by the more strategic Long and Medium Term Science and Technology Development Plan Guidelines for 2006-2020 issued by the Chinese government in December 2005. Importantly, nanotechnology development has become a national endeavor in China with many local universities and provincial authorities engaging into it and investing considerable amounts of money (Tang et al., 2010; Li and Jingjing, 2007).

In general, China chose the technocratic way of creating its own innovation capabilities in the nano field abandoning the view of several economists who continued to believe that the country should focus on building up its manufacturing capacity employing technology transfer from multinational corporations rather than spending huge sums of money on its own research and development (Appelbaum and Parker, 2008).

The country has also established network connections with many universities and individual researchers across the globe. For example, an extensive partnership program is sponsored by the US National Science Foundation through the Partnership for International Research and Education. Returning scientists also retain their international and personal links with the Western universities and organizations, which facilitates institutional-level cooperation like the one created between the Department of Chemistry at the University of California at Santa Barbara, the Dalian Institute for Chemical Physics, University of Science and Technology of China, and the CAS Institute of Chemistry (Appelbaum and Parker, 2008).
8.3. Impacts

Chinese successes in the area of nanotechnology have been quite impressive so far: the number of Web of Science nano papers increased from 3,245 in 2001 to 22,959 in 2010 with an average growth rate of 23.8 per cent per year (Klochikhin and Shapira, 2012a). Many institutions and programs were established to promote nano scale research and development supported by an investment of US$ 220 mln in 2006 (Tang et al. 2010). In general, China’s nanotechnology policy seems to have contributed significantly to overall national innovation development and system transformation.

8.3.1. Institutional development, knowledge flows, and network efficiency

Since 2001, China has created a number of new institutions and dedicated programs at the national and regional levels:

1) The National Center for Nanoscience and Technology (NCNST) was co-founded by the Chinese Academy of Science, Tsinghua and Peking Universities in 2004. Most interviewees names it the best center of excellence in Chinese nanotechnology and an important hub uniting many efforts and knowledge flows, especially in the areas of nanomaterials and nanobiotechnology. The massive investment allowed NCNST to install world-class equipment and attract best talent among the returnee scientists. In 2004, the Center published 13 nano papers indexed by Thomson Reuters Web of Scince while its output sharply increased over the following years to 229 publications in 2011.

2) The Tsinghua-Foxconn Nanotechnology Research Center is usually referred to as an icon of university-industry collaboration in China’s transformed national innovation system. Foxconn, a Taiwan-based IT company, have already invested RMB 300 million with further RMB 1 billion promised over the next ten years (People’s Daily Online, 2011). The center’s director Shoushan Fan has produced 78 publications and over 400 patents since 2005.

3) In 2005, China National Academy of Nanotechnology and Engineering was jointly established in Tianjin by MOST, CAS, local government and enterprises. The Academy mainly focuses on nano drugs, nanooptics, nanofilters, and nanoparticle precise classficiation (Bhattacharya and Bhati, 2011).

4) A number of development zones were established outside Beijing to promote nanotechnology growth and effective technology transfer. In Shanghai, the Nanotechnology
Promotion Center hosts a large number of small- and medium-sized enterprises and the National Engineering Research Center for Nanotechnology strives to connect nano scale research, development and production. Local scientists take benefit of these locations using their world-class facilities and establishing new networks.

5) The National Natural Science Foundation of China also established a number of nanoscience support programs including the NSFC Nanoscience Basic Research program launched in 2002 with total funding of 75 mln RMB and Nanotechnology Manufacturing started in 2008 with a total budget of 150 mln RMB (National Center for S&T Evaluation of China, 2011). This effort has been considered quite effective with an rapid increase from just over 3,100 nano papers published with NSFC funding in 2008 to 15,558 in 2011, which is a rise from 17.5% to 54.2% of all nanotechnology publication in China in just three years (Klochikhin and Shapira, 2012a).

Notably, nanotechnology has had a significant impact on international and cross-regional knowledge flows with a sharp increase of collaborations with the US and Japanese nanoscientists since 2001 (see Figure 17).

Figure 17. China’s top-5 international collaborators, nanotechnology, 1996-2011.

Source: Klochikhin and Shapira (2012a).
Inside the country, the trends were quite controversial with some regions co-authoring more with other provinces while others putting more emphasis on local effort. The latter trend should not necessarily be considered negative since the decreasing number of co-authorships with other regions may be a sign of growing local nano capabilities where certain provinces become self-sufficient and hence have gained significant benefits from the national nanotechnology policy on the whole. Notably, Beijing – China’s top producer of nano publications – has been increasingly eager to share knowledge with scientists from other regions with its share of collaborative papers rising from 26% in 2001 to 43.6% in 2011 (see Table 15).
Table 15. Share of cross-regional collaborative papers in the overall nanotechnology publication output by top-20 Chinese regions, 2001-2011.

<table>
<thead>
<tr>
<th>Region</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Average annual growth by region</th>
<th>Total number of publications by region (2001-2011)</th>
</tr>
</thead>
<tbody>
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<td>25.5</td>
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<td>30.5</td>
<td>32.3</td>
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<td>37.7</td>
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<td>40.0</td>
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<td>43.6</td>
<td>5.7</td>
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<td>30.2</td>
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<td>41.1</td>
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<td>7967</td>
</tr>
</tbody>
</table>

Source: Klochikhin and Shapira (2012a).
8.3.2. Research and education capabilities

As noted in chapter 7, China has been making a particular effort to overcome a serious weakness of the state planning S&T system that is separation of research and teaching. Universities have been given massive support to transform into genuine research institutions and attract best talent. In nanotechnology, these developments are lucidly reflected by the rapid rise of the share of higher education establishments in China’s publication output: university researchers participated in only 45% of Chinese nanotechnology papers indexed by Web of Science in 1996 while their participation soared to 89% of publications in 2011 with the number of non-university affiliations falling from 46% in 1996 to 25% in 2011 (Klochikhin and Shapira, 2012a).

In the analysis of cross-disciplinary links by subject categories in Thomson Reuters Web of Science, it is quite hard to talk about particular path dependencies in nanotechnology as compared to the earlier disciplinary preferences in China in 1991 (compare with Figure 4). Perhaps, the major reason is the rapid rise of overall national publication output over the last two decades and further re-adjustment of disciplinary maps in this time of extensive transformation and expansion. At the same time chemistry is still in the center of China’s nanotechnology effort, which is quite consistent with earlier observations. Unlike in Russia, engineering is an isolated cluster, which means that it is probably more practice-oriented than theory-laden in China and therefore may have more positive impact on technology transfer and commercialization (see Figure 18).

8.3.3. Industrial and enterprise development

Commercialization is one of the major tasks of China’s nanotechnology policies. To this end, the government has created a number of platforms to bring the results of basic research closer to the markets including Tianjin Nanotech Industrialization Base (2000), National Engineering Research Center for Nanotechnology (2003), and Nanopolis Suzhou (2010).

According to the officials of the National Engineering Research Center for Nanotechnology (NERCN), the center unites 28 member universities and companies from across China and has a mission to bridge nanotechnology research and industry through engineering research and effective mechanisms of technology transfer in five major areas: functional nanomaterials, environment, energy, biomedicine, and information technology. Among others,
NERCN has applied for 224 patents over these years, established several links with industry, and participated in the work on nanostandardization, according to the center’s officials.

Nanopolis Suzhou is a recent initiative launched in 2010 as part of the International Science Park at the China-Singapore Suzhou Industrial Park. The cluster is located in a favorable environment with extensive opportunities to collaborate with over a dozen universities and CAS research institutes that have a record in nano scale research and development. Several technologies have already been transferred to Nanopolis and were supported by the local authorities. Until 2012, the cluster has attracted over 2,700 nanotech-related experts, entrepreneurs and engineers and supported over 100 nanotechnology companies from China and abroad during the last five years. Nanopolis Suzhou puts particular emphasis on the areas of micro- and nano-manufacturing technologies, nanomedicine, and energy and clean technologies.

As a result of these and other activities, the Chinese nano market was estimated to reach US$ 31 bn by 2010 and US$ 145 bn by 2050. The number of Chinese nanotech companies increased from about 300 firms in 2001 to 800-1000 companies in 2009 (Italian Trade Commission, 2009). It was reported that most nano enterprises are located in Beijing and Shanghai, but strong clusters exist in Jiangsu, Zhejiang, Shandong and Guangdong provinces. Over 90 per cent of companies are domestic firms, of which 95 per cent are small- and medium-sized enterprises. Less than 10 per cent are foreign-invested companies mostly located in Shanghai (Bhattacharya and Bhati, 2011).
Figure 18. Cross-disciplinary collaborations in nanotechnology publications in China, 1996-2011.

Source: Klochikhin and Shapira (2012a).
The patent analysis shows that, despite consistent growth, research institutes (including universities, colleges and CAS institutes) and industry still rarely co-invent with about 4.27% of all patents co-invented by companies and research institutes in 2011 (see Figure 19).

Figure 19. Science-industry co-inventorships, as percentage of total patents by companies and research institutes in 2001-2011.

Source: Klochikhin and Shapira (2012a).

Italian Trade Commission in Shanghai (2009) also mentioned that over 80 per cent of Chinese nano companies collaborate with universities and research institutes. They establish joint research centers, share facilities, sponsor projects, do contract research, and others. Since local firms mainly focus on lower-value technology, they rarely collaborate with foreign research centers that are developing new and more advanced technology.

It was also reported that many domestic nanotechnology companies have large shares of state ownership or receive extensive support from the national, regional or local government. These firms seem to have limited incentives to innovate and put much emphasis on research and development with few marketing initiatives. This situation, together with the poorly articulated domestic demand, may lead to a waste of public money since many projects can be found non-competitive once they set off to an open market environment (Klochikhin and Shapira, 2012a). This argument is also supported by the fact that most Chinese nano companies focus on nanopowder and coatings that are a
lower-value technology derived from domestic research centers (Italian Trade Commission, 2009).

8.3.4. **Cluster and network development**

Several clusters and networks have been created in China over the last ten years. Most of them have already been mentioned here including the National Center for Nanoscience and Technology in Beijing, National Engineering Research Center for Nanotechnology in Shanghai, Nanopolis Suzhou, Shanghai Nanotechnology Promotion Center, and others. Chinese Academy of Sciences (2010b, p.52) presented a map of nanotechnology research centers: expectedly, most of them are situated in the east and north east of China while quite a few may be also found in the central and western provinces. NSD Bio Group (2009) supported that about 80 per cent of nanotechnology activity is concentrated in the north (with the center in Beijing) and in the east (centered on Shanghai).

It has been also noted that several regions have emerged most rapidly in the recent decade and tend to form the new clusters around nanotechnology activities: Jilin, Anhui, Hubei, Hunan, Sha’anxi, Sichuan, and Heilongjiang. These provinces outside the three major economic zones have become important locations for nano scale R&D with 18-41% average growth of nanotechnology publication output per year (Klochikhin and Shapira, 2012a).

8.3.5. **Regional spread**

Bibliometric analysis shows that nanotechnology effort has made a substantial contribution in promoting more even distribution of S&T activity across regions. It has already been mentioned in section 8.3.1 that the number of cross-regional collaborative papers is decreasing in some provinces where local research capabilities might have grown enough to ensure self-sustained S&T growth.

The share of Beijing – the country’s top producer of nano publications – dropped from 36% in 2001 to 17.4% in 2011 with virtually no Chinese region left without at least some nanotechnology publications today (see Figure 20).
8.3.6. Product innovation

Product innovation in Chinese nanotechnology has had mixed success like in many other countries. As was evidenced by Subramanian et al. (2010), the world has just started moving from passive to active nanostructures that would offer some more disruptive improvements to existing products. So far, Appelbaum and Parker (2008) observed that certain nanotechnology applications like self-cleaning glass and nano-paints are widespread in China. However, several interviewees mentioned that China puts most emphasis on nanomaterials rather than more complex nanostructures and nanodevices. Bhattacharya and Bhati (2011) also reported that the majority of Chinese nanotech companies (80 per cent) focus on production of nanomaterials, primarily nanometal powder, nano-compound powder, and nanooxide.

This situation creates particular tensions in terms of domestic demand and diversification of value chains, which gives certain advantages to international competitors, primarily Japan and the United States. At the same time Appelbaum et al. (2011) found that invention patents comprised 89% of all nanotechnology patents issued
by SIPO in the period between 1991 and 2006 as compared to only 33% in all patents, which suggests that China’s nanotechnology effort is focused on product applications.

8.4. Summary

This chapter provided an assessment of the early impacts of nanotechnology on the Chinese innovation system, economy, and society, similar to the one provided for Russia in chapter 6. Although the observed effects may suggest some differences between the two countries discussed in more detail in the next chapter, it seems evident that nanotechnology plays a positive role in fostering China’s innovation growth and successful catch-up. In some areas these effects are more visible than the others but all of them seem to benefit from the new policies to a certain extent.
Chapter 9. Conclusion

This concluding chapter recaps the main research questions, conceptual and empirical findings and seeks to link them explicitly to the theoretical, analytical and methodological framework. I start with a review of research questions and contributions based on the extensive theoretical and empirical discussion presented in the preceding chapters. Next, I go on to present a detailed comparison of the Russian and Chinese innovation transitions over the last twenty years after both countries embarked on the route of substantive reform. Answering the first and second research questions, section 9.2 focuses on the complementarities between national innovation systems and policies of the two countries as well as their inherent similarities based on the common state planning legacies. Section 9.2.2 answers explicitly the third research question by providing a set of specific opportunities for mutual learning between Russia and China derived from the preceding analysis. A discussion of whether the United States can serve as a good model to follow concludes the second section with a basic idea suggesting that the compatibility and complementarity of national innovation models is an important prerequisite for successful policy learning and effective technological catch-up.

The second section addresses the fourth research question and evaluates the role of nanotechnology in the strategic transformation of national innovation systems in Russia and China. This summary relates directly to the literature review and conceptual framework presented in chapter 2.

In the final sections I am providing a broader summary of this analysis as related to the conceptual implications and specific contributions of this work as well as seek to give a number of policy recommendations to make this dissertation useful both for the academic and practical purposes and increase the range of the interested audiences.

9.1. Major findings

In the course of this study I attempted to answer four main research questions as well as two sub-questions related to the role of nanotechnology in the strategic transformation of innovation systems in Russia and China. The conclusions achieved in this work are both conceptual and empirical and seek to address a broad range of problems discussed in the largely diverse and interdisciplinary research area studying
innovation as a multi-faceted phenomenon embedded in a wide range of institutional, cultural, social, political and economic frameworks.

So, in answering the first question – ‘How can Russia and China exploit their science and technology to promote indigenous innovation development and resolve the weaknesses of the former state planning system?’ – it was found that both countries share a wide set of institutional and historical legacies and path dependencies dating back to the communist era. Many features of the Soviet S&T system, which was established in Russia after 1917 and largely imitated in China after 1949, persist and create a range of path dependencies that prevent rapid transition to the effective market-oriented innovation systems in both countries. However, several strengths including good level of theoretical research and curiosity-driven (as opposed to solely market-driven) science culture make important contributions to the survival (as in the 1990s in Russia) and rapid development (as in the 2000s in China) of science and technology in transition economies. In this sense, a key conceptual finding supports that history matters and impacts the contemporary decisions and developments to much extent. Among others, persisting system path dependencies do not allow for effective reform of the Russian Academy of Science and hinder the process of turning universities into full-fledged research institutions in both countries. Similarly – despite its multiple benefits – the gradual transition route chosen by China after 1978 has already accumulated a large set of policy path dependencies and programs that are not that easy to change and terminate over time (as Rose, 1990, teaches us in his account of inheritance in public policy).

In this context, science, technology and innovation play a vital role in changing this reality as they appear to be among the major drivers of economic growth and social development in the contemporary world. Among others, the former achievements of Russia seem to lay a powerful foundation allowing the country to leapfrog particular stages of technological development in case the government finds the right route to support effective institutional development, improves legal framework and transparency of its STI policies that would open ways for effective technology transfer and knowledge diffusion. In China, the past achievements are much less in scale and scope, which prevents the country from using the existing scientific base to full extent. At the same time this current position also offers a number of positive implications including the advantages of a catch-up economy and bypass many mistakes that have already been
found in other more advanced countries (as Gerschenkron, 1962, would largely advocate).

Related to the second research question – ‘Are there any particular complementarities between the Russian and Chinese innovation that can contribute to their socioeconomic development?’ – I find that Russia and China have many complementarities that can contribute to their socioeconomic development based on multiple common features taking root in their state planning past. Several strengths of the former system allowing, for instance, to rapidly mobilize resources and direct them to big projects in science and technology are widely used by both nations and often bring good results (such as the space program in China or many positive impacts of Russia’s nanoindustry infrastructure development program, especially in the area of regional development).

Based on a number of ‘common problems’ experienced by both Russia and China in the strategic transformation of their innovation systems, it is possible to conclude there are good opportunities for mutual policy learning between the two countries in the following areas: turning universities into research institutions, increasing productivity of state-owned enterprises, constructing effective science parks, promoting indigenous innovation, ensuring more even distribution of innovation development across regions, turning ‘brain drain’ into ‘brain gain’, and improving intellectual property rights protection.

Finally, in answering the fourth question touching upon the role of nanotechnology in the strategic transformation of national innovation systems in Russia and China I establish that, although largely embedded in the historical, organizational and cultural routines, this emerging S&T area can be developed bypassing many path dependencies dependent on the policy objectives and effectiveness of implementation mechanisms. For example, Russia has achieved much success in transforming its regional innovation systems through encouraging more nano research in cities and universities that have never undertaken such work mostly due to the lack of opportunities and infrastructure. Similarly, China has been using nanotechnology to accumulate much of its S&T potential in such centers of excellence as the National Center for Nanoscience and Technology in Beijing or Nanopolis in Suzhou. In supporting this new S&T field both
countries hope to leverage rapid innovation development and commercialization through engaging into the area where no clear leader has been already established.

9.2. Innovation systems and policies

As prescribed by the method of agreement discussed in section 3.2, this study proceeds from the major notion that many challenges facing Russia and China today have their roots in the common state planning legacies that are shared by both countries. Having one starting point in the post-1949 period, the countries followed divergent tracks after 1978. Social scientists would later call them ‘gradual transition’ in China and ‘shock therapy’ in Russia (Popov, 2007).

Yet, many old problems persist and prevent both countries from taking off on a self-sustained innovation-driven growth trajectory. Existence of these ‘common problems’ provides Russia and China with particular learning opportunities in order to select the best practices ensuring smooth transition from the state planning S&T model to an effective market-oriented innovation system.

This chapter discusses historical path dependencies and common challenges shared by Russia and China, areas where both countries may benefit from a mutual policy transfer, and also other sources for learning, particularly the world technological leader – the United States.

9.2.1. Innovation system transformation

After communists came to power in 1949, China largely emulated the Soviet S&T model:

- Five-year plans became the basis of state planning and mid-term development;
- Industrial organization was substantially reshaped, especially in the military sector where massive technology transfer was observed in the 1950s involving 11,000 Soviet specialists working on site in China;
- Academia Sinica founded in 1928 was reorganized into the Chinese Academy of Sciences along the lines of its Soviet analogue;
- Science, technology and production were isolated from each other following the linear model of innovation – CAS assumed primary responsibility for basic
research, industrial institutes were active in applied research and development, and most enterprises were production-oriented with little incentives to innovate;

- Strong political involvement at every stage of the innovation process;
- The university system expanded dramatically in the 1950s with a few universities, several polytechnic institutes, medical schools and other specialized institutes under individual ministries;
- Teaching and research were clearly separated with universities playing a marginal role in scientific output;
- Socialization of knowledge to make it accessible to a wide circle of users at industrial enterprises, research institutes, higher education establishments, and overall society.

In the post-1978 era, the countries followed divergent routes and applied different instruments to ensure smooth system transformation. As a result, Russia and China have achieved quite diverse outcomes in their transition efforts and the prospects of their growth are estimated rather differently by international bodies (U.S. National Intelligence Council, 2012).

The social and political status of science and technology has been growing steadily in China over the last thirty years. The prestige of higher education has improved significantly with the growing number of university graduates and students going to study abroad. The number of researchers per million has more than doubled over the last decade.

In contrast, discontinuity in Russia’s S&T development following the destruction of the 1990s has resulted in a plummeting prestige of scientific labor and decreasing interest to the matters of science and technology. The number of universities – both public and private – has increased significantly but concerns have been raised with regard to the quality of higher education and reforms have been widely criticized.

The quality of science, technology and innovation and technology transfer remains one of the most difficult challenges facing both China and Russia on their way to integrate into the world science and international economy.
The rankings of Chinese universities have improved dramatically in the recent years particularly due to the serious effort undertaken in a number of national and regional programs. The number of publications and patents has surged. At the same time the quality of this S&T output has been questioned quite regularly. Contradictions have been also observed in the market development where private sector still faces particular difficulties. Technology transfer and science-industry links have also been developing quite slowly primarily because of some institutional barriers. Although evidenced quite good in some sectors (e.g. in ICTs – see Li et al., 2006), domestic demand has been reported to be quite poorly articulated in a number of research-intensive industries (see chapter 8 for a more detailed discussion on the case of nanotechnology).

The drastic change of economic, social and political structure in Russia following the USSR collapse was supposed to improve the market mechanisms and ensure rapid liberalization of the national economy. However, the state had no or limited opportunities to reform the S&T sector. Knowledge networks were very slow to emerge, and where they were created corruption and nepotism tainted the advancement. The major effort to transform Russia’s S&T system was launched only in mid-2000s when the government started paying increasing attention to the issues of modernization and innovation growth. As a result, the publication and patent output of Russia’s science and technology has been particularly low compared to other emerging markets, especially that the country enjoys serious S&T might inherited from the Soviet Union. The university system has undergone significant expansion in the last decades but poor quality of higher education has raised growing concerns. Private sector has been also under pressure when the system of ‘state capitalism’ was adopted in the Putin era to consolidate many profitable assets under the state ownership and establish a number of state-owned enterprises that are supposed to decrease tax avoidance and contribute to the Russian budget. Corruption and nepotism have been recognized as a serious threat to the country’s revival and effective transformation to ensure innovation-driven economic growth. Like in China, poor technology transfer and science-industry links have been a particular challenge in Russia.

In STI policy system, poor evaluation mechanisms and lack of transparency are shared by both countries. Chinese policymakers have become increasingly aware of these problems and have started to apply new schemes of bringing more expert advice into the
policy process and improving transparency of their planning. Among others, NSFC held a large-scale international evaluation of its activities and the CAS Institute for Policy and Management has been providing regular support to the STI policymaking community.

In other aspects, China has been quite consistent in tuning its STI policy system towards particular objectives of innovation transition. These objectives have been evolving over time and long-term planning seems to have been quite successful. The country is also effectively utilizing the state planning strength of massive resource mobilization for a limited number of priority areas. Several specific programs were discussed in section 9.1.2. In the military area, China seems to be free of Soviet-type path dependencies and is following a western style of research and development where military and civilian technology are developed at same facilities to ensure better learning and knowledge spill-overs.

Russia has been far less consistent in its STI policy reform in the last twenty years. Corruption and nepotism, political involvements, and rampant departmentalism have been to most notorious obstacles to effective transformation. Similar to China, Russia has been trying to utilize the Soviet strength of prioritizing major S&T mission-oriented projects through a set of federal and regional programs. However, the success of these programs has been rather doubtful with a number of corruption scandals tainting their realization. Funding of R&D activities has been also quite low compared to other emerging markets and developed countries.

The system of intellectual property rights protection is a painful issue for both China and Russia. Both countries are desperately struggling to stimulate patenting activity in their scientific and industrial sectors. While China has been quite successful in building up the amount of patents surpassing the United States in 2009, the quality of Chinese patents has been considered questionable. According to a Chinese scientist, the major problems restraining rapid progress of quality IPR in China resides in inadequate institutional and cultural frameworks rather than inadequate STI policies.

In Russia, the situation has been far gloomier than in China with low patenting activity both in industry and in science. Beside institutional and cultural barriers that largely come from the Soviet S&T system, public policies have been particularly ineffective in Russia (unlike in China). Among others, scientists complain about imperfect
tax system that makes them pay duties on an invention regardless of its utility for the national economy and any delays in production. Imperfect legislation has also resulted in a number of copyright scandals and inadequate judicial practices.

Overall, divergent transition trajectories followed by Russia and China in the recent decades have put the countries in substantially different positions in today’s international S&T and economic comparisons where the former is rapidly losing its status of a country with high innovation capabilities and the latter is emerging as a new technological superpower (see Table 16).

Table 16. Main economic and R&D indicators of Russia, China, Brazil, India, and the United States, 2009.

<table>
<thead>
<tr>
<th></th>
<th>Russia</th>
<th>China</th>
<th>Brazil</th>
<th>India</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (millions)</td>
<td>141.9</td>
<td>1,331.5</td>
<td>193.7</td>
<td>1,155.3</td>
<td>307</td>
</tr>
<tr>
<td>GDP (billions, constant 2000 US$)</td>
<td>397.95</td>
<td>2,937.55</td>
<td>856.02</td>
<td>885.43</td>
<td>11,250.7</td>
</tr>
<tr>
<td>GDP per capita (constant 2000 US$)</td>
<td>2,805</td>
<td>2,206</td>
<td>4,419</td>
<td>766</td>
<td>37,016</td>
</tr>
<tr>
<td>Gross R&amp;D expenditure (as % of GDP)</td>
<td>1.24</td>
<td>1.7</td>
<td>1.08*</td>
<td>0.76**</td>
<td>2.79*</td>
</tr>
<tr>
<td>High-technology exports (billions, current US$)</td>
<td>4.6</td>
<td>348.3</td>
<td>8.3</td>
<td>10.1</td>
<td>141.5</td>
</tr>
<tr>
<td>Export market share of R&amp;D intensive industries</td>
<td>0.17*</td>
<td>13.09*</td>
<td></td>
<td></td>
<td>15.41*</td>
</tr>
<tr>
<td>Patent applications (residents)</td>
<td>25,598</td>
<td>229,096</td>
<td>3,921</td>
<td>7,262</td>
<td>224,912</td>
</tr>
<tr>
<td>Researchers in R&amp;D (per million people)</td>
<td>2,602</td>
<td>1,199*</td>
<td>696*</td>
<td></td>
<td>4673**</td>
</tr>
</tbody>
</table>

Sources: Klochikhin (2012b), World Bank (2012).

* Data available for 2008.
** Data available for 2007.

Nevertheless, this study demonstrates that Russia and China do share a number of important complementarities in their innovation trajectories. It seems obvious that history provides a range of common problems faced by the governments of both countries and continues to play significant role in the national innovation transitions with multiple path dependencies still hindering effective technical progress. This conclusion supports the assumptions of the world-systems approach and varieties of capitalism stating that every nation is unique in its institutional and evolutionary environment and similarities should be traced back to the historical developments and studied over time.
This research also offers an effective way of applying the systems-of-innovation approach outside of the developed world. The critique of firm-centered approach seems relevant to this discussion since both Russia and China continue to have strong states with a rather marginal role of private sector in the innovation process. Besides, this research proposes a way to study innovation systems from the dynamic perspective by identifying a set of reference points in the countries’ history that would be used as a start of long-term analysis.

Broader development agenda seems to be particularly relevant to the Russian and Chinese contexts where acute social and political challenges often hinder rapid progress and technological emergence.

9.2.2. Science, technology and innovation policies

Science, technology and innovation policies continue to be a major matter of concern for both the leadership in both countries. China and Russia understand that if they want to catch up with the world leaders they have to transform their S&T systems and promote innovation-driven growth that will put them a par with other technological power. History seems to have taught both countries an important lesson: overreliance on manufacturing or natural riches will never serve as a solid basis for sustainable growth.

Complex politics and ideological commitments have been a difficult barrier to overcome on the way to efficient STI policies. However, China seems to have surpassed Russia in many extents in this area.

Chinese policymakers and academics, many of whom had a chance to study and work abroad, have largely absorbed the concept of system failure and are striving to adopt third-generation policies. In contrast, Russian bureaucrats and scientists are still struggling to transfer from first-generation linear thinking to the chain-linked innovation modeling. System thinking has been announced at the top political level but the approach has been perceived quite formally so far.

China has also successfully introduced and implemented a number of strategic policies that are guiding the country through a difficult system transition. Mid- and long-term planning is a norm at the national and regional level and mission-oriented projects are applied to resolve specific objectives relevant to the current needs. Strategic
intelligence tools are applied extensively. In contrast, Russia has been quite slow in adopting concepts of long-term development, and where it did serious shortfalls were reported like in the case of the Strategy for Innovation and Science Development until 2015 that had reached only 40% of its goals by 2010. Strategic intelligence tools are becoming increasingly popular among Russian policymakers and academics but seem to lack the large scale and regularity observed in China.

Government failures are caused by similar factors in Russia and China and deal primarily with the inadequacies of their political system. Lack of voluntary cooperation, policy path dependencies and ideological commitments are important challenges preventing effective policy making and implementation. In Russia, these factors are also aggravated by poor penetrative capacity and institutional overhead and in China, by the awkward center-region relations and ‘structured uncertainty’.

All in all, it seems obvious that despite their multiple differences Russia and China continue to face a number of ‘common problems’ coming from their similar history and shared challenges of innovation transition, as concluded in the previous section. These similarities allow for a number of opportunities for policy learning between two countries. Although originally China had emulated significant parts of the Soviet S&T system after the establishment of communism in 1949, today the nation seems to be ahead in many instances as compared to its former ‘mentor’ Russia, with the following areas presenting common problems to both nations (Klochikhin, 2013):

- **Turning universities into research institutions.** China seems to be quite successful in making way for its universities as major providers of basic research and hubs of technological development. Many programs have been aimed to establish world-class laboratories and advanced S&T infrastructure at universities (programs 863, 973, 985, and 211). As a result, most of China’s scientific output now comes from higher education institutions rather than the Chinese Academy of Sciences and other public research institutes (Zhou and Leydesdorff, 2006). The Peking and Tsinghua Universities are now both in top-100 world schools (Times Higher Education, 2012). In this aspect, Russia’s achievement has been less impressive: the country has introduced several measures to make its universities important research centers quite recently. Since 2007, eight federal and 29 national research universities were
established by transforming the country’s best schools with a large resource allocation of 24 bn roubles (US$ 0.8 bn) (Klochikhin, 2012b). However, these measures have not proven to be an effective instrument to take Russia to the science frontier yet nor they promoted the international image of the Russian universities, with only 12 per cent of all teaching staff categorized as researchers and 6-7 per cent of gross R&D expenditure allocated to the higher education sector (Cooper, 2010).

- **Finding effective ways to employ state-owned enterprises as major innovation actors.** Both countries seem to make a stake on state-owned enterprises as the major drivers of innovation growth. However, this strategy has gone through multiple failures in the recent decades (Fu et al., 2011; Klochikhin, 2012b). In 2012, Russia’s government ruled to implement a new wave of massive privatization of the federal assets in the next 5-10 years but many of the companies in the list have little to do with innovation (Gasparyan, 2012). So, both countries have to rethink their approaches and study each other’s mistakes to ensure the best possible solutions.

- **Foreign direct investment (FDI) and knowledge spillovers are not an only solution for innovation growth.** The leadership of both countries stresses the importance of FDI for the economic growth and innovation development. Yet, many pitfalls have occurred in the market-for-technology strategy of China before 2006 (Fu et al., 2011) and limited positive effect has been observed in Russia (Klochikhin, 2012b). As a result, today both nations share similar objectives of improving the mechanisms of FDI-driven knowledge spillovers and rethinking their former strategies, a process where China seems to be ahead with its zeal for indigenous innovation.

- **Development zones and special economic zones.** Both countries have been realizing the policies of establishing development zones and special economic zones to promote S&T development for several decades now. Most high-tech parks in China were established in the late-1980s and early 1990s (Cao, 2004) and Russia has a long tradition of science cities with an increasing number of new development zones and clusters established since mid-2000s (Klochikhin, 2012b). In the meantime, both countries continue to meet the challenges of poor technology transfer and low innovation capabilities of these special zones. Moreover, both nations basically impede competition by leaving the final decision on the inclusion of new firms into
the industrial parks and on the provision of incentives to the local authorities and
government bureaucracy (various interviews, 2012).

- **Regional distribution of S&T development.** In recent years, Russia has been
  supporting a variety of infrastructural developments across the entire country with
  new regions emerging as important centers of excellence (e.g. Tomsk as nanotech
  center). The government sponsored 417 multi-user facilities to provide scientist in
  most regions with high-level equipment and promote interactive learning through
  supporting interdisciplinary communication. The government also puts pressure to
  ensure that most regions benefit from new programs including the establishment of
  federal and national research universities (Balzer, 2010). Meanwhile, China has
  limited mechanisms to support S&T development in less developed provinces: few
  institutes of the Chinese Academy of Sciences are based in the west and NSFC has a
  relatively small special grant program to support scientists from these provinces
  (National Center for S&T Evaluation of China, 2011). The reason for this leeway of less
  developed regions in China is a sort of ‘vicious circle’ when the government is eager to
  provide support only in exchange for results but the successful outputs are impossible
  without extensive investment in infrastructure and industrial development (various
  interviews, 2012). Therefore, the government might choose to be more altruistic and
  invest more eagerly in infrastructure with the objective to provide more opportunities
  for local innovators who can be expected to deliver better results in future (as is
  basically done in Russia).

- **Turning ‘brain drain’ into ‘brain gain’.** China has a long history of policies to attract
  the returnee scientists who make significant contribution to the national S&T
development. Since 1978, the country has introduced a number of programs to send
Chinese students to the best western schools and make sustainable connections with
  top-level researchers to involve their country into the world science (e.g. China
Scholarship Council, One Thousand Talents program, and others). As a result, many
good scientists now work in China and publish in the best English-language journals
(Cao, 2004; Jonkers and Tijssen, 2008). On the contrary, Russia has experienced
severe ‘brain drain’ since the 1990s and has not reversed the trend yet (Graham and
Dezhina, 2008; Klochikhin, 2012a), which means that the country can potentially learn
much from its neighbor in this area.
IPR protection. Although the notion of knowledge as a public good has evident advantages of free information flows and interactive learning and has been advocated by some western scholars (Dasgupta and David, 1994; Nelson, 1959), the protection of intellectual property rights in the market economy seems critical to develop a viable private sector that is central to the national innovation system. The difficulties that Russia and China came across recently due to the poor patent systems and culture are a vivid proof of this vision. License fees and technological dominance of western corporations present a threat to the rapid innovation growth of transition economies. However, it seems obvious that both Russia and China have encountered these difficulties due to the common state planning legacy and former policy practices that have to be re-arranged to achieve better results.

9.2.3. Comparing with the United States

In a world of increasing uncertainty and rapidly converging public policies (Freeman, 2008), it may seem that any advanced country can serve as a good source for learning. In fact, the approaches pursued by various nations are substantially different, and unique historical, institutional and cultural contexts of every civilization (world-system) play a critical role in defining their development trajectories.

The United States is a liberal free-market economy that has a long tradition of self-regulated growth and competition where many problems are resolved without direct involvement of the government. In 2003, the federal government contributed 28 per cent of US R&D expenditure and performed 11 per cent of R&D activities while most support for innovation remains indirect. While some government programs are industry-oriented, many others, including several initiatives of the National Science Foundation, are aimed primarily at basic or pre-competitive research. Industry itself is responsible for the bulk of R&D activities undertaking 71 per cent of the US R&D in 2006 (Shapira and Youtie, 2010).

Some features of the US innovation system have been criticized by academics who argue that basic research must be more eagerly supported by the government because the market is largely unwilling to invest in high-risk ‘blue-skies’ research where nobody is genius enough to predict the potential outcomes (Nelson, 1959; Dasgupta and David, 1994). Russia and China have a large experience of supporting research by the state,
although proper IPR protection is also essential for their future success. Therefore, some features of IPR protection may be probably adopted from the United States.

Other practices may be also worth transferring from the United States. Among others, the SBIR/STTR (Small Business Innovation Research/Small Business Technology Transfer) and DARPA programs have been highly successful providing effective support to small- and medium-sized innovative enterprises. Bonvillian (2006) summarized the reasons for this success as flexibility, autonomy, individual focus, team- and network-building priorities and project orientation. Russia and China largely emulated the SBIR/STTR and DARPA models in the last two decades. The former established the Foundation for Small Business Support in the Science and Technology Sphere (also known as the Bortnik Fund or FASIE) as well as the science-oriented Foundations for Basic Research and for the Humanities. However, lately there was a particular setback leading to reduced funding of these institutions and questions regarding their future. In China, the Natural Science Foundation is active since 1986 and the Innovation Fund for Small Technology Based Firms was established in 1999 – both are widely recognized as highly successful and are getting increasing budgets every year.

Another achievement of the US innovation system is also quite useful to follow: the multi-faceted role of universities as knowledge hubs and centers of education and research excellence. American universities have basically undertaken a role of major innovation actors sustaining close links with industry. Today, the National Science Foundation is supporting two initiatives that link education, industry, and research missions – the Industry-University Cooperative Research Centers and the Engineering Research Centers (Shapira and Youtie, 2010). The 1980 Bayh-Dole Act was a landmark that brought university research closer to the market allowing them to have more freedom using intellectual property achieved through government-sponsored research. This law boosted up technology transfer and growth of small- and medium-sized enterprises around the U.S. universities. Recently, Russia and China have also been looking thoroughly at the American legal framework in this area and seem to have emulated some of its elements (as vividly reflected by the Russian federal law 217-FZ from 2 August 2009 that officially allowed universities to open new innovation companies and support spin-offs).
In other aspects, China has been using the U.S. market-driven approach in one of its recent endeavors dealing with the home digital video networking standards. In this case, the Chinese government chose to play a regulatory state mode rather than take an active standard-setting position allowing two alliances led by Lenovo and Haier to compete with each other for some time (Suttmeier and Yao, 2008).

Despite these instances of successful policy transfer from the United States, some more substantive factors prevent Russia and China from using the United States as a regular source for learning. The catch-up theory suggests that developing countries should better have three components to succeed: strong state, effective bureaucracy, and economic nationalism (Johnson, 1995). This argument is based on a large number of accomplished national and regional case studies involving success stories of Japan, Asian tigers and some Latin American countries. In this context, the United States that had to catch up itself in the 19th – early 20th century presents a somewhat unique case where entrepreneurship and invisible hand of the market played a crucial role in the country’s development and eventual leadership. Because of their long histories and cultural traditions, Russia and China would be probably better off following other developed and emerging economies that have already identified useful practices of catch-up and economic growth. This conclusion once more supports the arguments presented by the world-systems analysis that complicated histories and customs are an important constraint as well as an advantage that puts every nation (or world-system) in its unique position making it very difficult to copy other countries.

This vision also supports that the system failure approach to STI policy prevailing modern innovation research is probably more relevant for the Russian and Chinese context. Liberal policy instruments developed from the pure market-failure perspective seem to have demonstrated rather unfavorable results in both countries over the last two decades. At the same time the literature on government failure and inheritance in public policy helps to identify a number of critical problems that do not allows Russia and China to catch-up quickly with the world technological leaders. The work on policy learning provides a major framework for the identification of specific experiences and practices to be shared between Russia and China and seems to be particularly useful in the international policy analysis.
9.3. Nanotechnology

This section compares the major outcomes of the significant effort undertaken by Russia and China in the area of nanotechnology and links them to the existing literature discussed in section 2.4. It revisits the findings related to the assessment of transformative capacity of nanotechnology in Russia and China and its (potential) role in the process of transition towards a full-fledged national innovation system.

As mentioned, nanotechnology has deserved increasing attention by almost all large countries in the last decade. More than sixty countries have launched a national initiative or special program to support nanotechnology development on their territory. In the meantime, a particular hierarchy is starting to shape around the question of who is winning the global nano race (Huang et al., 2011).

Hullmann (2007) compared countries in terms of nano-related R&D expenditure and found that the United States is a definite leader followed by a number of European (Germany, France, and the UK) and Asian (Japan and the Republic of Korea) countries. China was ranked at the 8th place. Russia has surged among these countries quite rapidly after allocating a large sum of US$ 4.3 bn to Rusnano responsible for supporting commercialization of nanotech applications and established in 2007; the money was supposed to be spent over a few years on approved investment projects. In 2009, the country’s nano-related R&D expenditure equaled US$ 504 mln (see Table 17).

Table 17. Selected nanotechnology-related indicators of Russia, China, Brazil, and the United States, 2009.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Russia</th>
<th>China</th>
<th>Brazil</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross nanotechnology-related R&amp;D expenditure (millions US$)</td>
<td>504</td>
<td>220***</td>
<td>27-40***</td>
<td>3,700*</td>
</tr>
<tr>
<td>Nanotechnology patents issued</td>
<td>338</td>
<td>97***</td>
<td>6,729*</td>
<td></td>
</tr>
<tr>
<td>R&amp;D personnel in the sector of nanoscience and nanotechnology</td>
<td>14,500</td>
<td>260***</td>
<td>c. 150,000*</td>
<td></td>
</tr>
<tr>
<td>Number of nanotechnology publications (08.2008-07.2009)</td>
<td>c. 2,700</td>
<td>c. 20,100</td>
<td>1,071**</td>
<td>c. 21,000</td>
</tr>
<tr>
<td>Domestic market for nanotechnology products (billions US$)</td>
<td>2.7</td>
<td></td>
<td>80*</td>
<td></td>
</tr>
</tbody>
</table>

* Data available for 2008.
** Data available for 2007.
*** Data available for 2006.
In terms of nano patents, the triad countries (United States, European Union, and Japan) have been the definite leaders. At the same time South Korea, Australia and Taiwan are rapidly catching up with these nations (Wong et al., 2007). China was ranked at the 20th place of top producing countries judged by the number of nano patent applications in the United States Patent and Trademark Office (USPTO) and European Patent Office (EPO) (Li et al., 2007; Huang et al., 2003).

In the meantime, China surpassed the United States in the number of nano publications in 2010. Russia has been losing its position since 1990. In contrast, South Korea and India have been building up their strength in nano scale research in the same period (see Table 18).

Table 18. Ten most producing countries by the number of nano publications.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of nano publications 1990</th>
<th>Number of nano publications 2010</th>
<th>Number of nano publications 1990-2010</th>
<th>Rank 1990</th>
<th>Rank 2010</th>
<th>Rank 1990-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>561</td>
<td>10,959</td>
<td>95,908</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>China</td>
<td>35</td>
<td>11,904</td>
<td>65,106</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Japan</td>
<td>130</td>
<td>3,583</td>
<td>36,163</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Germany</td>
<td>138</td>
<td>3,379</td>
<td>29,366</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>South Korea</td>
<td>0</td>
<td>3,459</td>
<td>19,656</td>
<td></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>82</td>
<td>2,311</td>
<td>19,346</td>
<td>5</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>120</td>
<td>2,2</td>
<td>17,616</td>
<td>4</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Russia*</td>
<td>40</td>
<td>1,693</td>
<td>15,528</td>
<td>6</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>India</td>
<td>22</td>
<td>2,945</td>
<td>13,596</td>
<td>10</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Italy</td>
<td>23</td>
<td>1,395</td>
<td>10,576</td>
<td>9</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>


Overall, the international comparisons studying nanotechnology growth in various countries suggest that the triad countries remain at the top of the world rankings. At the same time new players (such as Taiwan, South Korea, and China) are rapidly catching up with the leaders. Although leading in the number of nano publications, China still has to go a long way to close the gap in the number of nano patents and improve the quality of publications (Huang et al., 2011).

9.3.1. Policy designs

As noted, the United States was the first country to launch a National Nanotechnology Initiative in 2000. Like many other nations, the USA certainly was
pursuing a number of other nano projects before the date (as evidenced by 561 nano papers already published in 1991). Similarly, China and Russia already made a significant effort to promote nano scale research and development in their countries before the 2000s but their large-scale national nanotechnology programs started only in 2001 and 2007 respectively, which puts China in the group of front-runners and Russia – among ‘up and comers’ (see Table 19).

The attitude towards nanotechnology differs in three countries: the United States launched its nanotechnology initiative at the presidential level and supported the program by the 21st Century Nanotechnology Research and Development Act passed by U.S. Congress in 2003. Russia followed suit and issued a presidential Strategy for Nanoindustry Development in 2007. In contrast, China has been investing in a number of sectors related to nanotechnology but has not established an umbrella national program yet. Notably, one interviewee in Beijing mentioned that the subject of uniting all nano programs under one initiative is now actively discussed among the Chinese policymakers.

Table 19. Nanotechnology policies of Russia, China, and the United States.

<table>
<thead>
<tr>
<th></th>
<th>Russia</th>
<th>China</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch of the national nano program</td>
<td>2007</td>
<td>2001</td>
<td>2000</td>
</tr>
<tr>
<td>Significance of nano component in STI policy</td>
<td>Highly important</td>
<td>One of the areas to support</td>
<td>Important</td>
</tr>
<tr>
<td>Policy design</td>
<td>Highly centralized</td>
<td>Dispersed among diverse programs and institutions, center and regions</td>
<td>Balanced: centralized coordination plus much autonomy left for the agencies</td>
</tr>
<tr>
<td>Scale</td>
<td>Several fields (mostly nanomaterials)</td>
<td>‘Across the board’ (but mostly nanomaterials)</td>
<td>‘Across the board’</td>
</tr>
<tr>
<td>Regional spread</td>
<td>Across the country</td>
<td>Concentrated in several key regions (but also supported in other locations)</td>
<td>Concentrated in major clusters</td>
</tr>
<tr>
<td>Commercialization mechanism</td>
<td>Rusnano</td>
<td>Tianjin Nanotech Industrialization Base; Shanghai Nano Promotion Center; Nanopolis Suzhou, and others</td>
<td>Issue left to policy objects (so far)</td>
</tr>
<tr>
<td>Regular evaluations</td>
<td>Annual, carried out by the Ministry of Education and Science</td>
<td>Varied (basically part of larger STI policy evaluations)</td>
<td>Triannual, independent evaluations</td>
</tr>
</tbody>
</table>

Source: Klochikhin (2011b).
As a result of different attitudes and peculiarities of respective political systems, nanotechnology has achieved varied significance in the overall STI policies. In Russia, this area has been generally considered as highly important, although a certain setback has been observed in the last one or two years. In the United States, the area has also deserved substantive investment and public attention with 26 government agencies already involved in the nanotechnology initiative (Roco, 2011). Meanwhile, in China, nanotechnology is generally seen as just one of the areas to support; in other words, the country has probably taken a wait-and-see attitude trying to keep up with the latest developments but basically playing a waiting game like the one already observed in Europe between industry and public agencies (Rip et al., 2007).

Subsequently, the scale of the national nanotechnology effort undertaken by Russia, China, and the United States differs significantly across these countries. Despite top political support, Russia does not have enough resource and innovation capabilities to support nanotechnology research and development across all disciplines and sectors and it seems to be mostly concentrating on nanomaterials that are relatively easy to develop and produce. China also lacks particular capabilities to boost up its nano effort but seems to be investing in a broader variety of sectors. The United States enjoys the status of the world largest economy and therefore develops and produces nanotechnologies ‘across the board’ with particular focus on nano medicine and pharmaceuticals, a traditional strength of the country.

In terms of regional spread, Russia seems to be quite concerned with using nanotechnology as a vehicle to improve S&T and innovation capabilities of underdeveloped regions (see chapter 6). In the United States, traditional clusters with high levels of scientific and industrial potential are definite leaders in nanotechnology output without any special effort made to improve the performance of underdeveloped states, although Shapira and Youtie (2008) mentioned that some new clusters have been emerging as a result of the National Nanotechnology Initiative. All Chinese regions have at least some nano-related activity, although major developments are still concentrated in three major clusters – Bo Hai Rim, Pearl River Delta, and Yangtze River Delta (Klochikhin and Shapira, 2012a).
Commercialization has been a major concern of all countries having their national nanotechnology initiatives. It is widely admitted that only evidence of substantial economic and social effect may justify such massive investment into the area as is done in the United States, Russia, and China. To promote rapid technology transfer and commercialization, Russia established a special Rusnano corporation; China opened several industrial clusters including Tianjin Nanotech Industrialization Base, Shanghai Nanotechnology Promotion Center, Nanopolis Suzhou, and others; and the United States left the issue to policy objects as would be generally expected in the market-driven American context.

The scheme of nanotechnology policy evaluations in Russia and China largely confirms the earlier point that the countries have rather non-transparent STI policy systems with limited effort made to improve the evaluation mechanisms. So, the Russian Ministry of Education and Science takes on the major responsibility to evaluate the federal program on nanoindustry development where the Ministry itself if the head organization and implementer (Dementyev, 2009), and China carries out regular reviews as part of larger STI policy evaluations. In the United States, there is evidently much more transparency and public deliberation: regular evaluations are carried by the President’s Council of Advisors on Science and Technology, the National Academy of Sciences, and the National Nanotechnology Coordination Office, while other organizations, e.g. Lux Research, can also contribute to the debate.

As a result of these rather different nano policy trajectories pursued by Russia, China and the United States, there seem to be limited opportunities for policy learning in this emerging area. Every country seems to be trying various instruments to support nano scale research and development and vivid divergences are observed between Russia, China and the United States. Here, the term ‘policy diffusion’ may be more appropriate to describe the process of rapid dissemination of nanotechnology programs across multiple countries. In this case, the United States is probably “too big to ignore” (Rose, 2005, p. 51), and governments may have to follow the world technological leader not to lose their opportunities to catch up later. However, prospects of the National Nanotechnology Initiative are still considered quite vague after more than a decade in action, and the U.S. Congress itself starts asking questions about the rationale of providing continued investment in nanotechnology (U.S. House, 2011; U.S. Senate, 2011). Since policy learning
is about the outcomes of particular programs rather than the mechanisms as such, this situation raises many questions about the usefulness of national nanotechnology programs in other countries where resources are much more scant than in the United States.

As an emerging technological area, nanotechnology and related policies do not seem to incur many historical path dependencies. The major constraints concern traditional clustering of research and development in several academic centers (especially in China and the United States) and a number of political particularities (including complicated relations between the regions and the center in China and a highly centralized approach in Russia). Other factors discussed in this study seem to have limited effect on the design and implementation of nanotechnology strategies, although presumably other path dependencies originating in the post-Soviet era may have a more significant influence (e.g. the particular stake on state-owned enterprises in the last five years in Russia).

9.3.2. Impacts

Both Russia and China seem to be quickly catching up with the world nanotechnology leader, the United States. In terms of R&D investment, both countries have allocated significant amounts of money to this emerging technological area, although China still prefers to play a so-called ‘waiting game’.

Multiple institutions and networks have been established in Russia and China to promote nano scale research and development. The former has encountered particular problems on the way to commercialize its achievements in the nano field although the Rusnano Foundation for Infrastructure and Education Projects has been especially successful in raising the public awareness and spreading knowledge about nanotechnologies. In China, the new institutions are well equipped and employ the best talent suggesting that nanotechnology is gaining an elite status in the nation’s science and technology. As a result, China and Russia have achieved quite different outcomes in the nano effort so far (see Figure 21 for a comparison of publication outputs).
In the meantime, both countries struggle to promote rapid commercialization and technology transfer in nanotechnology. Here, industrial and enterprise development has been quite slow in Russia and China with most projects focusing on nanomaterials that are at the low end of the nano market. Although China seems to be well ahead of Russia in the number of nano patents (see Figure 22), some studies mentioned that it is still far behind the world leaders as evidenced by USPTO and EPO patents (Huang et al., 2011).

Source: Klochikhin and Shapira (2012b).

Figure 21. Number of nano publications produced by Russia and China, 1996-2011.

Source: Klochikhin and Shapira (2012b).

Figure 22. Number of basic nano patents produced by Russia and China, 1996-2010.

Source: Klochikhin and Shapira (2012b).
The regional spread of nanotechnology activities has been improving in both countries since they launched their national nano programs. Although China shows particular improvements (cf. Figure 20), Russia’s nano effort seems to have a special emphasis to build up scientific capabilities in underdeveloped regions.

Path dependence of nanotechnology in terms of disciplinary preferences has been particularly vivid in Russia where physics and mechanics are at the center of nano scale research and development while engineering seems to be deeply embedded in theory. This situation may incur certain disadvantages compared to the disciplinary distribution of nano activity in China where chemistry is at the core of nanoscience and nanotechnology. Over the next few years it may prove that the methods of production offered by physicists and mechanists will be more expensive than the ones offered by chemists due to their different nature of experimentation and development, which will certainly provide more opportunities for Chinese nanotechnologists and industry.

9.3.3. Transformative capacity

It seems quite early to assess the transformative capacity of nanotechnology as it is still an emerging S&T area with continuing search and experimentation of best instruments and policy mechanisms to bring the results of basic research closer to the market. Meanwhile, nanotechnology policies seem to have already offered several significant improvements of the national innovation systems by promoting market-oriented culture and developing general S&T infrastructure. New institutions have been set up both in Russia and in China to promote nanotechnology, which makes it an important step forward in renovating the system. Numerous regions have been involved in the national programs with a chance to improve their infrastructure, promote industrial growth, and establish viable knowledge flows with other R&D centers.

Yet, serious problems preventing rapid commercialization suggest that the economic benefits have surfaced very vaguely so far, and we have to offer other instruments of nanotechnology assessment and foresight, such as life-cycle assessment (Shapira and Youtie, 2012), constructive technology assessment (Rip and Te Kulve, 2008), and critical systems heuristics in nanotechnology foresight (Loveridge and Saritas, 2009).
In the current situation it is still unclear who will reap the most benefits of nanotechnologies in the next few years. Some experts say that the poor will take many advantages of new products and improved capabilities (Salamanca-Buentello et al., 2005). Others suggest that although useful to resolve many development issues, nanotechnologies will remain largely inaccessible by the developing countries due to their lack of resources (Invernizzi et al., 2008).

Among all countries, Russia and China are found in a rather favorable environment where they have enough natural resources and national income to use nano scale research and development for the benefit of their economies and societies. However, corruption and system inadequacies may prevent them from distributing the benefits of nanotechnology growth among the vulnerable groups of population. Besides, smaller countries may enjoy better governance and manageability of their innovation systems that will allow them to be more competitive in their niche markets.

Strategic intelligence tools have been generally seen useful to assess the transformative capacity of nanotechnology and provide an estimate of its benefits for the future. Among others, a nanotech foresight study in Russia identified three key sectors where Russia can become competitive in the next 10-20 years: nanomedicine, nanomaterials, and energy applications. The success of these sectors is critically dependent on the development of innovation infrastructure and continuous financial support (Sokolov et al., 2009).

9.4. Conceptual implications and contributions

Policy learning can happen across time and across space (Rose, 2005). History may serve both as a source for such learning and a constraint. In any case it does matter and deserves special attention when trying to capture the dynamics of an innovation system evolution and, to some extent, predict the future.

This study has addressed a number of criticisms aimed at the systems-of-innovation approach that has gained much popularity in the study of innovation and STI policies across the world in the recent years. First of all, it analyzed the transformation of national S&T and innovation systems in China and Russia over time to be able to trace historical path dependencies and find the sources for learning and constraints in the
countries' common legacies. In policy analysis, the system-evolutionary approach was used to provide a more dynamic and strategic view of the countries’ STI policy system and assess the effectiveness of instruments used by the Chinese and Russian governments.

Secondly, this dissertation aimed to justify the use of the systems-of-innovation approach to the study of catching up economies – an approach that was primarily based on empirical evidence from technologically advanced countries and criticized for the remoteness from the context of developing countries (Lundvall, 2007). Although it is recognized that a next step is needed in innovation theory today, the approach proved to be quite useful as a heuristic to analyze the challenges and opportunities facing Russia and China today. Yet, certain limitations have been observed:

- Private firms are not the only form of social organization where innovation activities may be concentrated as the core of the national innovation system;
- Economic growth is not the only objective of innovation development while other goals of social development should also be taken into account;
- Countries differ in multiple parameters of their respective innovation systems – not only in the role and place of firms but also in entire configurations of their institutional and cultural frameworks;
- Perhaps, nations are not the best unit of analysis because innovation is not constrained by national or regional boundaries today (while policies are) – a world-systems approach may be a good alternative (cf. Delvenne and Thoreau, 2012).

Russia and China are making significant effort to improve their national innovation capabilities. Despite multiple differences, Russia and China share a number of vivid similarities that make the BRICS concept valid at least with respect to these two countries.

On the way to build up an effective national innovation system, Russia and China are facing a number of path dependencies coming from their common state planning legacies. Starting from a similar point in the post-1949 era, the countries have taken quite divergent routes after 1978. As a result of these policy differences, China has achieved impressive successes while Russia is still struggling to overcome the consequences of the ‘shock therapy’ and ‘wild capitalism’ of the 1990s.
Science and technology have gained high social and political status in China today while Russia has been losing its former achievements with other occupations coming to the forefront of prestige rankings. The quality of science, technology and innovation has been gradually improving in China (although more with respect to the quantity of scientific output rather than quality so far) while rapidly degrading in Russia (despite the country’s massive resource allocation to science and technology in recent years and quick growth of S&T infrastructure).

Where Russia and China are very similar, though, are the challenges of poor market absorption of new technologies and slow commercialization. This issue seems to be a major constraint inherited from the past that prevents Russia and China to build up their national innovation capabilities rapidly. Perhaps, the shortfalls of political system are the key reason for inadequacies in private sector and lack of desire to innovate. Many expectations are set for the nearest future with the change of leadership in China and growing middle-class discontent in Russia with both events prodding the countries’ leadership towards further liberalization.

IPR protection is one more challenge that keeps back both countries in their S&T progress. Low patenting activity, imperfect institutional and cultural frameworks are a hard legacy of the former state planning system where knowledge was generally considered as a public good and various institutes and individuals had to find other ways to protect their intellectual property. New legislatures have already been set up in Russia and China but a more significant effort is required to change the situation dramatically.

Another important similarity is lack of transparency in the STI policy systems of Russia and China. Both countries have underdeveloped mechanisms of policy evaluation and rarely use the evidence-based approach in the policy process (cf. Terekhov, 2012). At the same time China also seems to ahead of Russia in its policy reform: NSFC has carried out an international evaluation of its activities in 2011 and a number of CAS institutes, the National Science Library, and multiple universities and other research institutes provide support to the policymaking community and conduct regular studies of science and technology in China including a number of strategic intelligence tools (the most vivid
example of these activities is the recent release of a series of roadmaps to 2050 edited by
the CAS President Yongxiang Lu and published by Science Press in Beijing and Springer\(^{60}\).

Russia has been quite slow to adopt these instruments as well as proceed from the
first-generation linear thinking to the third-generation systems thinking in terms of its STI
policies. The main contradiction separates scientific community from progressive
policymakers as they adopt varied perspectives and either look to the past striving to
restore the former Soviet S&T might (primarily scientists in the Academy of Sciences) or
try to construct the future forgetting many historical roots of the contemporary system
and seeking to implement disruptive changes often regardless of potential implications
(primarily younger policymakers in the liberal environments including the Ministry of
Economic Development or Agency for Strategic Initiatives).

In the systems with such strong role of state as they are, China and Russia
experience serious government failures. Inadequate voluntary cooperation and
institutional overhead are probably the critical barriers impeding rapid system
transformation in both countries. The massive inflow of qualified talent in China is
probably compensating for another important failure that is inadequate penetrative
capacity while Russia is still struggling to transform the thinking of its policymakers and
improve the governance of its innovation system. Policy path dependencies do not seem
to present serious challenges in both countries, although both theory and practice
support that it may be especially difficult for Russia and China to implement disruptive
changes if they come across particular impasses in the process of their innovation system

As Rose (2005) prescribed, many of these ‘common problems’ shared by Russia
and China through their similar state planning legacies provide a number of opportunities
for policy learning between these two countries. Turning universities into research
institutions, finding effective ways to employ state-owned enterprises as major
innovation actors, rethinking the role of FDI in the innovation transition, establishing
effective development zones and special economic zones, improving regional distribution
of S&T activities, turning ‘brain drain’ into ‘brain gain’ and reforming the IPR protection

\(^{60}\) See more details at http://www.springer.com/economics/r+%26+d/book/978-3-642-04822-7.
system are the key areas where countries can share experiences and work together to identify the best practices supporting quick system transformation.

Nanotechnology is an emerging S&T area that provides limited opportunities for policy learning. It is obvious that the United States is “too big to ignore” (Rose, 2005, p. 51), and many nations are following the leader to establish their own nanotechnology programs. Due to its explorative nature and unclear outcomes, it is very difficult to predict where nano development will go in the near future. In the meantime, this area has already proven to be independent of many historical path dependencies with the traditional regional clustering of S&T activities and political system peculiarities being, perhaps, the only constraints of the new policies.

Furthermore, Russia and China have taken quite different approaches in their nanotechnology strategies that have already resulted in rather diverse outcomes. Although the impacts of new policies have been quite positive in some areas including better distribution of S&T activities across regions, institutional development and network growth, and industrial and enterprise development, the observed effects have been rather marginal with a mix of other programs and policies contributing to these developments together with the nano efforts.

In both cases – broader STI policies and nanotechnologies – the United States remains an important nation to watch but probably not the best example to follow. The USA is a liberal free-market economy where many problems are resolved without direct involvement of the government (either federal or state). Competition and self-regulation are the main principles that allow the nation to retain its leading positions in many market segments. Market failure has proven to be an effective rationale for public action in the United States with the systems-of-innovation approach gaining popularity over the last decade.

Meanwhile, both Russia and China have a long tradition of strong state that is involved in virtually every sphere of economy and social life. Moreover, Johnson (1995) prescribed in his meticulous study of Japan that a catching up country should better have three components to succeed: strong state, effective bureaucracy, and economic nationalism. In this scenario, the US liberal model may indeed prove to be rather harmful.
9.5. Policy recommendations

A number of policy recommendations have come out of this study and seem relevant to both Russia and China in their transition stages. These can be divided into the following categories:

A. Need for more democratization and transparency of the science, technology and innovation policy making process with broader involvement of the academic community and wider public.

As discussed throughout this study, the STI policy system supports limited involvement of the independent expert community and lacks transparency. As a result, this situation raises the problems of corruption and elitism of the policy making process, which should be resolved to ensure further progress of innovation growth in China and Russia.

The potential solution seems to be two-fold:

a) involvement of a bigger circle of university researchers and think-tanks into policy consultation and evaluation; and

b) establishment of an independent agency that would openly present the interests of the academic community at the top political level.

The former will permit to break the ‘personal access’ scheme and create a competitive environment for the policy studies in Russia and China that will promote more transparent evaluations and more attention to the quality of academic work.

Among others, Nature (2012) suggested establishing a special advisory board in Russia, ideally to include foreign experts. As mentioned above, this way has already been followed by the NSFC and the international evaluation report was hailed by the academic community, but the impacts of this foreign involvement are still to be seen at the policy level.

Besides, the establishment of an independent agency to represent academia at the top political level seems to be an important tool in ensuring that the interests of the academic community are properly articulated at the national level, and will also allow for the creation of an effective feedback mechanism for the government that can eventually improve the policy governance and give more control over the directions of scientific
development with a more open exchange of ideas and problems between the academic and policy communities. The major requirement for this measure is to ensure independence and democratic nature of such agency, which would be ideally funded directly from the national/federal budget and would be elected by the scientific community itself (e.g., by the General Assembly of the Academy of Sciences that has already proven to be quite independent in Russia on several occasions).

B. Urge to introduce better legislation and regulation for the innovation process.

It was amply discussed here that there are a number of shortfalls in the areas of intellectual property rights protection, funding mechanisms for innovative enterprises as well as general legal environment for the innovation-based growth in Russia and China.

In order to improve the situation, the government has to create more incentives to stimulate patenting activity by the research institutes and private companies to ensure smooth technology transfer and commercialization of basic research. Such policy would basically require a change of the entire IPR culture that was significantly different in the state planning economy. It seems imperative to promote applications to the patent organizations in the developed countries such as the European Patent Office and the US Patent and Trademark Office, which will ensure the competitiveness of national technologies in case the patents are granted to the Russian and Chinese assignees.

Although there is already a number of relevant policies in place to subsidize the international patent applications and transfer intellectual property from public institutes to the spin-offs or other companies, several interviewees in China and Russia mentioned relative inefficiency of these measures and an urge to design more transparent procedures to identify the companies and scientists who can get special support from the government. (Among others, such measures would include a better scheme of technology assessment that needs to involve a bigger circle of experts and independent consultants).

In addition, the government has to play down its role in controlling the financial flows and adopt a better regulation that would allow for easier circulation of venture capital and other forms of investment into the risky innovative projects. It may be difficult to implement this politically but a better legal environment can be an important step forward.
C. More attention to the development of private sector and reducing the role of the state in the national economy.

It is not the private sector that is important by itself but the competition that comes with a free market economy and seems to be essential for successful innovation development. State-owned enterprises both in Russia and in China usually enjoy a monopolistic status and stable subsidies from the national government, which makes them somewhat relaxed and uneager to innovate at a fast pace because the risks of change seem to be higher than the potential rewards. In the meantime, private firms are the core of a national innovation system not so because of their unique nature and structure that allows them to innovate more efficiently and learn faster but due to the rapidly changing and competitive market environment in which they have to work and excel. Hence, a possible explanation for Russia’s lagging behind in industrial innovation and productivity that is: serious lack of competition in the domestic market and low penetration of foreign companies and foreign direct investment (as also noted in McKinsey, 2009). Therefore, it seems valid to assume that state-owned enterprises can also be a good vehicle for innovation growth if they are put in a highly competitive environment but both Russian and Chinese experience shows that the governments are quite reluctant to push up the competition for the publicly owned companies, which leads to their strident inefficiency.

Among others, it must be a good measure to make a stake on producing domestic S&T equipment in the current transition stage of Russia and China. There are two reasons for that: first, S&T equipment is usually the most advanced machines and devices that are produced at the world’s technological edge to ensure that scientists come up with significant results and work at the science frontier. In this sense the creation of a domestic instrumentation industry can pull forward the entire innovation sector of China and Russia because it will produce multiple knowledge spillovers and increase the competence of domestic enterprises in research and development (provided that proper networks are established not only between S&T equipment producers and scientists but also between the instrumentation industry and other business sectors). Secondly, domestic production of S&T equipment will reduce the dependence of the national innovation sector on the more advanced countries and can serve the goal of promoting indigenous innovation. As history shows, the USSR lagged behind its competitors in the
1980s for a number of reasons but, most importantly, due to the trade embargo from the western countries who stopped exporting scientific instrumentation into the Soviet Union creating a vacuum in promoting basic research and development (Balzer, 1989). Several interviewees in China also mentioned that the topic of producing domestic S&T equipment is high on the development agenda today.

To promote science-industry links and technology transfer, the governments should support the emergence of special brokers/network organizers to facilitate the knowledge flows and exchange of intellectual property. The functions of such brokers may be fulfilled either by the state (e.g., through more active and possibly reformed government-supported technology transfer centers that are already established in both countries and through the publicly organized expos such as the Rusnanoforum but of more frequency and deeper specialization) or by special private service companies such as idea scouts and venture capitalists (both underdeveloped in Russia and China due to the strong role of state). Regionally, the Beijing-Guangdong axis may be a promising channel of effective technology transfer in China due to the varied institutional and market environments of these provinces to connect the Bo Hai Bay Area scientific capabilities and Guangdong’s entrepreneurial activity (Tagscherer et al., 2012).

Finally, the demand for innovative products in the internal market must be supported more efficiently through special incentives for domestic enterprises and public procurement. These areas are still underdeveloped in both countries (OECD, 2008; Radosevic, 2011). One of the major requirements for future policies would be to create full-scale value chains in the internal market so that both components and final products are assembled domestically.
References


Ministry of Education and Science of the Russian Federation, 2009. Order No.276 on indicators, criteria and regularity of the evaluation of the efficiency of the program implementation for the development of universities that were given the status of the “national research university”, 29 July 2009.


People’s Daily Online (2011). Foxconn to donate 1 billion yuan to Tsinghua University, 14 April 2011.


RIA Novosti (2012). Foreign colleagues are not interested in Russian nanotechnology articles, 6 March 2012.


Shapira, P. and Youtie, J. (2010). The innovation system and innovation policy in the United States. In M. Frietsch and M. Schuller (Eds.), *Competing for global innovation leadership: innovation systems and policies in the USA, EU and Asia*. Stuttgart: Fraunhofer IRB Verlag, pp. 5-29.


TV Rain (2012). Every sixth businessman in Russia has been in jail (in Russian), 6 April 2012.


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Appendix. Information on related peer-reviewed publications.


**Abstract:** For the last twenty years Russia has been struggling to turn itself into an efficient market economy. Innovation and technological development are considered to be one of the best ways to achieve impressive results. The country has succeeded in retaining certain strengths of the Soviet science and technology system but it has often failed to address the former weaknesses and emerging challenges. There are a number of external and internal factors that make reforms inevitable and urgent. In the last five-six years the political leadership has started an unprecedented attempt to reverse the negative trends and boost Russia’s innovation performance. This paper studies the new policy approaches and suggests several others that might be considered useful at this stage of the country’s development. This work contributes to the wider debate on the heterogeneity of national innovation systems and adaptation of the respective analytical approach to the study of technological development of the emerging economies. It also provides a detailed review of the literature and data sources on the Russian science and technology, and aims to start filling in the gap in this seriously understudied research area.

**Web URL:** [http://dx.doi.org/10.1016/j.respol.2012.03.023](http://dx.doi.org/10.1016/j.respol.2012.03.023).

**Relation to this study:** This paper was produced on the mid-way to this final dissertation and is a result of extensive literature review and historical analysis. This article helped me to frame the present study and identify the exact research questions that I am addressing here. The theoretical contributions of this paper guided me to the proper understanding of the strengths and weaknesses of the systems-of-innovation approach and its practical applicability to the context of emerging economies with a way to adapt it as a useful heuristic to the study of innovation transitions in Russia and China.

**Abstract:** China and Russia – two giants in the group of emerging markets – continue to attract wide attention as emerging science and technological superpowers. Both countries demonstrate mixed success in innovation development and are struggling to overcome the legacies of the former state planning system and accelerate their transition to effective national innovation systems. This study evaluates the existing path dependencies and compares the achievements of China and Russia. It is suggested that there are a number of policy complementarities and opportunities for mutual learning between the two nations especially in the areas of: university reform, cluster development, and increasing productivity of state-owned enterprises. The case of nanotechnology policies offers an interesting and somewhat contrasting view.

**Web URL:** [http://dx.doi.org/10.1093/scipol/sct021](http://dx.doi.org/10.1093/scipol/sct021).

**Relation to this study:** This latest paper is a result of my continuous intellectual development throughout the PhD program and relates significantly to this dissertation. The article touches upon the issues of policy learning and compares national innovation systems of Russia and China in much detail. Although many ideas are already put forward, this dissertation takes them to a new level of aggregation and provides a more comprehensive comparison due to the wider scale and scope of a PhD project. Besides, this article does not pay as much attention to the transformative capacity of nanotechnology as discussed in the present study.

**Abstract:** Nanoscience and nanotechnology—involving the engineering of materials, devices, and systems at very small scales—have emerged as important priorities not only for science but also for economic development. In this article, we propose an analytical framework that considers the socioeconomic effects of nanotechnology in six key areas: institutional development, knowledge flows, and network efficiency; research and education capabilities; industrial and enterprise development; regional spread; cluster and network development; and product innovation. We apply this framework to assess the early impacts of the evolving domain of nanotechnology for development, with a focus on China and its transitioning economy, where nanotechnology is assuming an important role in breaking existing innovation system lock-ins and historical path dependencies. We suggest that the analytical framework adds value in assessing the developmental impacts of new technologies and could be used to probe such impacts in other countries and locations.

**Web URL:** [http://dx.doi.org/10.1111/j.1541-1338.2012.00596.x](http://dx.doi.org/10.1111/j.1541-1338.2012.00596.x)

**Relation to this study:** This paper co-authored with my main supervisor Professor Philip Shapira seeks to test the six-impact framework to provide an assessment of early impacts of nanotechnology on China’s innovation development, economy, and society. In this study, I am using several findings presented in the paper as well as extend my analysis to Russia where I am providing similar analysis to lay the foundation for effective comparison and valid conclusions in chapter 9.

**Abstract:** Innovation-based growth has become an important policy objective for emerging markets these days. By fostering innovation they seek to increase their competitiveness, boost their economies and achieve wider development goals. The BRIC countries have adopted various mid- and long-term strategies that will allow them to reach these aims. However, they face multiple challenges on the way to realising them. This article looks at one of the BRIC giants, Russia, which is considered to be one of the most promising economies in the contemporary world. It invests ample resources into its 'Five I's' - institutions, investment, infrastructure, innovation, and intellect - with the major goal of re-building the national innovation capabilities. Meanwhile, many obstacles hinder stable progress and postpone the country's ascension into the group comprising the world's leading economies. Major implications include the need to significantly improve policy design and policy governance as well as develop a firm-centred innovation system.

**Web URL:** [http://inderscience.metapress.com/content/n8w8l31741853357](http://inderscience.metapress.com/content/n8w8l31741853357).

**Relation to this study:** This paper is a result of substantive empirical work based on extensive literature review and documentary analysis. It provides a detailed analysis of contemporary STI policies in Russia and studies them through the prism of ‘Five I’s’ – institutions, investment, infrastructure, innovation, and intellect – a framework proposed by President Medvedev in 2008. The ‘Five I’s’ have been guiding the Russian innovation policy for the last five years and provide an opportunity to evaluate the major instruments utilized by federal government to foster innovation growth.

The particular relation to the dissertation consists in the empirical guidance and evidence about Russia’s innovation development that is useful for the PhD project. Although I do not use the analytical frameworks applied in this earlier work, they have allowed me to structure the available evidence accordingly and present it in a more fluent way here.

**Abstract:** Recently, there has been a popular trend in academic research for paying more attention to ‘pro-poor’ policies and theoretical studies. This tradition has emerged from a broader understanding of development that includes not only economic but also social and political dimensions. Meanwhile, innovation researchers are still considering development as mere economic growth without much focus on the social impacts of technological change. This article recognizes that, despite these fundamental differences, the concepts of innovation and development have much in common and are, in fact, positively connected and mutually beneficial. This assumption has some important implications for the innovation and development of policy-making process. The article concludes by arguing that the new cross-disciplinary approach is required in order to answer the questions posed here in a more meticulous way.

**Web URL:** [http://dx.doi.org/10.1057/ejdr.2011.20](http://dx.doi.org/10.1057/ejdr.2011.20).

**Relation to this study:** This article is my first peer-reviewed publication providing a conceptual framework for the analysis of innovation-development link in the broader socioeconomic and political context. It relates directly to section 2.3 of this dissertation but focuses primarily on the subject of ‘pro-poor’ innovations that is more topical to the group of less developed countries. Therefore, in this study I am putting more emphasis on the problems relevant to emerging markets and transition economies while playing down the pure development agenda not to interfere with the main argument of this research and deliver it in a logical way.