Zuzana Kittová[*]
Barbora Družbacká[**]

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DEVELOPMENTS IN THE FIELD OF INNOVATIONS IN CHINA AND CHINESE EXPORTS

The aim of the paper is to examine whether efforts aimed at expanding Chinese innovations are reflected by changes in Chinese exports. To achieve the aim the combination of both qualitative and quantitative approach was used incorporating linear regression analysis.

The results show that China has firmly established itself as one of the leaders in innovations, as expressed in terms of patent applications, as well as of research and development expenditure. Although this achievement has not been accompanied by unambiguously positive development in the export share of high-tech products, the share of domestic value added in Chinese exports has been increasing continuously since 2010. With positive annual increase in the number of patent applications by residents per million inhabitants as well as in the research and development expenditure (as a percentage of gross domestic product), a positive annual increase in the domestic value added share in gross export may be expected with two years lag.

[*] Z. Kittová, prof. Ing. Ph.D., M.B.L.-HSG, Professor, University of Economics in Bratislava, Faculty of Commerce (e-mail: zuzana.kittova@euba.sk).

[**] B. Družbacká, Ing., Ph.D. student, University of Economics in Bratislava, Faculty of Commerce (e-mail: barbora.druzbacka@euba.sk). The paper was received on 06.04.2021. It was accepted for publication on 20.10.2021.

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These results indicate that China's innovation-driven development strategy has positive impact on increasing the domestic value added in export, thus improving the competitive position of China on global markets.

Even though several studies may be found showing that innovation had a positive impact on export performance at the level of companies in China, this study contributes to the existing literature by providing country level data analysis considering the origin of exported value added.

When interpreting results of this study, certain limitations should be borne in mind. First, as the value of Chinese innovations may be challenged, patent applications as a measure of innovation could overestimate China's innovation capability. Second, only a limited number of observations including time series from 2005 to 2016 was available for the quantitative analysis, with respect to the used trade in valued added indicator. These limitations could be addressed in future research.

Keywords: *China, innovation, patents, export, value added*

1. INTRODUCTION

Innovations play a key role as a driver of economic growth, prosperity, and competitiveness. This is extremely important for China that has presented its ambition to become a leading global technological superpower by 2049. Through innovation, it can overcome its reputation for being a "world's factory" and capture the higher end of the global value chain. The article focuses on China's development in the field of innovations and its exports.

In China, the government has been historically playing a decisive role in directing country's innovation system (Liu & Cheng, 2011). It has adopted several strategies aimed at improving national innovation capacity. An important strategy was announced in 2006, namely The National Medium- and Long-Term Program for Science and Technology (S&T) Development. This 15-year program built on previous policy initiatives including the 1995 commitment to strengthen the nation through science, technology, and education (Cao, Suttmeier & Simon, 2006). The 2006 – 2020 plan aimed at enhancing indigenous innovation capability and S&T level, improving basic research as well as technology development, thus reducing a heavy reliance on foreign technologies. Its goal was to make China a globally significant innovative country as well as a world power in S&T by mid 21st century (The State Council of the People's Republic of China, 2006). Main features and achievements of the indigenous innovation strategy were summarised by Liu and Cheng (2011, p. x): "Through establishing government-led research consortia (collaborations involving leading companies, universities and government-led research institutes) and key government-procurement-policy tools, China's government was able to increase its control over the resources available for innovation. While, even after 2006, the government has continued to favour State-Owned Enterprises as the main elements for the indigenous innovation, during this time private enterprises have become significantly more important relative to these government entities."

In 2012, strategy of innovation-driven development was formally endorsed at the 18th Chinese Communist Party Congress and it became a priority of Xi Jinping's presidency. The three-step roadmap for implementing the strategy of innovation-driven development was proposed:

- the first step was to build China into an innovative nation by 2020,
- the second step was to move China to the forefront of innovative countries by 2030,
- and the third step was to make China an innovation power by 2050 (Zhao, 2016).

Targets for the first step have already been set by the 2006 – 2020 plan. With respect to research and development (R&D) expenditure, they included reaching the level of 2.5 % of GDP. As far as the number of granted invention patents is concerned, China was to become one of the top five countries in the world. By 2030, the target for the R&D expenditure was defined at the level of 2.8 % of GDP.

An important element of the innovation-driven development strategy was presented by Chinese Prime Minister Li Keqiang in 2015. It was a 10-year comprehensive strategic plan for the period 2015 – 2025 called Made in China 2025 (MiC 2025). It focused on improving manufacturing sector, increasing production of high-tech products and services. It aimed at reducing China's dependency on foreign technology and making China a global technological leader by 2049. The plan identified ten technologically advanced priority sectors: new information technology, high-end numerically controlled machine tools and robots, aerospace equipment, ocean engineering equipment and high-end vessels, high-end rail transportation equipment, energy-saving cars and new energy cars, electrical equipment, farming machines, new materials, such as polymers, biomedicine, and high-end medical equipment (The State Council of the People's Republic of China, 2015). These sectors are central to the so-called fourth industrial revolution. McBride and Chatzky (2019) describe the main policy tools used to support the MiC 2025 such as providing direct subsidies through state funding, low interest loans and tax breaks, supporting investment in foreign companies to gain access to advanced technologies as well as forced technology transfer agreements. According to Kania (2019), the MiC 2025 objectives imply "the ambition not merely to catch up with other advanced economies but to surpass and displace them to achieve a dominant position in these industries worldwide." The global position of China in these industries manifests itself in the ability of China to supply foreign markets. Thus, the nature of Chinese export serves as a suitable indicator, expressing the shift in Chinese production towards high-tech production or production with higher domestic value added. The purpose of this paper is to examine whether these efforts aimed at expanding Chinese innovations have manifested themselves in changes of Chinese exports. This is of particular interest to those countries that have a high share of China on their imports, including Croatia as well as most of the EU countries. To achieve the aim, the authors combined both qualitative and quantitative, inductive, and deductive approach. The relationships between indicators expressing the level of innovation and export indicators were tested using both the pairwise regression analyses and panel data analyses. The article is structured as follows: First, an overview of existing literature examining the impact of innovation on Chinese export is provided. Within this literature, several studies may be found showing that innovation had positive impact on export performance at the firm level. However, empirical studies based on country level data considering the origin of the exported value added are missing. The study contributes to the existing literature on innovation-export nexus in China by providing the country level data analysis, working not only with gross export data but also with the indicator of exported domestic value added, as the latter reflects more specifically country's export capacity. After the literature review the study comprises the explanation of applied methodology. Subsequently, relevant results of the analyses performed are presented. The paper concludes with the main findings related to the impact of innovation on Chinese export.

2. LITERATURE REVIEW

The relationship between innovations and exports has been well established in the existing literature in the recent years. "Innovation activity largely determines how efficiently products ... match the preference of foreign consumers, and in turn significantly affects ... export behavior (Wu, Wu & Zhang, 2020, p. 1). Next, brief overview of literature dealing with innovation and export nexus in China is provided. Baláž, Zábojník & Harvánek (2019) considered China's economic policy, foreign direct investment and its long-term development strategy for decisive factors advancing China's foreign trade. Dai, Li & Lin (2020) have focused on impact of innovations on firms' export survival. Using a large micro-level Chinese dataset covering years 2000–2010 they found that innovations played a positive role in the export survival of direct exporters. Innovative firms demonstrated higher survival probability on the export market than non-innovative ones. For indirect exporters, however, the study showed an insignificant innovation-export survival nexus. The authors explain this by an assumption that indirect exporters suffer more from costly innovation activities. Moreover, they are not able to benefit from technology spillover effects as they trade via intermediates.

Guo, Guo & Jiang (2016) investigated effectiveness of Chinese government R&D programs on firm innovation outputs, measured by the number of patents, sales of new products, and exports. Using a panel dataset of Chinese manufacturing firms from 1998 to 2007 they concluded that innovation fund-backed firms generated significantly higher technological and commercialized innovation outputs compared with either their non-innovation fund-backed counterparts or with the same firms before winning the grant. According to this study, if a company has received a governmental grant of 1 mill. RMB, it was able to generate significantly higher sales from new products and exports. The probability of generating higher export by this company increased by 2.63%. Moreover, authors evaluated effects of change in the governance of Innofund R&D program (being the largest governmental program financing R&D activities of small- and medium-sized enterprises in China) from a centralized to a decentralized one on innovation outputs of companies. They found that technological innovation outputs became significantly stronger after decentralizing the governance of the Innofund.

Ma and Rauf (2019) investigated the impact of domestic innovation efforts, innovation capability, foreign knowledge spillovers and technology transfer on export performance by large-and-medium-sized industrial enterprises in China. They used 1998-2013 panel dataset and found that domestic innovation efforts measured by domestic R&D expenditures significantly promoted industrial export performance, however, being limited by a lack of highly skilled human capital in China at the same time. Technologies imported from foreign countries have also contributed to increase export competitiveness in China. According to their findings, however, foreign knowledge spillover channels (assessed by foreign direct investment) were more effective drivers of export performance than domestic innovation efforts. Spillovers from foreign technology are critical for companies in emerging countries like China as these countries may lack necessary domestic technical skills and expertise. Multinational enterprises as a source of such spillovers provide an easy access to export markets and training for workers in host economies.

Based on panel data of 26 manufacturing industries in China from 2000 to 2010, Gan and Cheng (2020) investigated the impact of exchange rate changes on export sophistication. They found that the appreciation of the RMB significantly augmented the sophistication of China's exports by promoting R&D investment. They describe the impact mechanism as follows: the exchange rate appreciation made it possible for Chinese companies to import more advanced equipment and technologies and at the same time it has forced Chinese companies to increase investment in R&D to maintain export competitiveness. Thanks to this "mechanism", China's R&D investment in the manufacturing industry increased by 26.07% per year on average, and consequently, technological complexity of export rose by 6.48% per year, on average.

According to the Li, Cai, Lin & Gu (2020), who studied micro-level data of Chinese enterprises from 2000 to 2007, the innovation-driven quality improvement of imports contributed significantly to improve quality of similar exports. The study shows that quality of imports exerted a significant promoting effect on corporate innovation in general trade. However, the effect in processing industries was not significant. The quality of imports had the highest impact in promoting quality of exports in the monopolistic and labor-intensive industries (including manufacture of leather, fur, feather and related products and footwear, manufacture of articles for culture, education and sport activity, manufacture of furniture, and manufacture of rubber), while the effect was small in the capital-intensive industries and insignificant in competitive industries.

Howell (2017) analyzed the benefits of clustering on China's export. He based his study on assumption that for exporting firms, information sharing about foreign markets served as a strong incentive to co-locate. He found that the main benefits of being located in a cluster arose indirectly through investments in innovations and productivity. Boosting overall efficiency helps firms to export and become competitive. "Better endowed geographical area improves international competitiveness mainly by enhancing the super-additive effects of investments in technology on productivity, which, in turn, enhances exporting performance (Howell, 2017, p. 1)."

Based on a large sample of Chinese manufacturing during the period of 1998-2007, Wu, Wei, & Wang (2021) examined the role of business groups in the relationship between innovation and exports. They showed that both innovations and business groups' affiliation had a positive effect on exports, although business group affiliation weakened this positive effect. They explain this by complex governance arrangements, resource misallocation, organizational inertia or managerial complacency that may hinder not only exports but also innovation by business group affiliated firms. Contrary to that, stand-alone firms have fewer routines and bureaucratic processes. They face a higher level of resource constraint and operating volatility. These factors serve as a strong incentive for them to maximize returns on innovation.

According to Chan (2020), Chinese policies to promote technological progress and indigenous innovation were instrumental in bringing structural changes in China's intermediate goods trade with East Asia. First, China was continuously reducing its reliance on import of intermediate goods for production and export, and second, the country remained integrated with East Asian economies in several technology-intensive sectors such as machinery and electronic devices.

Attention needs to be paid also to the recent trend of production reshoring, i.e. transferring back to countries of original investors. It emerged as means of overcoming impacts of the global financial crisis (Shahovskaya & Matkovskaya, 2016) and it has strengthened significantly by the Covid-19 aftermath, as numerous companies faced "dramatic exposure to supply chain disruptions during the pandemic and the subsequent lockdowns" (Barbieri, Boffelli, Elia, Fratocchi, Kalchschmidt & Samson, 2020, p. 131). In case of China, rising domestic wages along with production robotization in countries of original investors have played an important role in reshoring in recent years, too (Krenz & Strulik, 2021).

Reshoring as the reversal process of offshoring (Arik, 2013) has impacted the Chinese innovation system. Besides the indigenous innovation system, it comprises also an FDI-based innovation system (Mingfeng & Hussler, 2011). Several studies confirmed a positive effect of inward FDI on innovation in China (e.g. Chen, 2015; Geng & Shen, 2004; Kui, 2010). According to Xiaolan & Yundan (2011), foreign-investor companies in China have played a decisive role in technological upgrading, particularly in the high-tech sectors. Reshoring thus implies a reversal in the positive effects of inward FDI on innovation performance of China. Reshoring also implies substitution of imports by national production in countries of original investors (Fuster, Lillo-Bañuls & Martínez-Mora, 2020; Vachan, Mulhall & Bryson, 2017), thus, from China's point of view, replacing exports with production abroad. The analysis of the China – US trade between 2013 and 2019 (van der Veen, 2020) showed the most significant decline of US imports in the computer and electronics sector, especially in three high-tech product groups (radio/TV broadcast and wireless communication equipment, printed circuit assemblies and semiconductors). The study of Swiss Re Institute (2020) estimates that within 5 years, China should lose 20% of value added exports, of which 10% to be moved back to developed countries.

From the above-mentioned literature review on Chinese innovation and export, it follows that:

– studies by Chinese authors prevail but we believe that the topic is significant also for the EU authors and countries for which China represents an important import partner. For the seventeen EU countries including Croatia, imports from China represented the largest share on their total imports from the third countries (from almost 18 % in the case of the Czech Republic to over 4,5 % in the case of Portugal) in 2020 (TrendEconomy, 2021),

– results indicate that either direct positive relationship between innovations and exports in China exists or the relationship is indirect through the influence of other factors such as existence of clusters or business groups, quality of imports, or technology transfers,
– different methods were used for investigating innovations-exports relationship. The studies were based mostly on microdata using gross exports data. However, empirical studies based on country level data and considering the origin of the exported value added are outstanding. Aiming to fill this gap, this study seeks to prove an assumed relationship between innovation and export not only on the basis of gross export data but also on the basis of exported domestic value added.

3. METHODOLOGY

The objective of this paper is to examine whether efforts aimed at expanding Chinese innovations are reflected in changes of Chinese exports. To achieve the aim the authors combined both qualitative and quantitative, inductive, and deductive approach. The research was based on studying and understanding the developments in Chinese innovation capacity.

The innovation capacity of a nation is rooted in the intensity of R&D and degree of protection of intellectual property. To measurably express the innovation capacity, the authors selected two country-level indicators: 1) expenditure on R&D, 2) number of patent applications by residents.

Expenditure on R&D as a % of GDP is a well-established indicator of innovation capacity. It is provided by The World Bank (2021a) as country's "key indicator of ... efforts to obtain competitive advantage in science and technology." It includes capital and current expenditures not only by resident companies, but also by government, higher education and private non-profit sectors. The limitation of this indicator is that it is based on national R&D surveys mainly of known performers, even though attempting to identify new or occasional performers. Moreover, as national R&D surveys may use various sampling and estimation methods, the comparability of results is also limited.

The indicator of number of patent applications is based on number of patent applications filed with a national patent office (if the patent protection is sought in the territory of a country concerned) or by the Patent Cooperation Treaty procedure (offering the protection in 153 signatory states on the basis of a single application). Country's innovative performance is best reflected by the resident patent filings indicator (while the indicator of nonresidents filings in a country rather shows an attractiveness of its market for foreign patent owners). Therefore, the total number of patent applications by residents (the World Bank, 2021b) as well as per million inhabitants (the number of inhabitants was drawn from the World Bank, 2021c) was used in this paper. The indicator has, however, some limitations too. For example, it does not capture innovations for which secrecy has been chosen as a way of intellectual property protection. Some patents may also relate to inventions with low commercial potential.

As far as exports are concerned, the authors analyzed data on gross exports and expressed the share of high-tech exports in gross exports. The indicator of high-tech exports as a % of manufactured exports – the data are included in the World Bank (2021d) database – is based on the classification of exports introduced by the Organization for Economic Co-operation and Development (OECD). It reflects the R&D intensity (measured as R&D expenditure divided by total sales) for exported groups of products. High-tech products include, for example, aircrafts, computers, pharmaceuticals, or scientific instruments. The authors used the share of high-tech exports as an indicator of country's ability to apply results of R&D on global markets. As for the limitations of this indicator, the R&D intensity is not the only characteristics of high-tech. There are also other ones not captured by the indicator, such as the use of knowhow or scientific personnel (Hatzichronoglou 1997).

Considering that data on gross exports do not always provide an accurate representation of country's export capacity (see e.g. Koch, 2021; Xing, 2020 or Baláž, Borovská, Daňo, Drábik, Krošláková, Kubičková, Orgonáš, Rehák, Steinhauser, Strhan & Zábojník, 2019), the analysis was broadened by adding data on value added in exports. In the past, gross exports accounted for almost 100 % of the value that was added within the exporting economy. However, with emerging of global value chains, intermediate goods cross borders several times, thus being included repeatedly in gross trade statistics. Therefore, an alternative approach to export quantification is used in the literature, based on expressing the origin of value added contained in gross exports. The authors have used data on domestic value added in exports contained in the OECD – Trade in Value Added (TiVA) database (OECD, 2021). This indicator expresses how much value added, generated both directly by the domestic exporting industry and indirectly by domestic supply industries, is contained in gross exports.

The authors analyzed the time series from 2005 to 2016. This is the longest possible time series for which the TiVA database reports data. The dataset was checked for missing data. The data were analyzed using MS Excel and Gretl software. The authors performed the linear regression analysis.

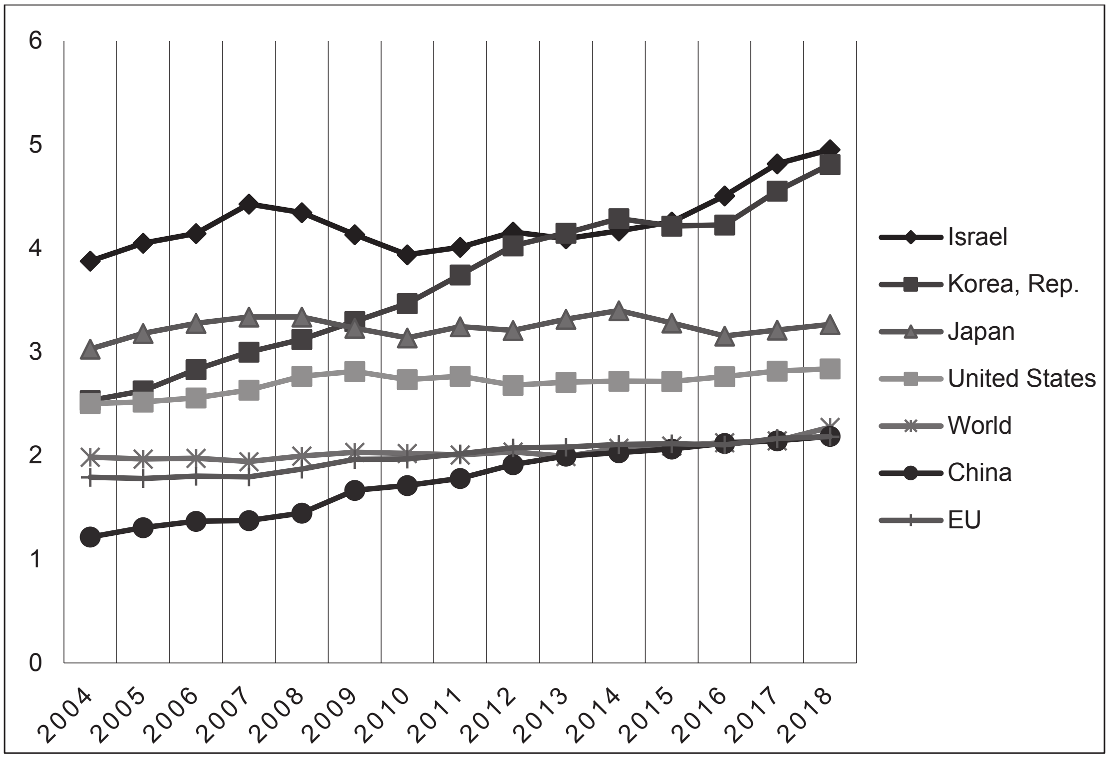
4. RESULTS AND DISCUSSION

Following the implementation of indigenous innovation strategy for the years 2006 – 2020, China increased its R&D expenditure. Specific goal was to increase the R&D funding up to 2 % of GDP by 2010 and 2.5 % of GDP by 2020. Graph 1 demonstrates that China significantly increased the R&D expenditure as a percentage of GDP during the period under review. Even after the global financial crisis when the R&D expenditure share on GDP declined in the USA or stagnated in the EU, China was able to increase R&D expenditure up to 1.71 % of GDP, the highest level in its history. China caught up with both the EU and world average in 2016, when it spent 2.11 % of GDP on R&D. China's R&D expenditure as a percentage of GDP still lagged behind to that of Israel, Korea, Japan and United States that reached the highest levels of R&D intensity in the world.

China's R&D expenditure was growing at double digits from 2005 to 2013, since 2014 the growth rate was reaching about 8 %. In 2018, the most recent year for which comprehensive data were available, Chinese spendings on R&D in absolute terms were the second highest in the world (following the United States) and China accounted for more than 26 % of global R&D expenditures (OEDC, 2021).

Graph 1:

INTERNATIONAL COMPARISON OF R&D EXPENDITURE SHARE IN GDP (%)



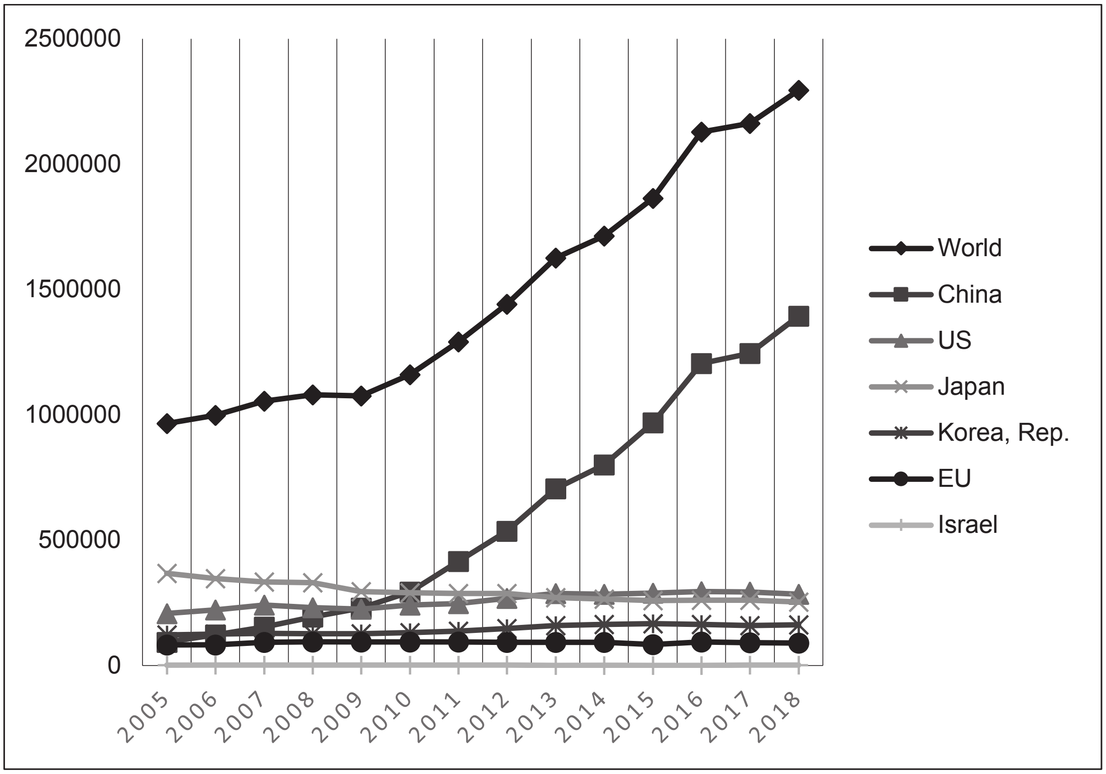
Source: Own processing based on The World Bank (2021a).

Despite positive development in Chinese R&D expenditure there are, however, several problems concerning the Chinese R&D system that have to be addressed. Public complaints appeared that research funds were misused (Rui, 2016). Government funding was said to be highly fragmented in terms of funding and management. According to Zhao (2016), there were about 100 funding schemes managed by more that 40 governmental bodies. Systematic coordination was difficult in such circumstances. Better evaluation of R&D benefits was recommended.

Graph 2 shows countries with the globally largest number of patent applications by residents, based on the number of patent applications in 2018. To allow the comparison for the same countries as in graph 1, Israel is included as well. China has been the global leader since 2010 when it overtook Japan. In 2018, China was followed by the United States, Japan, South Korea, and the EU. Its share on global number of patent applications exceeded 60 % in 2018.

Graph 2:

INTERNATIONAL COMPARISON OF NUMBER OF PATENT APPLICATIONS BY RESIDENTS

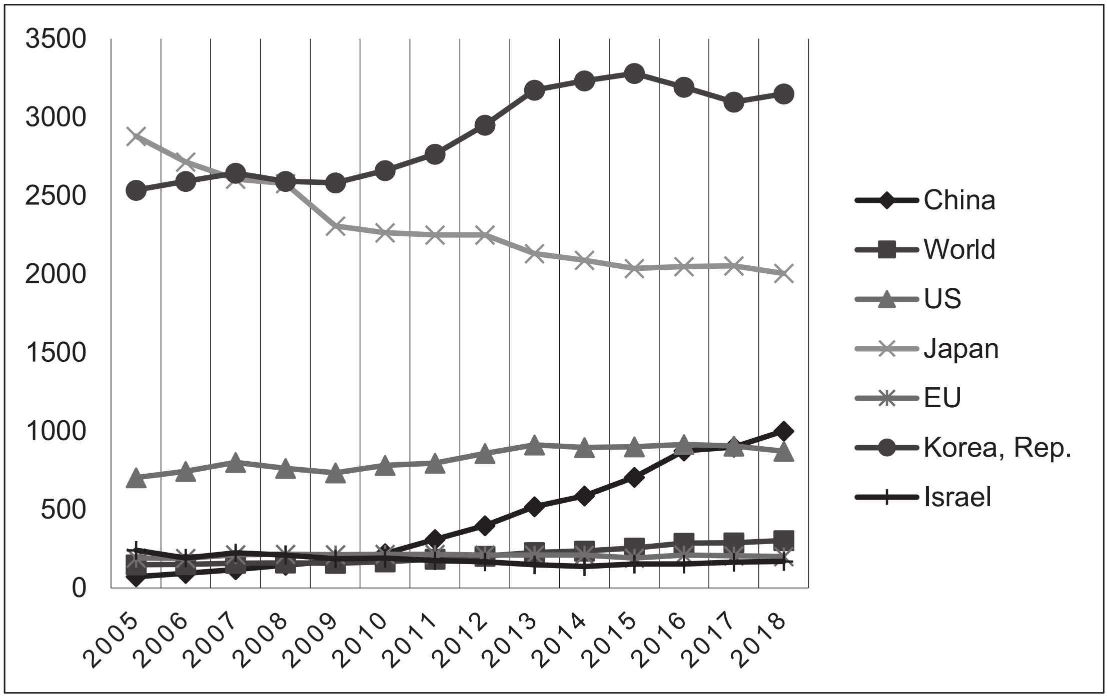


Source: Own processing based on The World Bank (2021b).

The international comparison shows a different picture, however, if countries are compared according to the number of patent applications by residents per million inhabitants (graph 3). Although China was not the global leader in this indicator, still it was able to increase the number of patent applications per million inhabitants steadily during the period under review. In 2018, China got ahead of the United States.

Graph 3:

INTERNATIONAL COMPARISON OF NUMBER OF PATENT APPLICATIONS BY RESIDENTS PER MILLION INHABITANTS



Source: Own calculation based on The World Bank (2021b, 2021c).

However, there are several concerns with respect to the rapid growth of patent filings in China. The main concern is that this increase stems from inventions of low quality or value. Value of a specific patent can be measured for example by its retention rate or by the number of its citations in other patents where the earlier patent was relevant in creating the latter. The more citations, the higher the influence of a specific patent on the subsequent innovation development. Citations for Chinese patents are relatively rare. According to Lim (2016), citations of Chinese patents in the field of data processing reached on average only 17 % of that of the U.S. in 2013 indicating limited influence they had on global innovation. The retention rate of Chinese patents is also short. Owners terminated maintenance fees payments after 5 years, being the shortest possible period, for 91 % of design patents, 61 % of utility patents, and 37 % of invention patents granted in 2013 (Chen, 2018).

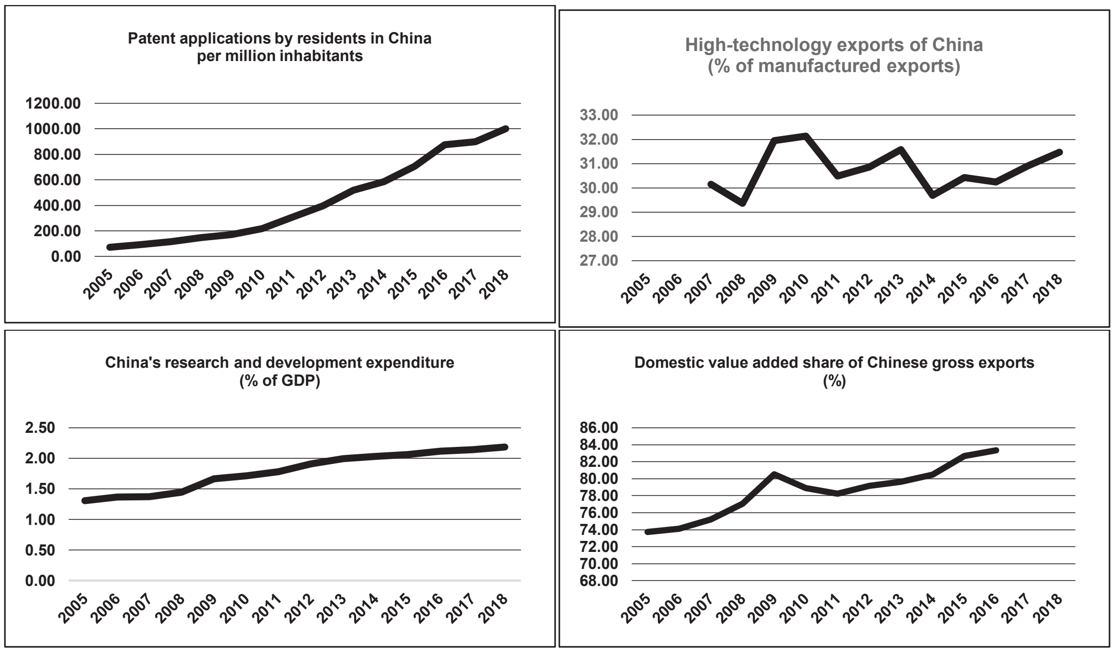
Another way of measuring patent quality was proposed by Eberhardt, Helmers & Yu (2016). They examined whether Chinese companies have sought patent protection only domestically with the Chinese Patent Office, or also in the United States. The ambition of patent applicant to supply to foreign market indicates a higher value of product in which an invention is embodied. Moreover, in the U.S. the novelty requirements on inventions are more demanding and the cost for patent filings is higher compared to China. The findings of Eberhard et al. (2016) suggest that only a small number of large Chinese companies from the ICT sector filed patents in the U.S. These patents were mostly related to electronics and semiconductors that are industries known for patent battles among producers. Accordingly, the number of the PCT (Patent Cooperation Treaty) applications may be used as an indicator of innovation value and its potential to be marketed on international markets. In 2018, China reached lower number of PCT filing than the U.S. Questionable quality of Chinese patents may result from the governmental policy aimed at promoting indigenous innovation and technological leadership. Patent subsidies were granted by the government pursuant to patent filing without considering the quality of the underlying innovation.

Although Chinese patent legislation for the most part complies with international standards set by the World Trade Organization (Fojtíková, 2018), its effective enforcement is doubtful. Most of the patent infringement cases are handled by local administrative agencies that are often underfunded and lax in enforcement. Moreover, no monetary damages are awarded to victims in administrative procedures. Only about 100 cases yearly are passed to courts. Monetary damages awarded by courts are relatively small (Yip & McKern, 2016).

Despite the above-mentioned drawbacks, significant growth of both the Chinese R&D expenditure (as a percentage of GDP) and number of patent applications, as well as improved position of China in international comparison indicate that China has enhanced its innovation capacity. Next, we analyze, whether this development was reflected in changes in Chinese exports. Graph 4 illustrates the development of two export indicators for China (the share of high-tech exports on gross exports of manufactured goods and the domestic valued added share of gross exports) together with the development of China's R&D expenditure as a share of GDP and patent applications per million inhabitants. High-tech exports involve products such as computers, office machines, electronics, telecommunications, pharmaceuticals, chemical and aerospace products, scientific instruments, non-electrical machinery, or armament production. Thus, the share of high-tech exports in total exports indicates the innovation intensity of exported production. According to the OECD (2013) study, innovation can also significantly promote domestic value added in exports. Graph 4 presents the comparison of examined indicators development.

Graph 4:

COMPARISON OF SELECTED INDICATORS DEVELOPMENT



Source: Based on data from World Bank, 2021a-d and OECD, 2021.

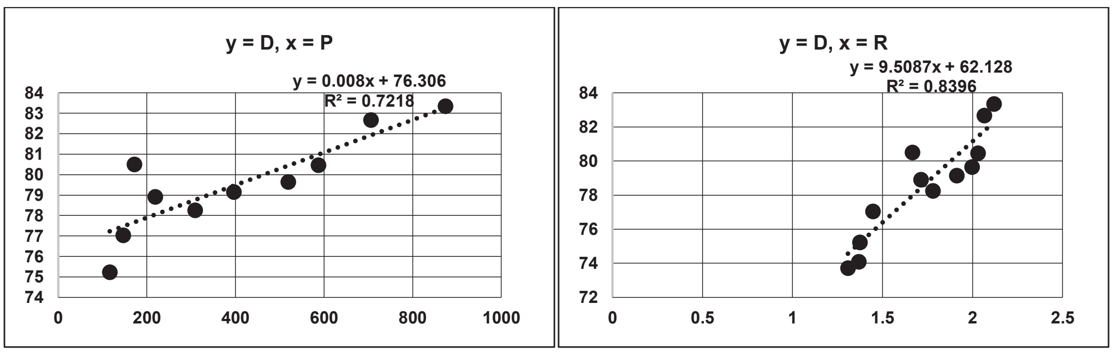
An increasing trend may be observed for the values of three out of four indicators during the reviewed period. The share of high-tech exports on Chinese exports is the only indicator for which no explicit trend can be observed. There were fluctuations until 2014, since when the trend started to grow. A pairwise regression analyses was performed for the R&D expenditure as a share of GDP and the number of patent applications by residents per million inhabitants as explanatory variables and the share of high-tech exports and the domestic value added share on Chinese exports as dependent variables.

Based on the graphical pairwise regression, relationships were not significant for the dependent variable high-tech export share in gross exports. This may by explained by the fact that China stands out technologically only in some sectors (e.g. 5G telecommunications, mobile commerce, entertainment and payments, space technology) as Kheyfets (2020) pointed out, while it is still lagging behind the world technological leaders in other sectors (e.g. robotics clusters are mainly located in the US and Europe according to Keisner, Raffo & Wunsch-Vincent (2016), despite a growing presence in South Korea and China).

To the contrary, a direct relationship may be observed for the dependent variable of value added share in gross export with both analysed explanatory variables (graph 5).

Graph 5:

SCATTER PLOT



Legend: D – domestic value added share on Chinese gross export, P – patent applications by residents in China per million inhabitants, R – China's R&D expenditure as a % of GDP.

Source: Authors' calculation based on data from World Bank, 2021a-c and OECD, 2021.

The value of Pearson correlation coefficient was 0,916 in case of patent applications per million inhabitants as explanatory variable and 0,8496 in case of R&D expenditure as a share of GDP, respectively. These values may indicate a strong linear dependency between the explanatory and the dependent variables. In order to overcome the limitation of short time series that have been available for China, the existence of the examined relationships was verified by performing panel data analyses for countries with the highest R&D expenditure share on GDP in the world. In 2018, they included Israel, Korea, Japan, United States, China, the EU, Norway, Iceland and Canada. After considering the result of Hausman's test, a fixed-effects model was used (table 1).

Table 1:

ECONOMETRIC MODEL 1 – PANEL DATA

Dependent variable: domestic value added share on gross export Time-series length = 12	Model 1 Fixed-effects, 120 observations			
Variable	Coefficient	Std. Error	t-ratio	p-val.
Const	78,4852	1,03209	76,04	<0,0001 ***
x1: number of patent applications by residents per million inhabitants	0,00423051	0,00128249	3,299	0,0013 ***
Mean dep. var. S. D. dep. var. S.E. of regression LSDV R-squared Within R-squared Rho Durbin-Watson	81,83025 8,413809 2,104350 0,942703 0,090767 0,604870 0,682750			
Wald test for heteroskedasticity (p-val.)	4,49016e-159			
Test for normality of residual (p-value)	0,133473			

Probability of parameter´s estimation: *** 99% probability; ** 95% probability; * 90% probability.

Source: Authors' calculation based on data from World Bank, 2021a-c and OECD, 2021.

In this case, only the relationship between the number of patent applications by residents per million inhabitants and the domestic value added share on gross export turned out to be significant, however, a low probability value (p-value) in the Wald test for heteroscedasticity was achieved. The authors proceeded by using robust standard errors, HAC (table 2).

Table 2:

ECONOMETRIC MODEL 2 – PANEL DATA

Dependent variable: domestic value added share on gross export Time-series length = 12	Model 2 (HAC) Fixed-effects, 120 observations			
Variable	Coefficient	Std. Error	t-ratio	p-val.
Const	78,4852	1,65804	47,34	<0,0001 ***
x1: number of patent applications by residents per million inhabitants	0,00423051	0,00209694	2,017	0,0744 *
Mean dep. var. S. D. dep. var. S.E. of regression LSDV R-squared Within R-squared Rho Durbin-Watson	81,83025 8,413809 2,104350 0,942703 0,090767 0,604870 0,682750			
Joint test on named regressors (p-val.)	0,0744255			
Robust test for differing group intercepts (p-value)	2,87073e-033			

Probability of parameter´s estimation: *** 99% probability; ** 95% probability; * 90% probability.

Source: Authors' calculation based on data from World Bank, 2021a-c and OECD, 2021.

Based on low value of Durbin Watson in model 2, model 3 (table 3) was compiled where the first differences of variables were used. Statistical significance was confirmed for 2 years lag. The authors assumed that intensification of innovation activity at time "t" influences the domestic value added share in gross exports with 2 years lag. The drawback of model 3 lies in loosing 30 observations. Based on Hausman test results, the fixed effects method (FEM) was used (Lukáčiková, 2013).

Table 3:

ECONOMETRIC MODEL 3 – PANEL DATA

Dependent variable: first difference of domestic value added share on gross export (d_y_percDVAonGE) Time-series length = 9	Model 3 Fixed-effects (FEM), 90 observations Included 10 cross-sectional units			
Variable	Coefficient	Std. Error	t-ratio	p-val.
Const	0,182251	0,0281311	2,529	<0,0001 ***
x1: first difference of number of patent applications by residents per million inhabitants (d_x1_nPatMilInh_2)	0,0154773	0,00612083	2,017	0,0323 **
x2: first difference of R&D expenditure as a percentage of GDP (d_x2_percRDEonGDP_2)	0,289417	0,0593803	4,874	0,0009 ***
Mean dep. var. S. D. dep. var. Sum squared resid S.E. of regression LSDV R-squared Within R-squared Log-likelihood Akaike criterion Schwarz criterion Hannan-Quinn Rho Durbin-Watson	0,265778 1,804660 237,7403 1,745839 0,179796 0,152061 −171,4161 366,8322 396,8299 378,9290 −0,188455 2,032377			
Hausman test REM estimates are consistent (p-value)	0,0247258			
Robust test for differing group intercepts (p-value)	0,846655			

Probability of parameter´s estimation: *** 99% probability; ** 95% probability; * 90% probability.

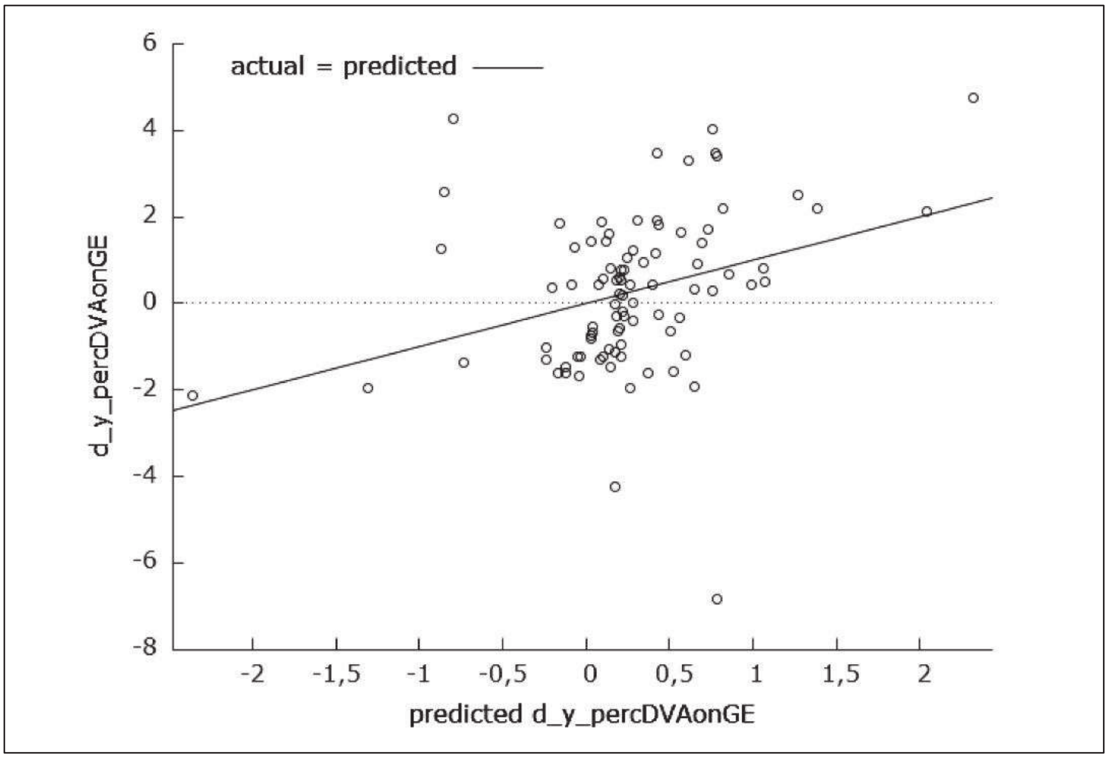
REM – random effects model

Source: Authors' calculation based on data from World Bank, 2021a-c and OECD, 2021.

The coefficient of determination (R-squared) in model 3 is low due to Japan and Korea being extreme observations, as followed from the pooled ordinary least squares method (graph 6). Low coefficient of determination, however, does not prevent accepting the model 3 as regards the type of dependency.

Graph 6:

POOLED OLS – ACTUAL VS. FITTED VALUES OF DEPENDENT VARIABLE



Source: Authors' calculation based on data from World Bank, 2021a-c and OECD, 2021.

The results show that with positive annual increase in the number of patent applications by residents per million inhabitants as well as in the R&D expenditure (as a percentage of GDP), a positive annual increase in the domestic value added share in gross export may be expected with two years lag. These findings are in line with results of several empirical studies on factors influencing domestic value added share in exports focused on different countries. For example, Vrh (2018) studied the reasons behind a lower domestic value added shares in exports of CEE-10 countries compared to EU-15 countries during 2000-2011. She identified investment in intangible capital, in particular investments in R&D (measured by business enterprise R&D expenditure), as the main driving force for the domestic value added share growth. Caraballo and Jiang (2016) explained the decline in domestic value added share in exports observed during 1995 to 2008 for the most of their countries sampled, including 39 countries representing 85% of world GDP. They used the number of patent applications as a representative for the domestic R&D. Based on the results of panel data regressions, they assumed that the "value-added erosion" is less likely to occur within countries with better domestic R&D.

5. CONCLUSION

Since the beginning of this millennium, China has been pursuing strategies strongly supporting domestic innovation capacity. It can be concluded that China has succeeded in establishing itself firmly as one of the world innovation leaders, when expressed in terms of patent applications, as well as R&D expenditure. Although this has not been accompanied by unambiguously positive development in the share of high-tech products on Chinese exports, the share of domestic value added in Chinese exports has been increasing continuously since 2010. The results of panel data analysis show that with positive annual increase in the number of patent applications by residents per million inhabitants as well as in the R&D expenditure (as a percentage of GDP) positive annual increase in the domestic value added share in gross export may be expected with two years lag. Despite the limitations of this study, including the limitations of indicators used as well as the limited number of observations that were available for the quantitative analysis, the results presented in this paper offer an insight into the relationship between innovations efforts of China and its exports.

At the same time, China faces several challenges in this field. Problems have been noted especially with respect to patents, possibly having questionable value. Thus, the authors understand that patent applications as a measure of innovation could overestimate China's innovation capability. This may pose a challenge to China in achieving the goal set by the "Made in China 2025" strategic plan. Considerable progress in terms of R&D expenditure and patents applications should be accompanied by improving Chinese intellectual property rights protection system, also with respect to the enforcement of these rights.

Future research is recommended concerning the assumedly positive impact of China's innovation-driven development strategy on its export competitiveness at the time when the "Made in China 2025" plan is expected to be fully implemented and additional data on the domestic value added share of gross export will be available.

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KRETANJA NA PODRUČJU INOVACIJA U KINI I KINESKI IZVOZ

Sažetak

Cilj rada je ispitati odražavaju li se napori usmjereni na širenje kineskih inovacija na promjene u kineskom izvozu. Za postizanje cilja korištena je kombinacija kvalitativnog i kvantitativnog pristupa uključujući linearnu regresijsku analizu.

Rezultati pokazuju da se Kina čvrsto pozicionirala kao jedan od lidera u inovacijama, što je izraženo u smislu prijava patenata, kao i izdataka za istraživanje i razvoj. Iako ovo postignuće nije popraćeno jasnim pozitivnim razvojem izvoznog udjela visokotehnoloških proizvoda, udio domaće dodane vrijednosti u kineskom izvozu kontinuirano raste od 2010. Uz pozitivan godišnji porast broja patentnih prijava rezidenata na milijun stanovnika, kao i izdataka za istraživanje i razvoj (kao postotak bruto domaćeg proizvoda), može se očekivati pozitivan godišnji porast udjela domaće dodane vrijednosti u bruto izvozu s dvije godine odmaka. Ovi rezultati pokazuju da kineska razvojna strategija vođena inovacijama pozitivno utječe na povećanje domaće dodane vrijednosti u izvozu, čime se poboljšava konkurentska pozicija Kine na globalnim tržištima.

Iako se može pronaći nekoliko studija koje pokazuju da su inovacije imale pozitivan utjecaj na izvozne rezultate na razini poduzeća u Kini, ova studija doprinosi postojećoj literaturi pružajući analizu podataka na razini zemlje s obzirom na podrijetlo izvezene dodane vrijednosti.

Prilikom tumačenja rezultata ove studije treba imati na umu određena ograničenja. Prvo, budući da bi vrijednost kineskih inovacija mogla biti dovedena u pitanje, patentne prijave kao mjera inovacije mogle bi precijeniti inovacijski kapacitet Kine. Drugo, za kvantitativnu analizu bio je dostupan samo ograničen broj opažanja, uključujući vremenske serije od 2005. do 2016., s obzirom na korišteni pokazatelj trgovine s dodanom vrijednosti. Ova bi se ograničenja mogla riješiti u budućim istraživanjima.

Ključne riječi: Kina, inovacije, patenti, izvoz, dodana vrijednost