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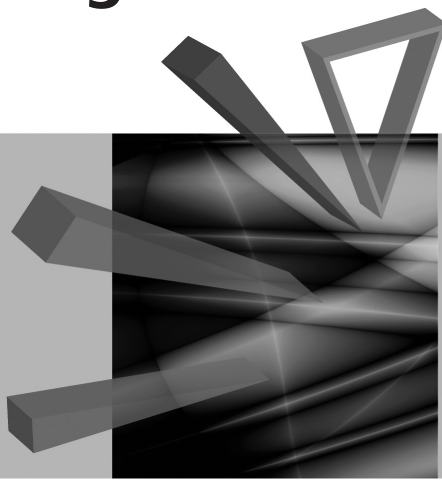
Innovation as a Factor of the Development of the Asia-Pacific Region



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Innovation as a Factor of the Development of the Asia-Pacific Region ISSN 1899-3192

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CHINA'S NATIONAL INNOVATION SYSTEM[1]

Summary: China's international competitiveness has been improving steadily. The country's science, technology, innovation and education policies have set ambitious goals of transforming the country into world's technological leader relying on "indigenous innovation". This article explores China's National Innovation System, its characteristics, main actors and recent related policies that shape the future of the system. It also provides a brief summary of its strengths and weaknesses that shed light on system's readiness and capacity to fulfill the above-mentioned goals.

Keywords: China, National Innovation System, science and technology policy, education policy.

"A nation's technological competitiveness determines its place and future in international competition."

Hu Jintao, 2010[2]

1. Introduction

Innovation, broadly understood as product or process novelties, is a determinant of resource-scarce country's global competitiveness and main driver of economic growth. Therefore, nowadays country's ability to innovate and construct a successful innovation system adequate to its developmental stage is the main concern of policymakers worldwide.

China's innovation-related indicators of World Economic Forum's Global Competitiveness Report have improved steadily over the years. Recently China has

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[1] The article is a result of the research conducted at the World Economy Research Institute, World Economy Collegium, Warsaw School of Economics within research project No. 3926/B/H03/2011/40 funded by the National Science Centre on "Human capital and innovation as factors of long-term competitive advantages in international trade. Implications for Poland".

[2] Quoted in: M. Springut, S. Schlaikjer, D. Chen, *China's Program for Science and Technology Modernization: Implications for American Competitiveness*, CENTRA Technology, Arlington 2011, pp. 1–143.

moved up the development stage and is now among efficiency-driven economies. In terms of innovation, the country ranks higher (4 out of 7) than the average of other efficiency-driven economies (3 out of 7). However, the higher education and training index is the same for China and its reference group.

After the success of the reforms of opening up, introduced in 1978, which transformed China into "the factory of the world" based on its cheap labour. Currently China has an ambition to change its label from "Made in China" to "Innovated in China". The latest 12th Five-Year Plan assumes an ambitious goal of the increase of R&D expenditures to 2.2% of GDP and increase of patents to 3.3 per 10 thousand population.[3]

The article attempts to characterise China's NIS, its main actors as well as discuss the latest policies related to China's science, technology, innovation and education, which provide insights into future developments in the country's NIS.

2. Characteristics of China's National Innovation System

China's National Innovation System (NSI) as the whole Chinese economy is under transition process from plan to market. The **government** is its important part as it sets up country's research and development (R&D) goals, provides support through various science and technology (S&T) measures (mainly financial) and chooses key technologies that are to be developed. Government promotes interactions among key actors through establishment of S&T programmes, science parks, incubators and high-tech development zones. For the realisation of its goals, the state mobilises human capital and material resources.[4] Government's share in GERD has been declining from 29.9% in 2003 to 23.4% in 2009.[5] The government directly integrates a few entities that have required capacities such as leading universities, research institutes and high-tech companies. Thus, China's NSI is often called "islands of innovation".[6]

The Chinese **education** provides human capital to NSI as well as performs R&D. However, it is one of the weakest pillars in China's global competitiveness rankings. Indicators such as "tertiary education enrollment rate", "local availability of research and training services" and "extent of staff training" even worsened between 2008–09

[3] A. Gradziuk, J. Szczudlik-Tatar, Kierunki rozwoju gospodarczego Chin w dwunastym planie 5-letnim (2011–2015), *PISM* 2011, nr 39 (788).

[4] Y. Sun, F. Liu, A regional perspective on the structural transformation of China's national innovation system since 1999, *Technological Forecasting and Social Change* 2010, Vol. 77, pp. 1311–1321; M. Springut, S. Schlaikjer, D. Chen, *op. cit*.

[5] OECD, Science and Innovation: Country Notes. China, 2010, http://www.oecd.org/dataoecd/30/15/46663975.pdf (accessed: 15.06.2012).

[6] H. Kroll, D. Schiller, Establishing an interface between public sector applied research and the Chinese enterprise sector: Preparing for 2020, *Technovation* 2010, No. 30, pp. 117–129.

and 2010–11.[7] Problems that negatively impact quality of education and research in China include: passive learning; teaching preparing for test-taking, no fostering of creative and entrepreneurial skills; producing graduates with skills inadequate for market needs; inequalities in terms of access and quality of education (due to introduction of tuition fees, partial privatisation of education, *hukou* system that hinders allocation of the best students to the best universities); corruption (nepotism, bribery, exchange of favours); plagiarism.[8]

However, Chinese higher education has been generating impressive results in quantitative terms: new university intakes growth from 2.7 million in 2001 to 6.1 million in 2008; graduates growth from 1 million in 2001 to 5.1 million in 2008; total enrollment growth from 7.2 million in 2001 to 20.2 million in 2008; science and engineering degrees constituting almost 40% of all the degrees in 2005.[9]

Higher education's R&D activities are concentrated at a few large universities and focus on basic and applied research in a few key disciplines in natural sciences and engineering (16% and 66% in 2005, respectively).[10] In 2005, R&D expenditure by the top 50 universities accounted for 66% of total R&D expenditure in natural sciences and engineering in the higher education sector.[11] In spite of the 1993 plan to increase public education spending to 4% of GDP, it was fluctuating from 2.3% in 1990 to 3.2% in 2003 and 1.8% in 2007.[12]

China's NSI is becoming **enterprise-centred** as the industry sector is the largest source of gross R&D expenditure (from 57.6% in 2000 to 71.7% in 2009) and has the largest share of domestic patent applications (64.6% in 2005).[13] Industry expenditures on R&D as percentage of GDP have been growing rapidly by 27% a year in real terms since 1997 and in 2009 amounted to 1.24%.[14] However, industry

[7] WEF, *The Global Competitiveness Report 2010–2011*, 2008, https://members.weforum.org/pdf/GCR08/GCR08.pdf (accessed: 15.06.2012); WEF, *The Global Competitiveness Report 2010–2011*, 2010, http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2010-11.pdf (accessed: 15.06.2012).

[8] University entrance exams. Testing times, *The Economist*, 13 June 2012, http://www.economist.com/ blogs/analects/2012/06/university-entrance-exams?page=9; S. Schwaag Serger, M. Breidne, China's Fifteen-Year Plan for Science and Technology: An assessment, *Asia Policy* 2007, No. 4, pp. 135–164.

[9] L. Zhao, J. Zhu, China's higher education reform: What has not been changed?, *East Asian Policy* 2010, Vol. 2, No. 4, pp. 115–125; OECD, Science and Innovation…, *op. cit*.

[10] M. Schaaper, *Measuring China's Innovation System: National Specificities and International Comparisons*, OECD Science, Technology and Industry Working Papers, 2009/1, OECD publishing, OECD, 2009, doi:10.1787/227277262447.

[11] *Ibidem*.

[12] C.J. Dahlman, D.Z. Zeng, S. Wang, *Enhancing China's Competitiveness through Lifelong Learning*, World Bank Publications 2007.

[13] OECD, *OECD Stat. Extracts. Main Science and Technology Indicators*, 2012, http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB (accessed: 15.06.2012); M. Schaaper, *op. cit*.

[14] OECD, Science and Innovation…, *op. cit*.

sector R&D activities focus on experimental development and applied research (83.7% and 32.4% in 2005, respectively).[15]

China's continually growing **R&D expenditures** reflect the country's ambitions to move up the technological ladder. China's spending on R&D in 2011 grew by 21.9% year-on-year to 139.7 billion USD and constitutes 1.83% of the country's GDP (0.57% in 1995, 0.9% in 2000; 1.32% in 2005, 1.7% in 2009), which is close to the level of spending on R&D by developed countries, the average of 2.3% in 2008 for OECD countries.[16] Only in 2011 did China spend 39.6 billion yuan (approximately 5.88 billion USD) on basic scientific research projects and constructed 130 national engineering research centres and 119 national engineering laboratories.[17]

From 1995 to 2007, the number of resident **patent filings** per million population was growing sharply at the average of 116% annually; in 2007 it accounted for 116. However, it is still small when compared to the USA (800), Germany (581) and Finland (341). Moreover, domestic patents granted to Chinese nationals have been mostly non-invention patents, such as utility models or appearance-based designs.[18]

Linkages within China's NIS are weak. R&D financed from abroad has been small and since 2003 maintained the level of around 1% (1.34% in 2009).[19] From 2000 to 2005 business collaboration in R&D activities declined (independent research had grown from 70.8% in 2000 to 77.7% in 2005).[20] PRIs have the weakest interactions with other actors as only 4.5% of their R&D expenditures come from enterprises. Higher education cooperates more, 36.6% of its R&D expenditures is funded by the business sector. "However, Patent Cooperation Treaty (PCT) applications with foreign co-inventors rose to 12.6% during 2005–07".[21]

Venture capital is a new idea in China but due to its role in the support of S&T it has gained in importance. From 1995 to 2005 the number of venture capital organisations grew from 27 to 319. In terms of the level of venture capital, China ranks the second in the world after the USA. The government is an important source of venture capital (21% in 2005) through support to S&T Industrial Parks, high-tech zones, incubators, high-tech programmes and the innovation fund for small technology-based firms.[22]

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[15] M. Schaaper, *op. cit.*

[16] B. Naughton, *The Chinese Economy. Transitions and Growth*, MIT, Cambridge 2007; China Daily, *China's R&D Spending Surges 21.9%,* 2012, http://www.chinadaily.com.cn/bizchina/2012-02/22/content_14670805.htm, (accessed: 15.06.2012); OECD, Science and Innovation…, *op. cit.*

[17] China National Bureau of Statistics, quoted in: China Daily, *op. cit.*

[18] B. van Wyk, *Upstart: China's Emergence in Technology and Innovation, The Beijing Axis, INSEAD Knowledge*, 2010, http://knowledge.insead.edu/economy-china-technology-and-innovation-100527.cfm, (accessed: 15.06.2012).

[19] OECD, *OECD Stat. Extracts*…, *op. cit.*

[20] M. Schaaper, *op. cit.*

[21] OECD, Science and Innovation…, *op. cit.*

[22] M. Schaaper, *op. cit.*

3. The main actors of China's NSI

3.1. Government agencies

The Ministry of Science and Technology (MOST) plays a leading role in developing national science policy and working out and implementing many of the national funding programmes. It allocates funding for setting up and strengthening incubators, research labs, megaprojects, science parks and high-tech development zones.[23]

National Development and Reform Commission (NDRC) is an economic planning body under the State Council. It ensures compatibility of S&T planning with macroeconomic policy. It is in charge of strengthening innovation in SMEs, devising a plan for special projects promoting independent innovation capabilities, including such tasks as developing guidelines for increasing the recognition of Chinese brands and developing guidelines for building national engineering labs.[24]

The Ministry of Finance (MOF) was assigned a task to design fiscal incentives aimed at increasing R&D and innovation in enterprises and drafting policies for driving innovation through government procurement incentives.[25]

The Ministry of Education (MOE) is in charge of promoting basic research and developing human resources in science and technology policies together with MOST, China Academy of Engineering, China Academy of Sciences and Natural Science Foundation of China (NSFC). It also provides support for R&D at universities and science parks.[26]

China coordinates national S&T policy through the high-level State Council's Steering Committee on S&T and Education comprised of the leaders of major science agencies. However, it is said that this coordination mechanism is not efficient as bureaucrats carry out plans without coordinating them within the government and some institutions' goals overlap.[27]

3.2. Intermediary institutions

National Natural Science Foundation of China (NSFC) mainly supports basic research in science and technology, identifies and fosters talented researchers and manages the National Natural Science Fund. NSFC cooperates with the Ministry of Science and Technology to formulate principles, policies and plans for the development of basic research in China. NSFC supports other Chinese foundations

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[23] J. McGregor, *China's Drive for Indigenous Innovation. A Web of Industrial Policies*, APCO Worldwide 2010, p. 46.

[24] *Ibidem*.

[25] *Ibidem*.

[26] OECD, *OECD Reviews of Innovation Policy. CHINA. Synthesis Report*, 2007, p. 68.

[27] M. Springut, S. Schlaikjer, D. Chen, *op. cit*.

in natural sciences.[28] The main problem of NSFC is a limited number of staff and an increasing size of funds that it manages.[29]

The success of the Silicon Valley is a driving force behind the establishment of science parks in China. They were to “attract high tech manufacturing firms for the purpose of jump-starting economic development”.[30] By 1998 there were 53 national science parks and by 2007, 548 innovation centres. Four of the former ones are located in the municipalities controlled by the central government, Shanghai, Beijing, Tianijin, Chongqing. The rest is located along the eastern coast which reflects distribution of industrial resources, technological capabilities and skilled human resources.[31] Zhongguancun Science Park is the largest and oldest science park in China, established in 1988, located near Beijing. There are also many science parks and technology development zones at the provincial/municipal level.

3.3. Research and educational institutions, innovative firms

The Chinese Academy of Sciences (CAS) is China’s most prestigious research institution, called the “locomotive” (*huoche tou*) and the “backbone” (*gugan*) of the Chinese NIS. It employs approximately 50,000 China’s best scientific and engineering talents; comprising around 100 research institutes and laboratories. CAS was reformed with the aim of creating 30 internationally recognised research institutes, five of which were to be world leaders by 2010.[32] CAS is an important institution supporting China’s defense needs and high technology ambitions (in ICT, energy, biotechnology and nanotechnology). It is also a leader in basic and strategic research in the fields of natural resources and the environment, agriculture, medicine and public health.[33] CAS is faced with a challenge of delivering multidisciplinary research as it has problems connecting disciplines and institutes.[34]

Institutions of Higher Education (IHEs): the best of IHEs compete with CAS in search of research talents and their funding as well as in national leadership in basic and applied research. Chinese universities established their own spin-off companies and co-operate in terms of research with Chinese and foreign companies.[35] Leading Chinese universities that are under the programme of attaining world-class stan-

[28] NSFC, *Main Responsibilities*, 2012, http://www.nsfc.gov.cn/e_nsfc/desktop/zn/0101.htm (accessed: 15.06.2012).

[29] OECD, *OECD Reviews*…, *op. cit*.

[30] Walcott, Xiao, quoted in: S. Macdonald, Y. Deng, Science parks in China: A cautionary exploration, *International Journal of Technology Intelligence and Planning* 2004, Vol. 1, No. 1.

[31] H. Zhang, T. Sonobe, Development of science and technology parks in China, 1988–2008, *Economics: The Open-Access, Open-Assessment E-Journal* 2011, Vol. 5, doi:10.5018/economicsejournal.ja.2011-6. http://dx.doi.org/10.5018/economics-ejournal.ja.2011-6 (accessed: 15.06.2012).

[32] OECD, *OECD Reviews*…, *op. cit*.

[33] M. Springut, S. Schlaikjer, D. Chen, *op. cit*.

[34] OECD, *OECD Reviews*…, *op. cit*.

[35] M. Springut, S. Schlaikjer, D. Chen, *op. cit*.

dards are closely connected with top US universities. They are called "Chinese Ivy League" and include: Beijing University, Tsinghua University, Zhejiang University, Fudan University, Shanghai Jiaotong University, Nanjing University, the University of Science and Technology of China in Hefei, Harbin Institute of Technology and Xi'an Jiaotong University. These nine universities produce around 25% of China's scientific papers and citations.[36]

Among industry leaders of innovation there are Tencent (social networking, online games, etc.), Huawei Technologies (the world's second largest provider of telecom equipment), BYD (battery maker, electric cars), Alibaba (on-line sales) and Suntech Power (solar power).[37] Huawei in 2004 accounted for 80% of patenting in the Chinese ICT sector and it consistently spends 10% of its revenue every year on R&D.[38]

4. Characteristics of science, innovation and education policies in 2005–2010

China's current policy for science, technology and innovation is formulated in the National Medium- to Long-term Plan for the Development of Science and Technology (2006–2020) (MLP). The plan sets ambitious goals for China to become an innovative nation by 2020 and a world leader in science and technology by 2050.[39] According to the plan, China should develop indigenous innovation and reduce reliance on foreign technology to 30% or less by 2020;[40] raise the ratio of R&D to GDP to 2.5% or more by 2020; make S&T and innovation contribute 60% to GDP growth; and "be among the top five worldwide contributors to domestic patents and international citations in scientific papers".[41]

The plan's specific targets are to develop technologies related to energy and water resources and environmental protection; to master core technologies in information technology (IT) and production technology; to catch up with the most advanced nations in selected areas within biotechnology; to raise the pace of development in space and aviation technology as well as oceanology; to strengthen both basic and strategic research (the former is underdeveloped and receives only 5% of total GERD).[42]

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[36] *Ibidem*.

[37] Fast Company, *Most Innovative China Companies*, 2010, http://www.fastcompany.com/mic/2010/industry/most-innovative-china-companies, (accessed: 15.06.2012); Fast Company, *The World's 50 Most Innovative Companies. Top 10 China*, 2012, http://www.fastcompany.com/most-innovative-companies/2012/industry/china (accessed: 15.06.2012).

[38] H. Kroll, D. Schiller, *op. cit.*; B. van Wyk, *op. cit.*

[39] M. Springut, S. Schlaikjer, D. Chen, *op. cit.*

[40] OECD, *OECD Reviews…*, *op. cit.*

[41] B. van Wyk, *op. cit.*

[42] S. Schwaag Serger, M. Breidne, *op. cit.*; H. Kroll, D. Schiller, *op. cit.*

The MLP aims at enhancing international linkages of China's NIS. It encourages Chinese enterprises to establish overseas research and development centres, sets goals for expanded cooperation with foreign universities, research centres and corporate R&D centres.[43] It also calls for improving intellectual property rights system.

China's education system has been undergoing constant reforms. Among the latest major ones there are Action Plan for Invigorating Education (2003–2007), China's National Plan for Medium and Long-Term Education Reform and Development (2010–2020), National Talent Development Plan (2010–2020) and Thousand Talents Programme.

Action Plan for Invigorating Education is a blueprint for implementing strategies of "rejuvenating China through science and education". The main goals are to extend nine-year compulsory education to rural areas and eradicate illiteracy in the backward western regions as well as improve the quality of compulsory education in the eastern areas. The Plan extends 211, 985 and "High-Level Innovative Talents" projects that aim at developing China's leading universities into world-class teaching and research institutions, improving research in selected fields to compete internationally and contribute to overall enhancing of China's innovation system.[44] Moreover, within the Plan there are a number of projects, such as "Plan for the Innovation in Postgraduate Education", "Project for Scientific and Technological Innovation in Higher Education Institutions" and "Project for Social Science Prosperity in Higher Education Institutions". Their goal is an overall coordination of the development of various disciplines, talent training, science and technology innovation, the establishment of human resources in teaching and research, and international cooperation and exchanges.[45]

In terms of international cooperation the priorities include: developing Confucius institutes, increasing the number of international students coming to China and the number of degree programmes taught in English in China, and encouraging Chinese universities to collaborate with foreign universities and establish branches abroad.[46]

China's National Plan for Medium- and Long-Term Education Reform and Development (2010–2020) addresses issues not resolved by former plans, such as quality of teaching and problems not tackled before, such as pre-school education and migrant workers' children's equal access to education. The Plan also emphasises "education for all", as for decades the priority has been educational development in selected fields.[47]

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[43] J. McGregor, *op. cit*.

[44] S. Schwaag Serger, M. Breidne, *op. cit*.; J. Zhou, *The Full Implementation of The 2003–2007 Action Plan for Invigorating Education*, China Education and Research Network, 2004, http://www.edu.cn/ 20040324/3102182.shtml (accessed: 15.06.2012).

[45] J. Zhou, *op. cit*.

[46] Embassy of Switzerland, *Science, Technology and Education News from China*, Number 73, 2010.

[47] *Ibidem*.

National Talent Development Plan (2010–2020) aims at transforming China from "investment-driven economy to talent-driven economy".[48] The main goals are the increase of overall talent number from nearly 114 million in 2008 to 180 million in 2020; of the number of people in labour force with higher education from 9.2% in 2008 to 20% in 2020; of the ratio of human capital investment as a share of GDP from 10.75% in 2008 to 15% in 2020. The plan supports development of human resources in six categories: political leaders and officials; business entrepreneurs; technical professionals; highly-skilled talents; practical talents for rural areas and agriculture and professional social workers.[49]

The plan also enhances China's soft power strategy and provides support for research in such fields as philosophy, social science, news and publishing, culture and art, heritage protection and related social and humanities areas. The goal is to foster a group of highly respected and talented people who would have a strong influence. It also plans to attract outstanding overseas talents to work in China in next 5 to 10 years.[50]

Thousand Talents Programme targets to recruit overseas top scientists and talents to return to China and contribute to "the innovative industries, improve key technologies and develop the high-tech industries in state key labs, national key innovative programs, national enterprises, state-owned commercial and financial institutes and high-tech development zones".[51]

5. Conclusion

The main strength of China's NIS is large and growing R&D spending, which in 2010 accounted for more than 12% of the global total.[52] Secondly, human resources for R&D. In terms of the total number of researchers, China has ranked the second in the world since 2000 after the United States and ahead of Japan.[53]

However, China's NIS is inefficient when comparing inputs with outputs. Moreover, although in quantitative terms human resources for S&T constitute strength of NIS, but their quality is still poor and together with related infrastructure it is one of the major weaknesses of the system. Recent policies aiming at attracting highly skilled professionals educated abroad try to improve country's human capital necessary for the development of innovation. OECD points to inadequate institutional

[48] H. Wang, *China's Talent Plan. Where will it lead China to?*, Brookings Institution, 2010, http://www.brookings.edu/~/media/Files/events/2010/0920_china_talent/0920_china_powerpoint.pdf (accessed: 15.06.2012).

[49] *Ibidem*.

[50] *Ibidem*.

[51] China University of Hong Kong, University Extension in Shenzhen, http://www.szdo.cuhk.edu.hk/en-GB/research-funding/national-funding/1000-talents-plan (accessed: 15.06.2012).

[52] M. Springut, S. Schlaikjer, D. Chen, *op. cit*.

[53] OECD, *Executive Summary. OECD Reviews of Innovation Policy: China*, 2008, p. 7.

framework that hampers market-led innovation, such as stronger competition, capital markets, corporate governance and the enforcement of intellectual property rights.[54] China's NIS is not well coordinated: the public research system is fragmented, independently organised and characterised by overlapping responsibilities, without a clear division of tasks between universities and applied public research institutes.[55] Constituting element of NIS which is interactions and linkages is lacking in China, which impairs knowledge diffusion and spillover effects. Therefore, structural changes are needed for a more self-organising model.[56] Some researchers are concerned with the question whether universities are able to manage two significant tasks of improving teaching quality comparable with international standards and developing internationally competitive capacities in basic research.[57]

The MLP plan received some criticism. On the one hand, the plan is called unrealistic due to bureaucratic control and corruption as well as not adequate as an education system based on rote learning. On the other hand, it raises fears of techno-nationalism and technology theft as it "defines indigenous innovation as 'enhancing original innovation through co-innovation and re-innovation based on the assimilation of imported technologies'".[58]

The strong role of government, top-down arrangements and MLP policy aiming at limiting innovation to its country borders are contrary to global trends in innovation systems that are becoming more and more open and internationalised. China's NIS needs broad improvements and thus it remains questionable whether it can bring results expected by the country's leaders.

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54 *Ibidem*.

55 H. Kroll, D. Schiller, *op. cit*.

56 *Ibidem*.

57 *Ibidem*.

58 J. McGregor, *op. cit*.

Kroll H., Schiller D., Establishing an interface between public sector applied research and the Chinese enterprise sector: Preparing for 2020, *Technovation* 2010, No. 30, pp. 117–129.

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NARODOWY SYSTEM INNOWACJI CHIN

Streszczenie: Międzynarodowa konkurencyjność Chin stopniowo się poprawia i niedawno Chiny awansowały do grupy krajów opierających swój rozwój na wydajności. Polityka naukowa, technologiczna, innowacyjna i edukacyjna Chin wyznaczyły ambitny plan przekształcenia kraju w światowego lidera technologicznego opierającego się na ,,rodzimych innowacjach''. Artykuł analizuje Narodowy System Innowacji Chin, jego charakterystykę, głównych aktorów i najnowsze polityki związane z systemem innowacji, które kształtują jego przyszłość. Praca krótko przedstawia mocne i słabe strony chińskiego NSI, które wskazują na jego przygotowanie i zdolność realizacji ww. celów.

Słowa kluczowe: Chiny, Narodowy System Innowacji, polityka naukowa i technologiczna, polityka edukacyjna.