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Enabling innovation in extractive industries in commodity based economies

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As dependence on the extraction of natural resources seems inevitable in the short- and even medium-term perspective, commodity based economies will face the need to increase the sustainability and profitability of their extractive industries. This paper sets out to analyze the R&D policies of Brazil, Russia and South Africa, and benchmark them against the sizeable and innovative extractive industry of Canada.

Although the countries in our sample have similar economic features, we stress the differences between their social and economic stage of development. The particularities in each country's economic situation at times correspond with a different policy mix. Besides that, there are not many differences in the innovation policy instruments used in an economically advanced country vs. fast-growing economies. Rather, it is their synergy, governance, targeted design and application that make the difference.

Keywords: extractive industry; BRICS; competitive advantage; policy; Research & Development

All around the world, the recent financial crisis triggered massive government spending as economic stimulus investments to tackle the effects of the global recession; most of this was spent in 2009 and 2010. Only a limited portion of this money has found its way into R&D. Although Europe and the US have shown decreasing R&D levels over the past 2 years, it seems that emerging markets all over the world are catching up fast with developed nations.

Some countries, like Australia, Canada, New Zealand, Norway and Sweden, managed to derive a great amount of national wealth out of their mineral deposits and could convert this into sustainable economic growth, accumulation of capital and the improvement of the technological base of the countries. Studies have demonstrated that the accumulation of domestic technological capabilities, together with a favourable institutional environment and the presence of technology-intensive suppliers and specialized knowledge-intensive services, had strongly improved production organization capabilities (Bigsten, 2001; Katz, 2006; Pirela, 2007; Porter, 1990; Ramos, 2001).

The major commodity producers in Sub-Saharan Africa and Latin America, on the other hand, have suffered from the 'Dutch disease' (Martin, 2002; Matsuyama, 1992; Stevens, 2003) and did not succeed in turning their rich mineral deposits into lasting economic success. Their secondary sectors declined in favour of an ever-increasing primary sector and their economy became directed towards food production and the exploration of mineral deposits (Katz, 2006).

Extractive industries, like all low-tech industries, are characterized by low R&D intensity. However, low-tech and medium-low-tech (LMT) industries employ a large portion of the workforce, even in many OECD countries. Also, many companies are innovative and knowledge intensive without engaging in substantial R&D activities by themselves. Supportive policies, therefore, 'should encourage both the generation of knowledge and its diffusion between low-tech and high-tech sectors, and they should also promote stronger interrelationships between the sectors' (European Commission, 2006).

The focus of the paper rests on the policy mix aimed at increasing innovation activity of extractive industries in the four selected countries (Brazil, Russia, South Africa and Canada) and on a cross-country comparison. Our research question asks: Which policy mix did commodity-based emerging economies in the years 2008–2010 choose to best support increasing innovation activity of extractive industries? However, policy makers rarely target the extractive industry per se. Therefore, this paper firstly describes the policy systems in place that affect the extractive industry in each of the countries. Secondly, we analyze the policy mix in place, taking into consideration the particularities of the national economies and compare them with each other. It was not our intention to rank countries or their extractive industries, but to point out those areas where marked differences are found, as well as reasons for possible future failure or success.

This paper is structured as follows: after the introduction, there is a description of the policies and reforms regarding the extractive industry in Brazil, Russia, South Africa and Canada. The last country case is written as a benchmark for the three BRICS countries, followed by a chapter with a cross-country comparative analysis. In a second step, the policy settings are compared with key economic indicators as a basis for analysis. The paper concludes with a discussion of the salient points arising from the cross-country analysis that address the research question.

Methodology and data

The economies of Brazil, Russia and South Africa are strongly driven by the extractive industries. Innovative production methods may reduce the costs of extraction and production and, thereby, maximize earnings for the mining companies. This, in turn, would allow for higher taxes or higher wages for the workforce. Therefore, governments of fast-growing economies dependent on commodity exports should be interested in boosting technological innovation in extractive industries. It is in this sphere that underused opportunities for strengthening the competitive advantages of these countries, in the near future, lie. In addition, we include Canada with its sizable and innovative extractive industry to offer a perspective for benchmarking.

We used macroeconomic indicators as a proxy for entrepreneurial activities. Unfortunately, data on business R&D expenditure and innovation activity in the mining sector was not available from any major international statistical data producer for the four selected countries. Innovation activities are defined following the harmonised OECD/Eurostat definition as 'all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovation'; these also include R&D that is not directly related to the development of a specific innovation. We explicitly do not include existing supranational regulation mechanisms, like multilateral environmental agreements,[1] in this paper. The data that was consulted in the paper is produced by major international statistical agencies, like the OECD Statistics Directorate and Eurostat[2].

Country cases

Brazil

Since Da Silva became head of the government in 2003, the once liberal minimalist state has changed and now plays a major role in the world economy. The present policy of the government aims at improving Brazil's competitiveness through innovations, which required the creation of two new institutions: the National Council for Industrial Development (CNDI) and the Brazilian Agency for Industrial Development (ABDI). In addition, the existing organizations and agencies have been overhauled, like the National Financing Agency for Research and Projects (FINEP), the National Development Bank (BNDES), the National Institute of Metrics (InMetro), and the National Institute of Industrial Property (INPI).

The Ministry of Science and Technology estimates that 70% of R&D expenses are financed with public resources, while the business R&D expenditure remains rather low. The goal for 2010 investment/GDP indicator was set at a target ratio of 21%. Private companies are planning to increase R&D spending in 2010 (business sector R&D/GDP to 0.65%). Eighty percent of

[1] For example, the Montreal Protocol and the Expert Group on Technology Transfer (EGTT), Clean Development Mechanism (CDM) and the Global Environment Facility (GEF) under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC).

[2] Organisation for Economic Co-operation and Development [OECD] (n.d.) http://stats.oecd.org; United Nations Environment Program (n.d.) http://epp.eurostat.ec.europa.eu

Brazilian researchers are concentrated within public institutions (universities or research centers).

The National Plan for S&T and innovation is targeting the innovation policy, and US$ 20 bln has been allocated in its development (Finpro Brazil, 2008). The National Development Action Plan 2007–2010, issued by the Ministry of Science and Technology, sets a number of target indicators of enterprises' innovation activity, including increasing private R&D expenditures from 0.51% of the GDP to 0.65% by 2010. To effectively provide incentives to companies, Brazil has integrated different instruments and expanded financial support, such as R&D contracts, loans or venture capital. Other state measures aimed at institutionalising the state–business dialogue include competitiveness for a development institutions, chambers and working groups. New goals and instruments in cooperation with the private sector are in progress, including means to monitor and evaluate progress.

For increased innovation activity, the National Plan for S&T and innovation identifies the key technology areas and previews a number of policy measures concerning excellence, relevance and management of research in universities. To achieve the enhancement of business innovation and consolidation of the national innovation system, the plan breaks down four strategic priorities into 21 action lines and 88 programmes and policy initiatives.

The National Plan for S&T and innovation budget covers approximately USD 20 bln, and is supported by a mix of incentive measures like fiscal-financial and public procurement, as well as technical support and an agreement on joint goals for public and private sectors. The Program for Accelerating Growth (PAC) is aimed at overcoming infrastructure bottlenecks. Advancing innovations and attracting investments for sustainable growth is planned in the Productive Development Policy (PDP). The Action Plan on Science, Technology and Innovation (PACTI) program is oriented towards the promotion of innovation and science and technology development.

Specialized government agencies are set up in Brazil to support the creation and commercialization of knowledge (e.g., CNPq, FINEP, BNDES). Promopetro, for example, is a fund directed towards innovative projects for educational institutes to ensure the supply of desperately-needed key personnel in the areas of petroleum and gas, biocompostives and petrochemistry. FINEP also operates sectoral funds, like CT-Mineral. This fund supports SMEs in the extraction of minerals on Brazilian territory and in the acquisition of technical scientific knowledge. A similar fund, CT-Petro, exists for the petroleum industry. Its main objective is to stimulate productive innovation in the field of oil and gas, in the creation of human capital and the cooperation between companies and universities. The CT Petro resources are formed from royalties for mineral rights, which vary in Brazil from 5 to 10% of gross production.

Extractive industry companies could also make use of the Innovation Law adopted in 2004, which was meant to provide incentives for business innovative activity, as well as to encourage scientific and technological research by enterprises. The law also promotes the establishment of cooperation between public R&D institutions and enterprises and regulates the use intellectual property resulting from such joint activities, and provides the legal framework necessary to invent and commercialize technology.

The new institutions and policies will most certainly have a positive impact on the competitiveness of Brazilian business, including the extractive industry enterprises. Yet coordination, management, and evaluation are still weak. Another weak spot is the small number of innovative companies.

Despite the availability of diversified financing tools, funding for innovation-oriented research is often unavailable to business. Another major stumbling block is the concentration of R&D human resources in the public sector, as well as a noticeable lack of a cadre in engineering. As a consequence, the Annual Report on Competition Policy Developments in Brazil concluded in 2009 that the Brazilian Competition Policy System continued to suffer the same problems of scarcity of financial, human and material resources faced in 2008 (Organisation for Economic Co-operation and Development [OECD], 2010a). These problems are likely to remain.

The Russian Federation

Russia is rich in natural resources and ranks first in the world by the volume of explored reserves of natural gas, iron ore, coal, fossil linen, zinc and some other natural resources. The revenues from oil and gas mining activity form the bulk of federal budget revenues, which are projected to grow up to ~USD 254,533.62 bln by purchasing power parity (PPP) in 2010, which equals 8.3% of GDP or ~48% of the federal budget in 2010.

In 2008, Russia had 451, 000 researchers and the world's largest number of R&D personnel. The country had a high graduation rate of 53% in first university type-A degrees, well above the OECD average of 38%. (OECD, 2008). However, nearly three-quarters of organisations conducting R&D are state-owned and more than three-fourth of all R&D personnel work in state-owned R&D organizations.

Until 2008, the favourable market situation, macroeconomic and political stability allowed for the development and implementation of a wide range of measures to put together a modern national innovation system. This approach was laid out in key documents of state policy adopted in the year 2000 (Government of the Russian Federation, 2008; Ministry for Education and Science of the Russian Federation, 2007; President of the Russian Federation, 2002). The current list of Russia's S&T priorities was approved by the Russian President on July 7, 2011, and includes eight priority areas (President of the Russian Federation, 2006) among which are energy efficiency and energy saving.

The key task of Russia's Energy Strategy – 2030 is bringing the energy sector onto an innovation-based development path. The approach to this sector's innovation program, proposed by the strategy, features a number of priority directions, including the creation of leasing companies for the provision of advanced technologies and equipment; stimulating economic motivation of SMEs in the energy sector with due consideration of sectoral characteristics; the undertaking of innovative production; promotion of the re-equipment and innovative development of enterprises; and the organization and support of vocational training of all categories of staff (Government of the Russian Federation, 2009b).

In 2010, issues of energy production, transportation and use were named by the President as being among the five priorities for modernisation. To consolidate efforts of various state agencies in this area, a new Department for Science, High Technologies and Education was set up within the Government's Executive Office.

Gross domestic expenditure on R&D (GERD) had been steadily growing over the decade before the recession of 2009, bringing Russia into the top 10 countries in the world by this indicator (measured by PPP). In 2008, of the total volume of GERD in the priority areas of science and technology development, approximately 10% of all GERD, was allocated for energy and energy saving. Importantly, a mere 5.1% of this amount was allocated from the federal (state) budget and the rest came from other, including private, sources (European Commission, 2010).

The country's economic structure is characterized by large companies and a concentration on mining and heavy industry[3]. Moreover, the Russian S&T business enterprise sector is mostly represented by firms and organisations that are under direct or indirect government influence (for instance, through controlling shareholdings). Likewise, most of extractive industry firms in modern Russia are either fully state owned or partly owned and closely supervised by the state.

The 2009 Russian stimulus plan urged large Russian enterprises with state ownership, first and foremost energy sector companies, to develop and introduce corporate innovation strategies that would cover energy efficiency measures. Innovative energy-efficient technologies were named an important part of technological innovation in the economy as a whole. Among specific stimulus measures introduced in 2010, from which enterprises of the extractive industry may benefit, are long-term programmes (technological policies) by the state and partially state-owned companies and fiscal stimulus measures for modernisation and innovation activity, including tax incentives (i.e., widening the spectrum of R&D costs, which may be deducted from the taxable income).

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[3] Only 0.4% of the total number of small enterprises were registered in the extractive sector in 2008 (Russian Federal Service of State Statistics, 2009)

As an anti-crisis measure, the Government introduced system of budgetary grants (subsidies) for enterprises operating in priority innovation areas, including R&D, new samples of industrial products, and compensation of the costs of patent registration abroad. Of particular importance for large state-controlled extractive enterprises is the obligation for companies with state ownership to put together an innovative development programme, which should meet the requirements set by the Russian Government. In another programme, launched in 2010, companies are obtaining state vouchers to buy research services from universities under the conditions of co-funding (Government of the Russian Federation, 2009a, 2010).

The volumes of all key natural resources (oil, gas, coal) extraction have shown a tendency toward steady growth since 1995. At the same time, labour productivity at these enterprises has only somewhat increased[4], while the turnover has increased more than twofold. Certain indirect indicators, such as decreased water consumption and waste water disposal, show that hydrocarbon extractive industries increasingly use 'green' technologies, while non-hydrocarbon extractive industries continue using more resource-intensive technologies.[5] The major part of country's exports is constituted by commodities, which have not undergone any technological changes (Ministry for Education and Science of the Russian Federation, 2009).

Despite the intention of the Russian Government to diversify the economy and opt for an innovation-based growth path, the federal budget will still be dependent on oil and gas revenues in the short and medium-term. The predominantly state-owned and state-controlled extractive industry companies require centralized policy measures to launch green innovations. These obligatory measures were introduced as part of anti-crisis programmes and in the post-crisis period. For internationally listed companies, international standards and a good image in the eyes of their foreign partners also serve as motivators for going green. We note that shortly after the crisis, extractive sector enterprises regained a high profitability level, but these profits have generally not yet re-invested in innovation. The Russian government has put in place a range of economy-wide government policies, aimed at stimulating R&D and innovation for the benefit of the private sector. The extractive industry companies will benefit from these measures, in the event that they will be properly implemented.

South Africa

Up to 1990, South Africa had reached an R&D intensity level of 1.1% due to heavy investments in defence and oil security. When the new government after Apartheid came into power in 1994, these priorities changed. The economy opened up to global competition and R&D expenditure fell to 0.7% of GDP in 1994. The National System of Innovation in place now focuses on the implementation of key programmes on innovation to achieve mastery of technological change in the economy and society. Still, most research is done by companies, which spend three times more on research, than universities (Department of Science and Technology, 2007).

South Africa's GERD/GDP percentage of below 1% is lower than the average of 2.26% for OECD countries. In fact, few OECD countries have an R&D intensity of less than 1%. Yet, GERD is targeted to reach 1% (Department of Science and Technology, 2009).

In recent years, many companies have raised their investment in R&D and South Africa has been commended by the OECD for having an unusually intensive connection between research in private business and universities (OECD, 2007). However, up to the present day, the R&D density, as well as the number of patents held, is very low. The technological infrastructure in South Africa is by and large provided by the state and structurally organised in eight science councils and other science, engineering and technology

[4] Average number of staff decreased from 244 000 in 2007 to 190 600 in 2008.

[5] For hydrocarbon extractive industries the indicator changed from 1.0 bln cubic meters in 2005 to 0.5 in 2006 and 0.6 in 2008; for other extractive industries from 0.87 bln cubic meters in 2005 to 0.91 in 2007 and 0.86 in 2008 (Russian Federal Service of State Statistics, 2009).

institutes (SETI). The ministry's strategic plan provides insights into the planned actions for the years 2010/11 to 2012/13 and states the vision and mission of the department. Among the key achievements projected for 2014 is the promotion of investment in the mineral sector, and state regulation which aims to ensure a healthier, safer and equitably transformed mineral sector. For 2025, the vision is to become a leader in the transformation of South Africa through economic growth and sustainable development. Among the declared strategic objectives are the promotion, better regulation, and transformation of the mineral sector.

Administration of the licensing of prospecting and mining rights and compliance with the Mineral and Petroleum Resource Development Act (2002) is covered by the 'Mineral Regulation' programme. The programme issues regulations for the mineral and mining sector to foster economic development, employment and to guarantee transformation and compliance with environmental concerns. The mineral policy section falls under the 'Mineral Policy and Promotion' programme which assures the review of existing policies and the creation of new policies to achieve transformation while the mineral promotion section is dedicated to new technologies in the mining industry and to attracting investments. Finally, associated services, like Research and Development, are performed by the Council for Mineral Technology (Mintek), The Council for Geoscience (CGS), the Mine Health and Safety Council (MHSC) and the State Diamond Traders (SDT).

The programme 'Mineral Policy and Promotion' (Department of Mineral Resources, Republic of South Africa, 2009) lists the key performance targets. The department would like to see the mining sector grow beyond the normal GDP measure, namely one additional percent in 2010/11, 1.5% in 2011/12 and 2% in 2012/13. It aims to facilitate this development by reviewing and aligning policies and the legislative framework. The first national review recognised that the existing SETIs are technologically proficient and market-driven organizations. The percentage of income from the private sector for these institutions has consistently increased. Yet, the number of patents remains quite low. The Council of Science, Innovation and Research (CSIR) in South Africa, founded back in 1945, performs multidisciplinary research and technological innovation. The CSIR mandate as stipulated in the Scientific Research Council Act (Act 46 of 1988, as amended by Act 71 of 1990) asserts the Council's role in support of applied and interdisciplinary studies and technological innovations (Council for Scientific and Industrial Research [CSIR], 2009). It applies its efforts towards technologies that could potentially either be unique to local circumstances or already successful on an international level and that show the potential to enhance local competitiveness. Examples include nanotechnology, synthetic biology and mobile autonomous intelligent systems.

South Africa's national mineral research organisation, Mintek, specializes in mineral processing, extractive metallurgy and related areas (Mintek, 2010). One of Mintek's key activities is to pursue the resource-based technological strategy, the focus of which is to investigate how South Africa can use its expertise in mining and mineral production to shift the country's focus from primary mineral production into high-tech activities supplying inputs to the global resources sector (Mintek, 2010).

In its response to the global economic crisis, the presidency identified five objectives: protect the poor, build capacity for long-term growth, sustain employment growth, maintain a sustainable debt level and address barriers to growth and investment (The Government of the Republic of South Africa, 2008). To emerge from the global crisis on a sounder footing, government intends to take measures to sustain investment in productive capacity, expand employment in public works, continue advancing regulatory provisions for reforms, strengthen agricultural production and raise export performance. Government started the Accelerated and Shared Growth Initiative for South Africa (AsgiSA), which is intended to reduce unemployment and poverty while simultaneously increasing the country's growth rate of 6% by 2010. The main aim is to enhance public investment and fixed capital formation as a percentage of GDP, which should reach 25% by the end of 2014. The major focus for an enhanced quality of infrastructure will be on the electricity supply which, during the last years, has hampered industrial production, including mining (Republic of South Africa Government, 2008).

The minister of science and technology has put in place the 'ministerial committee to review the science, technology and innovation (STI) landscape and its readiness to meet the needs of the country'. Major initiatives have failed to be implemented effectively; one of these was the National Strategy for Research and Development concerned with technology and knowledge related to resource-based industries. Also, the lack of specialisation of research institutes has been criticised. Many of the policy setting activities lack integration between different departments as there is a lack of a cross-departmental body at Cabinet level. In their statement to the review of STI policies in South Africa, the OECD (2007) identified a couple of shortcomings. This point of critique was not only limited to scientific activity, but also addressed the field of training of new researchers. On various levels of the innovation process, too few resources were stretched over too many recipients. The ministerial commission recommended bringing in more persons with industrial experience, together with long-term commitment of key clients. At the same time, it was suggested that more post-doctoral positions be offered.

Canada

Canada enjoys the advantage of a diverse and balanced portfolio of energy resources and is one of the largest producers and exporters of energy – oil, natural gas and coal. The energy sector has contributed significantly to the development of the country's economy.

Among the key principles of the Canadian energy policy, which contrasts with the state-centric extractive industries of emerging economies reviewed above, is its market orientation. Canadian government policy regulations for industry are characterised by a certain flexibility and are intended to provide low economic impact. Among the options available to industry for meeting its obligations are contributions to a technology fund that is used to develop and deploy technologies to reduce emissions now and in the future across industries and regions.

The oil and gas industry currently runs a small number of high cost projects in the technology development value chain. However, like many other energy-producing economies, Canada faces the challenge of making the sector sustainable. Although the country's greenhouse gas (GHG) emissions account for only 2% of total global emissions, Canada is the second highest per-capita emitter in the OECD (after Australia) and has higher energy intensity, adjusted by PPP, than any IEA country. This is the result of a combination of factors, which also are relevant for Russia: vast territory, cold climate and a resource-based economy.

Provincial governments are the direct managers of most of Canada's resources[6]. The inter-level policy coordination between the federal and the provincial governments is organized in two ways: formal high-level committees and informal contacts and consultations. This legal setting sets Canada apart from Brazil, Russia and South Africa, giving vital importance to inter-level and interdepartmental (horizontal) coordination.

Due to its dependence on extractive industries until the 1990s, Canada spent relatively few resources on R&D. Particularly low were R&D expenditures from the private sector. Its GERD in 2008 was USD 23,781.0 mln by PPP, comparable to that in Russia (USD 24 492.8 mln by PPP), and Canada set the target of moving by 10 positions in the world ranking from 15th to 5th place in 10 years (2000–2010; Liljemark, 2005).

The increase in production of Canada's unconventional oil resources (oil-sands), which was forecast for the mid-term perspective, poses a challenge for their sustainable extraction. The Government and the industry, therefore, aim to control any extra emissions, which shall incur excessive emissions' penalties, as well as manage the broader environmental impacts of new

[6] Unlike the 10 provinces, the three territories of Canada do not own their ground resources, but have some management responsibility.

resources developments such as water management, post-mining reclamation and tailing ponds. A variety of policy measures to tackle the problem are tied together in the updated 2008 'Climate Change Strategy' (Liljemark, 2005).

While advancing innovations in extractive industries, Canada actively invests in research of renewable sources of energy. This strategic direction for energy development in the mid- to long-term perspective should be taken into consideration by countries that aspire to keep up fast and balanced growth in the future. One of the important state initiatives supporting innovation in the energy sector is the ecoENERGY Technology Initiative which provides funding for R&D and supports the development of next-generation clean energy technologies. The 4-year programme (2007–2011) mostly provides funding for renewable energy technologies. Moreover, the federal government sustains two funds to support the development and demonstration of innovative technological solutions operated by a not-for-profit foundation, Sustainable Development Technology Canada (SDTC).

The Economic Action Plan, developed in response to the economic crisis, established the Clean Energy Fund to support clean energy research and demonstration projects (Department of Finance Canada, 2009a, 2009b, 2009c). Canada owes a great deal of its fast economic development to concurrent efforts to develop domestic technological capabilities, advance institutions and improve production capabilities (Torres-Fuchslocher, 2010). The Canadian experience suggests that development of local technology-intensive suppliers may contribute to reinforcing the industry as whole and increase competitiveness of primary production. Recent assessments of Canada's innovation performance, undertaken by the Council of Canadian Academies in their 2006 report, 'The State of Science & Technology in Canada', concluded that Canada had not succeeded in 'converting strength in basic science into sustained commercial success' (Council of Canadian Academies, 2006). The Competition Policy Review Panel linked much of Canada's poor productivity performance to the comparatively poor performance of Canadian companies in the creation, diffusion and transformation of knowledge and the use of knowledge through commercialisation (Competition Policy Review Panel, 2008).

Canada's Science and Technology Strategy 'Mobilizing Science and Technology to Canada's Advantage' was approved by the Prime Minister on 17 May 2007 and aims to turn Canada into the world's leader in the sphere of S&T. Based on the previously adopted federal Government economic development programme 'Advantage Canada' in November 2006, one of the issues marked in the document is the need for transformation of scientific ideas into innovative solutions to the country's challenges in the sphere of environment protection, healthcare and other important social challenges, as well as increased competitiveness.

The economic and financial crisis of 2008–2009 did not change Canada's priorities with regard to innovation-led growth. The Economic Stimulus Plan of Canada in 2009 and 2010, measured as a percentage of GDP, was among the highest among G7 countries and amounted to 4%, comparable to that in Japan and exceeding plans adopted in the USA and Germany (International Monetary Fund [IMF], 2009a)[7]. The document previews action to support businesses and communities, which includes protecting jobs and supporting sectoral adjustment during the crisis[8], regions and communities (Department of Finance Canada, 2009a, 2009b, 2009c). More specifically, the mining sector in 2009–2010 benefited in the form of extended Mineral Exploration Tax Credit.

Extractive industries will also benefit from the cross-sectoral measures of the 2009 Plan, which are earmarked for future economic growth, i.e.,

7 IMF estimates exclude loans, including those to the auto sector, for all countries. The figure for Canada includes provincial-territorial stimulus in addition to that assumed in the Economic Action Plan as estimated by the Department of Finance Canada.

8 Automotive, forestry and manufacturing sectors. In addition, investment in the manufacturing sector will be aided by elimination of tariffs on manufacturing inputs and machinery and equipment.

train and 'attract talented people, strengthen the country's capacity for world-leading research, improve commercialization, accelerate private-sector investment, enhance the ability of Canadian firms to participate in global markets, and create a more competitive business environment' (Department of Finance Canada, 2009a, 2009b, 2009c).

Comparative cross-country analysis

Despite the fact that extractive industries' products constitute a major source of income for Brazil, Russia and South Africa, all countries discussed in the paper acknowledge the risky position of a high dependence on commodities. As part of their crisis response economic stimulus measures, introduced by national governments in 2009–2010, most of the funds went into the service industries, such as the financial sector, or into manufacturing, like the automobile industry. This is somewhat surprising, given the impact of raw materials prices on countries' budgets, especially in Russia (see Table 1).

Data on trademark filings, which reflect the creation of new goods or services, with or without technological content, shows that the business cycle affects a wide range of innovation. The current crisis data confirms these findings. A decline or slower growth in R&D spending was already reflected in many corporate reports for the fourth quarter of 2008, and the trend continued on in 2009. A McKinsey survey of 500 large enterprises world-wide indicated that 34% expected to spend less on a R&D in 2009, while only 21% forecast an increase (OECD, 2009b). Naturally, governments stepped in to support a critical mass of R&D in the economy (see Table 2).

Table 1: Loss of fiscal revenue due to commodity price movements, 2008–2009 (in percent of GDP)

	2008	2009
Brazil	1	–2.8
Canada	–0.1	–0.3
Russia	1.3	–6.4
South Africa	0.2	–0.1

Source: (IMF, 2009b, p. 13), IMF staff estimates.

We start our analysis by looking at the broader economic indicators for all the nations under discussion. In the subsequent steps we discuss the general situation for R&D.

The countries under review have shown remarkable differences in their resilience to the economic crisis. Whereas the booming emerging markets of Brazil and South Africa suffered mostly through economic growth forgone, Russia experienced a major decline of 7.9% of its GDP. The great share of this loss may be attributed to the decrease of commodity prices and subsequent budget revenue losses.

One of the differences between the national economic stimulus plans is the role of the state in R&D. In Russia and Brazil the main source of funds for R&D is the state sector (64.7 and 50.1% respectively, 2007/2008). These figures are much higher than in Canada (33%), which is rather successful in mobilizing private sector funds (see Table 3). The marked difference between Russia and the other BRICS countries is that the share of GERD allocated by the higher education science sector is rather low at 6.7% (2007/2008), as compared to 38.4% in Brazil, 20% in South Africa and 35% in Canada (Higher School of Economics, 2010). Many innovative economies are characterised by large-scale applied university research matched against the private sector demand.

The combinations of input–output R&D indicators of the selected countries show marked differences. Canada, with its advanced economy, shows a high GERD level and a high number of researchers, which correspond to a strong research output, like papers in scientific journals or patents. Brazil and South Africa, on the other hand, show patterns often seen in emerging economies. This factor causes low R&D outcomes at national level, and may further be illustrated by the high number of science and engineering degrees, coupled with the relatively low number of researchers working in these countries (see Table 4).

Russia shows high values on other input indictors, such as GERD, which do not result in similarly high outputs with regard to papers or patents. The situation may be attributed to low efficiency of government policies and spending

Table 2: Main objectives and targets of national budgetary stimulus packages, excluding measures aimed at the financial system (e.g., recapitalisation), May 2009

	The absolute size of fiscal packages (revenue and spending measures), 2008–2010	R&D, innovation, education and extractive industry related measures
Canada	USD 61.551 bln, of which on Innovation: 0.05% of GDP; Education: 0.12% of GDP; Green technology: 0.18% of GDP	Investments in clean water as well as in knowledge and health infrastructure (including post-secondary institutions, research equipment, digitalization of health records, extension of access to broadband services and green energy infrastructure); personal and business tax relief; access to financing, support and training to citizens affected by the crisis; and support to most affected sectors and communities (e.g., targeted funding for the auto, forestry, agriculture, and manufacturing industries).
Russia	USD 101 bln, 8% of GDP*	Tax cuts; maintenance and development of industrial and technological potential; retraining and employment; measures for SMEs; reduction of administrative burdens on businesses: measures to support R&D; and measures supporting energy efficiency
Brazil	USD 152 bln, 15% of GDP	Credits for firms and support to the automobile sector
South Africa	USD 7.5 bln (for 2009–2011) Around 11% of the stimulus package, representing USD 0.8 bln was allocated to environment-related themes, such as railways, energy efficient buildings, and water and waste management	Public investment in economic infrastructure; employment and skills development; effective industrial or sector strategies, higher levels of private sector investment and entrepreneurship; and improve and streamline government delivery and regulation.

Source: (OECD, 2009a, pp. 18–19, 22–24; OECD, 2009b, p. 6; UNEP); *This figure is based on Russia's response to the OECD policy questionnaire.

Table 3: Macroeconomic indicators of countries performance

	GDP (current prices, PPP bln USD), 2008P	Real GDP growth (%), 2009	GERD, PPP bln USD, 2009	GERD as % of GDP, 2009	2008 BERD intensity (as % of GDP)
Brazil	1984, 45	–0.7	18	0.9	0.5
Canada	1300, 2439	–2.6	23.2	1.95	1
Russian Federation	2262, 6549	–7.8	21.8	1	0.70
South Africa	493, 49	–1.7	3.6	0.7	0.53

Sources: OECD science, technology and R&D statistics; (OECD, 2010b, 2011, p. 405).

Table 4: Key science, technology and innovation performance indicators for Brazil, Canada, Russia and South Africa, 2008

	Scientific articles per one mln population	No. of researchers per 1000 employment	Triadic patents per one mln population	Share of science and engineering degrees in all new degrees, %
Brazil	141	1.5	0.3	11
Canada	1356	8.3	19	22.4
Russian Federation	176	6.4	0.5	25
South Africa	110	1.5	<1	16

Source: (OECD, 2008).

and, as a result, of the research sector. Particularly the latter can be interpreted through poor connections among various R&D and innovation actors and low commercialization activities.

One component of innovation-led development is the number of researchers interested in pursuing a career in the extractive industry R&D sphere and available for public and private research initiatives. The lack of qualified researchers in the relevant fields is certainly hampering major breakthroughs.

Policy makers can choose from a wide range of policy tools to support R&D and the foundation of new ventures. Also, shifting away from the dominance of the state to a greater involvement of R&D provided by and undertaken by companies is also a question related to the setup of the extractive industry sector and ownership of major companies in this sector. As the example of Russia shows, most extractive companies are state controlled and/or state owned. The situation is somewhat different in Brazil and South Africa, where the state ownership of extractive industry companies is less dominant. Therefore, the four countries under consideration should in principle have different instruments for stimulating innovation in the extractive industry due to the different shares of R&D funding and R&D performing institutions in the state and business enterprise sectors. To illustrate this proposition, we present in Table 5 the priority policy instruments employed by the four national governments, as well as missing areas of regulation.

In our example, we found wide-spread differences between the varieties of tools in use. Brazil shows little direct support for research activities whereas Canada, Russia and South Africa offer direct financial assistance, mostly in form of competitive grants. All emerging markets, however, engage in indirect support, which mostly consists of generous tax credits. Interestingly, only one of the three emerging economies under observation offers support for the creation of new tech ventures. However, it should be acknowledged that the setting up of such a vehicle is under discussion in the other two emerging economies.

Besides rational policy making, there are other factors which influence a nation's focus areas. In Brazil, Russia and South Africa, the history of each country seems to have significant influence

Table 5: Priority science, technology and innovation policy instruments, 2008

	Direct public funding	Indirect public support	Support for new tech
Brazil		Yes	
Canada	Credit loans, competitive grants		VC
Russian Federation	Competitive grants, R&D subsidies	Yes	VC
South Africa	Competitive grants, R&D subsidiese grants	Yesdies	

Source: (OECD, 2008), own compilations.

on its policy agenda. Besides the role of the state, it is also the political concepts of perceived justification in the distribution of resources that matter. Certain neo-Marxist ideas dominate the policy agendas and lead to government ownership and heavy taxation of extractive industry enterprises. This combination of ownership structure and taxation provides no incentive for innovations.

A country's social structure and history may also explain the setting of priorities by governments. Whereas Brazil dedicated the first 4 years of the present government to focus fully on pressing social issues, the second period of time was strongly geared towards the creation of wealth, economic growth and opportunities. In South Africa, in contrast, it seems that transformation overrides many initiatives to boost the country's competitive position. Despite the importance of transformation for a socially balanced society, it holds the danger that short-lived populist transformation policies win political support over long-lasting innovation policies.

Conclusion

During the economic decline of 2008–2009 all the countries analysed in this paper suffered significant cut-backs in their exports of natural resources due to a sudden slump in demand and a decrease of budget receipts due to a decline in prices. However, in 2010 the tendency reversed and the exports of raw material have picked up.

There are differences in the set of policy tools applied by developed countries vs. fast-growing economies, but most importantly, it is the differences in their synergy, governance, targeted design and application that are crucial. All four countries that were studied emphasised the overarching R&D-related policy goals and supporting indicators, like a certain GDP percentage of R&D expenditure. These macro indicators are necessary, but insufficient, opening up a demand for a balanced scorecard (a comprehensive set of interrelated indicators) that will take into consideration development of adjacent spheres and resources.

At the same time, following the example of innovative economies, countries with fast-growing economies are fine-tuning policy tools together with pursuing structural reforms. All these instruments and reforms should not only favor innovations, but also provide proper frameworks to create the necessary conditions for innovation. A good example is Canada's success in putting in place the necessary framework of economic conditions, such as the structural adjustment following an effective governance structure of the S&T sector, competition and SME policies, and the lowering of administrative barriers and corruption. Certain steps in developing framework economic conditions are already being done by emerging economies.

Globalisation leads to a strong cooperation of all countries in the rapid development of global markets of capital, natural, and human resources. At the same time, the scarcity of these resources forces countries, regardless of their state of development, to compete for them. In this situation, the countries rich in natural resources apply efforts to increase output and productivity, while prices are mostly dependent on global markets and are substantially decreased during the global economic recession. Although the prices for commodities are not within the sphere of influence of any individual producer, the application of innovations is capable of improving the margin of the extractive industry at any given production level.

Given the variety of factors in place, such as the structure of the economy, the legal and decision-making systems, common recommendations for the three countries – Brazil, Russia and South Africa – would be of limited value. However, it may be noted that all three face the challenge of adjusting their innovations policy instruments to the requirements of the existing industry base. As the entrepreneurial activity in these countries is naturally limited, and, with a few exceptions, clustered around resource-based industries, policy-making must not lose touch with these companies. As a first step, the establishment of institutionalised platforms of communications seems to be an imperative. Companies and research institutions need institutionalised lines of communications to ensure the flow of information into companies – and back. The value of the feedback from all stakeholders is in the successful transfer of best practice and cooperation in 'open innovations', involving all actors in the production and innovation chains, from suppliers to producers and consumers.

In summary, it seems that the deciding factors between success and failure in R&D between emerging markets and the economically leading nations is not to be found in the absence of certain policies, institutions or tools, but rather in the way the elements of their innovation systems are linked. This paper therefore urges that more research efforts be directed into understanding the relationship between different parts of national innovation systems and how to incentivise a more productive cooperation between them. More research is needed to gain a better understanding in how the structure of an economy and the culture in which it operates facilitates or hampers the cooperation of the different aspects of national innovation systems and how these systems can fulfil sector-specific needs like those of the extractive industries.

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