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THE EFFECT OF GOVERNMENT SUPPORT ON INTERNATIONAL R&D COLLABORATION IN CENTRAL AND EASTERN EUROPE

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ABSTRACT

Political and economic convergence presents a main goal of European Commission agenda. Despite huge transformation efforts, historical heritage of old socialist members presents an obstacle on this path. This is especially evident in stagnant innovation system. Leveraging global knowledge stock and collaboration with foreign technology partners should be the main source of accelerated convergence. Policymakers have recognized the importance of foreign partnerships, thus, they have introduced numerous government support mechanism to straighten innovation and business climate. In CEE (Central and Eastern Europe), introducing tax incentive and direct subsidies has been the main instrument for lowering cost of research activities, and attraction of foreign partners. Question arises whether have CEE countries succeed in attracting enough foreign knowledge to liberate themselves from the production of low added value products. This research was done on the sample of seven CEE countries, using Panel Vector Autoregressive model. Results of this research indicate that government efforts leave ambiguous effect on international cooperation. While direct government funding is negatively correlated, tax incentive is positively correlated with international cooperation. This reveals that in spite CEE government increased efforts in creating positive innovation environment, they have only partially succeeded in abandoning old innovation loop focused mostly on internal capabilities.

Key words: *CEE countries, international collaboration, tax incentive, direct subsidy, innovation system.*

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1. INTRODUCTION

Political and economic convergence is at the heart of European Commission agenda[1]. Thus, western, as well as CEE policymakers, are trying to find the fastest way to close the productivity gap between developed and developing Member States. Transition of CEE countries, formerly socialist, to market economy, has opened new models and tolls to enhance productivity, and catch-up developed countries[2]. Despite huge efforts in transformation of old socialist system, historical heritage has continuously undermined significant advancements of innovation system[3]. The history of excellence in basic research activities, as well as strong educational system, has provided CEE countries with optimism in global innovation race[4]. However, lack of rivalry in the previous system, left them without experience in global competitions, commercialization, and far from technological frontier. According to Goldberg et al., innovations originating from CEE countries tends to be less well-connected to high-quality prior research. Thus, position on global innovation map depends on leveraging international knowledge stock and integration into global innovation network[5]. Competition, as well as cooperation with foreign technology partners, ensures access to global knowledge stock. However, successful collaboration demands government alleviate obstacles and improve innovation and business climate in the country[6], which is according to Veugelers[7], most effectively done with tax incentives and government direct funding. The government's strong affection toward direct funding presents a relic from time of socialist system,

[1] European Commission: Convergence Report reviews Member States' preparedness to join the euro area and paves the way for Croatia's euro adoption on 1 January 2023, June 1 2022, <https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3312> last accessed on 20/10/2024.

[2] European Investment Bank: Innovation Investment in Central, Eastern and South-Eastern Europe: Building Future Prosperity and Setting the Ground for Sustainable Upward Convergence. 2023, <https://www.eib.org.>, last accessed on 03/08/2024.

[3] Radosevic, S., Lepori, B.: Public research funding systems in central and eastern Europe: between excellence and relevance: introduction to special section, *Science and Public Policy*, 36(9) 2009, pp. 659-666.

[4] Goldberg, J. et al.: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

[5] Goldberg, J. et al.: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

[6] Contractor, F. J. et al.: How do country regulations and business environment impact foreign direct investment (FDI) inflows?, *International Business Review*, 29(2) 2020, pp. 101640.

[7] Veugelers, R.: Research and innovation policies and productivity growth, *Bruegel Working Paper*, (8) 2021.

and according to Peng and Heath[8], it was, and it still is, used for inducing research activities of public institutes and government/public companies. However, transition period expanded old socialist innovation system introducing private sector. Hence, CEE governments have accepted widely used practice of other market economies, and introduced adequate tax systems which will lower cost of corporate sector research activates[9]. The basic idea behind direct government funding and tax incentive is to free corporate funds and rise R&D budget which will reinforce further R&D activities. Numerous studies focus on success of government incentives on boosting R&D activities. However, it is less known whether they incentivize international R&D collaboration and consequently the creation of new high-quality knowledge, or they reinforce internal research capacities in production of low added value knowledge. Results of this research indicate that government efforts leave ambiguous effect on international cooperation, hence the quality of knowledge created. While direct government funding is negatively correlated with scientific cooperation with foreign partners, government tax incentive is positively correlated. These findings are important because they reveal that in spite CEE governments' increased efforts in creating positive innovation environment, they have only partially succeeded in freeing themselves from old innovation loop focused mostly on internal capabilities.

In the next section, this paper will present an overview of previous literature on innovation collaboration and government incentives. After that, the research question, methodology and results of this research will be presented. Finally, the paper will end with a discussion of the acquired results and the conclusion.

2. LITERATURE REVIEW

Technological changes, rather than traditional inputs, such as capital and labor, have been recognized as an engine of long-term economic growth[10]. According to Veugelers[11], technological changes are a result of cumulative aggre-

[8] Peng, M. W., Heath, P. S.: The growth of the firm in planned economies in transition: Institutions, organizations, and strategic choice, *Academy of management review*, 21(2) 1996, pp. 492-528.

[9] Organization for Economic Co-operation and Development (OECD), R&D Tax Incentives indicator, <https://www.oecd.org/en/topics/r%26d-tax-incentives.html> last accessed on 20/09/2024.

[10] Solow, Robert M. A: Contribution to the Theory of Economic Growth. The Quarterly *Journal of Economics*, 70(1) 1956, pp. 65-94.

[11] Veugelers, R.: Research and innovation policies and productivity growth, *Bruegel Working Paper*, (8) 2021.

gation of new ideas, generated through systematic research and development effort. Through R&D, firms master and implement the design and production of new goods and services. In essence, R&D is internally financed process, however, it often faces lack of self-funding[12]. Hence, private or public external funding is necessary. Major sources of public funding include grants, subsidies, tax incentives, research loans and public venture capital, public R&D and public-private partnerships, public procurement and patents. Private funding includes bank financing, capital markets and venture capital[13]. While private investors are mostly profit oriented, public funding promotes R&D activities with high social return[14]. Non-appropriability, intangibility and information asymmetry prevent private investor from full monetization of R&D activities, allowing knowledge to spill on other agents which are not included in R&D process[15]. This leads to social rates of return above private, thus, private investment levels below socially desirable levels[16].

The above mentioned provides sufficient reasons for government to introduce institutional and financial support for R&D. However, numerous authors including Dai and Chapman[17], Zuo and Lin[18], Appelt et al.[19], Szücs [20], Rehman

[12] Xu, J., Wang, X., Liu, F.: Government subsidies, R&D investment and innovation performance: analysis from pharmaceutical sector in China, *Technology Analysis & Strategic Management*, 33(5) 2021, pp. 535-553.

[13] Guo, D., Guo, Y., Jiang, K.: Government R&D support and firms' access to external financing: funding effects, certification effects, or both?, *Technovation*, 115 2022, pp. 102469.

[14] Wu, T., Yang, S., Tan, J.: Impacts of government R&D subsidies on venture capital and renewable energy investment-an empirical study in China, *Resources Policy*, 68 2020, pp. 101715.

[15] Bryan, K., Williams, H.: Innovation: Market Failures and Public Policies, *Handbook of Industrial Organization*, 5(1) 2021, pp. 281-388.

[16] Veugelers, R.: Research and innovation policies and productivity growth, *Bruegel Working Paper*, (8) 2021.

[17] Dai, X., Chapman, G.: R&D tax incentives and innovation: Examining the role of programme design in China, *Technovation*, 113 2022, pp. 102419.

[18] Zuo, Z., Lin, Z.: Government R&D subsidies and firm innovation performance: The moderating role of accounting information quality, *Journal of Innovation & Knowledge*, 7(2) 2022, pp. 100176.

[19] Appelt, S. et al.: R&D Tax Incentives: Evidence on Design, Incidence and Impacts, *OECD Science, Technology and Industry Policy Papers*, (32) 2016.

[20] Szücs, F.: Do research subsidies crowd out private R&D of large firms? Evidence from European Framework Programmes, *Research Policy*, 49(3) 2020, pp. 103923.

et al.[21], Yi et al.[22], Ahn et al.[23], etc., highlight downside of government subsidies, providing evidence on high administrative expenses of subsidy programs, higher costs of research inputs and crowding-out of private R&D. Problems of R&D market, as well as downside of public incentive programs for R&D, impose a heavy task for government in choosing adequate R&D incentive instrument or combination of instruments. Encouraged by the evidence from successful innovation-driven economies, governments embrace direct subsidy such as grants and loans, and indirect such as tax incentive as two basic types policy interventions[24]. When selecting a project in a competitive process, the government usually grants funding to a project with highest social return. This refers mostly to specific needs of public interest, such as defence industry, public health, environmental protection[25]. Universities and research centres R&D programs are usually characterized with highest rates of social return. However, social return is not the only government's motive. Innovation performance and overall R&D investment are in the centre of innovation policy, thus, grants are also intended to support private sector, leader in innovation activities in most countries. Numerous scientific researches, such as Hong et al.[26]; Basit et al.[27]; Jiang et al.[28] highlight how government grants stimulate corporate R&D

[21] Rehman, N. U., Hysa, E., Mao, X.: Does public R&D complement or crowd-out private R&D in pre and post economic crisis of 2008?, *Journal of Applied Economics*, 23(1) 2020, pp. 349-371.

[22] Yi, J. et al.: The more the merrier? Chinese government R&D subsidies, dependence, and firm innovation performance, *Journal of Product Innovation Management*, 38(2) 2021, pp. 289-310.

[23] Ahn, J. M., Lee, W., Mortara, L.: Do government R&D subsidies stimulate collaboration initiatives in private firms?, *Technological Forecasting and Social Change*, 151 2020, pp. 119840.

[24] Sterlacchini, A., Venturini, F.: R&D tax incentives in EU countries: does the impact vary with firm size?, *Small Business Economics*, 53(3) 2019, pp. 687-708.

[25] Jiang, Z., Xu, C.: Policy Incentives, Government Subsidies, and Technological Innovation in New Energy Vehicle Enterprises: Evidence from China, *Energy Policy*, 177 2023, pp. 113527.

[26] Hong, J. et al.: Government Grants, Private R&D Funding and Innovation Efficiency in Transition Economy, *Technology Analysis & Strategic Management* 27(9) 2015, pp. 1068-1096.

[27] Basit, S. A., Kuhn, T., Ahmed, M.: The Effect of Government Subsidy on non-Technological Innovation and Firm Performance in the Service Sector: Evidence From Germany, *Business Systems Research Journal*, 9(1) 2018, pp. 118-137.

[28] Jiang, C. L. et al.: The Effectiveness of Government Subsidies on Manufacturing Innovation: Evidence From the new Energy Vehicle Industry in China, *Sustainability*, 10(6) 2018, pp. 1692.

investment, as well as induce private sector innovation performance[29]. However, next to direct subsidy, government often decides to stimulate investments in R&D indirectly, with tax incentive. This neutral instrument is non-discriminatory and must embrace efficiently public as well as private actors[30]. Tax incentives can take several forms to offset enterprises' investments losses (up-front tax credits for investments, reductions in capital gains taxes or tax rates on investments, and tax credits)[31]. Though, often emphasized as the best government R&D incentive instruments, its positive results are mostly seen in large corporations. It is often criticized as not adequately suitable for small innovative start-ups which do not have profits, thus they cannot offset tax liabilities[32]. Furthermore, countries with weak tax enforcement system might encourage tax avoidance, manipulating with regular expenses as R&D expenditures[33]. Tax incentives result in vague effect on budget preventing policymakers to conclude about successfulness of this economic measure.

International R&D collaboration is most prevalent in basic research and technological domains where nations exhibit either relatively low or high levels of technological advancement[34]. In this context, externalities stemming from collaborative R&D are crucial for enhancing technologies that are subsequently transferred through network partners. Specifically, the acquired knowledge is utilized by partners for their internal research activities within both private and public institutions. Incoming knowledge spillovers are a significant determinant for R&D collaboration with domestic public knowledge institutions[35]. Given that knowledge transmission and dissemination are vital sources of technological progress, countries actively pursue international R&D cooperation through various mechanisms such as tax incentives and investment

[29] Le, T., Jaffe, A.: The Impact of R&D Subsidy on Innovation: Evidence From New Zealand Firms, *Economics of Innovation and New Technology*, 26 (5) 2017, pp. 429-452.

[30] Veugelers, R.: Research and innovation policies and productivity growth, *Bruegel Working Paper*, (8) 2021.

[31] Goldberg, I. et al: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

[32] Dechezleprêtre, A.: .: Do Tax Incentives for Research Increase Firm Innovation? An RD Design for R&D, *NBER Working Paper* (w22405), 2016.

[33] Tian, B. et al.: Tax incentive, R&D investment and firm innovation: evidence from China, *Journal of Asian Economics*, 71 2020, pp. 101245.

[34] Oh, D., Kim, Y., Ahn, H.: An analysis of international cooperation in the public research and development programs of Korea, *Asian Journal of Technology Innovation*, 18(2) 2010, pp. 43-67.

[35] Van Beers, C., Berghäll, E., Poot, T.: R&D internationalization, R&D collaboration and public knowledge institutions in small economies: Evidence from Finland and the Netherlands, *Research Policy*, 37(2) 2008, pp. 294-308.

promotion agencies. Participating countries experience direct benefits from economies of scale in production, along with indirect effects manifested in increased research intensity and competition. These indirect effects are evident in economies of scale, complementarities of their expertise, and the avoidance of redundant research efforts[36]. Furthermore, they benefit from the internalization of spillovers, as patent protection is not absolute against imitations[37]. Analyzing the interplay between technology and proximity in international R&D networks within low-tech firms, Teixeira et al.[38] discovered that successful international collaborative R&D projects exhibit both cultural/geographical proximity and distance. More precisely, geographically distant projects tend to be technologically more advanced, whereas those situated closer together are typically focused on low-tech areas. Gassmann and Von Zedtwitz[39] emphasize that shifts in behavioural orientation require substantial time, rendering large-scale increases in international R&D challenging for firms. This underscores the need for government support. Intergovernmental support serves as a crucial channel for R&D, particularly in the energy sector, initially implemented through the public sector and subsequently extended to industry[40]. Using Ghemawat's[41] five dimensions of distance, Angué and Mayrhofer[42] investigated the influence of these dimensions on partner selection in international R&D cooperation. Their findings indicate that administrative, geographic, economic, and technological distance play significant roles, while cultural distance does not have a significant impact on partner selection, at least within the biotechnology industry and when projects receive subsidies. Narula and Dunning[43] argue that

[36] Miotti, L., Sachwald, F.: Co-operative R&D: why and with whom?: An integrated framework of analysis, *Research policy*, 32(8) 2003, pp. 1481-1499.

[37] Sadraoui, T., Ali, T. B., Deguachi, B.: Economic growth and international R&D cooperation: a panel Granger causality analysis, *International Journal of Econometrics and Financial Management*, 2(1) 2014, pp. 7-21.

[38] Teixeira, A. A., Santos, P., Oliveira Brochado, A.: International R&D Cooperation between low-tech SMEs: the role of cultural and geographical proximity, *European Planning Studies*, 16(6) 2008, pp.785-810.

[39] Gassmann, O., Von Zedtwitz, M.: New concepts and trends in international R&D organization, *Research policy*, 28(2-3) 1999, pp. 231-250.

[40] Liping, D.: Analysis of the relationship between international cooperation and scientific publications in energy R&D in China, *Applied energy*, 88(12) 2011, pp. 4229-4238.

[41] Ghemawat, P.: Distance still matters: The hard reality of global expansion, *Harvard Business Review*, 2001, pp. 137-147.

[42] Angué, K., Mayrhofer, U.: International R&D cooperation: the effects of distance on the choice of the country of partners, *Management*, 2010, pp. 1-37.

[43] Narula, R., Dunning, J. H.: Explaining international R&D alliances and the role of governments, *International Business Review*, 7(4) 1998, pp. 377-397.

government support for international R&D is most effective for basic research investments and enhancing international coordination of technology markets. Finally, international cooperation yields more concrete results when formalized through agreements[44].

3. RESEARCH QUESTION

Historically, CEE countries economic model lacked the private sector, relying exclusively on government initiatives. According to Peng and Heath[45], this is especially evident in R&D activities. Government sector retained the leading role through entire innovation circle; R&D, design, engineering, troubleshooting and other innovation activities[46]. Compared with western, CEE universities, companies and nonprofit research institutes were restricted in commercialization of federally funded inventions. This made them unwilling to innovate. Government innovation priorities overruled market feedback, leading toward concentrated technology portfolios (chemical and mechanical engineering)[47]. In the 1990s, CEE countries started transformation of economic model. Global integration was directed by western countries and international financial institutions which tried to achieve record speed institutional transformation[48]. During transformation period, in line with Washington consensus, maintaining macro-economic stability, fiscal discipline, trade and financial liberalization were the main goal for CEE countries[49], while innovation and

[44] Feitosa, P. H. A. et al.: Does international R&D cooperation under institutional agreements have a greater impact than those without agreements?, *Science and Public Policy*, 50(5) 2023, pp. 831-841.

[45] Peng, M. W., Heath, P. S.: The growth of the firm in planned economies in transition: Institutions, organizations, and strategic choice, *Academy of management review*, 21(2) 1996, pp. 492-528.

[46] Radosevic, S.: Transformation of science and technology systems into systems of innovation in central and eastern Europe: the emerging patterns and determinants, *Structural Change and Economic Dynamics*, 10(3-4) 1999, pp. 277-320.

[47] Lacasa, I. D., Giebler, A., Radošević, S.: Technological capabilities in Central and Eastern Europe: an analysis based on priority patents, *Scientometrics*, 111 2017, pp. 83-102.

[48] Kirankabeş, M. C., Erkul, A.: Regional knowledge production in Central and East European countries: R&D factor productivity and changes in performances, *Eastern Journal of European Studies*, 10(1) 2019, pp. 25-44.

[49] Wozniak-Jechorek, B.: Examining the European Transition: Central Eastern European Countries Two Decades post-EU Accession, *Revista Economia e Políticas Públicas*, 12(1) 2024, pp. 48-60.

technology development were not in the focus[50]. Thus, according to Aghion et al.[51], CEE countries found economic support mainly in privatization programs and foreign direct investment. Having the largest market experience, incoming foreign companies led industrial restructuring and innovation activities at that time. However, Kriaucioniene and Ragauskas[52] neglected positive effect of those companies, since their presence was mainly in low value-added industries. Even more, they see foreign companies disrupting all linkages between former R&D institutes and the enterprise sector, which led CEE companies to knowledge outsourcing. This triggered a downturn momentum in CEE economies, and an entire decade was needed to be able to reach growth rates of the pre-1990s. According to Mickiewicz, Radosevic and Varblane[53], this period completely neglected development of innovation policy, whose consequences are seen even today. Data retrieved from OECD database[54], indicate that even today CEE countries don't follow patterns of most developed countries, but nurture old socialist trends. CEE countries face an absence of corporate-private financing, lack of patent application and quality of research institutions, modest high-tech exports, etc. First indications of structured innovation policies appeared in the second half of the 1990s. They were a result of efforts CEE countries invested in fulfilling the EU accession criteria. According to Radosevic and Yoruk[55], foreign companies replace the lack of domestic capabilities in CEE. However, foreign partners' caution about technology infringement, as well as low absorptive capacity for global high-quality technology, prevented CEE innovators to connect to centres of technological excellence outside the region. This can be confirmed with small number of global partners[56]. Accord-

[50] Havrylyshyn, O.: Recovery and growth in transition: A decade of evidence, *IMF Staff papers*, 48(1) 2001, p. 53-87.

[51] Aghion, P.: Some Thoughts on Industrial Policy and Growth, in: Falck, O., Gollier, C., Woessmann, L. (eds.): *Industrial Policy for National Champions*, Boston: MIT press, 2011.

[52] Kriaucioniene, M., Arminas R.: Transition via R&D: emerging forms and strategies of corporate R&D in the catch up countries (Lithuanian case), *IV Globelics Conference at Mexico City*, 2008, pp. 22-24.

[53] Mickiewicz T, Radosevic S, Varblane U.: FDI in Central Europe: short-run effects in manufacturing, in: Fabry N. H., Zeghni S. H. (eds.): *Transition in Asia and Eastern and Central Europe: a closed door - two open windows?*. New York (US): Nova science, 2001. pp. 31-53.

[54] Organisation for Economic Co-operation and Development (OECD), R&D expenditure indicator, <OECD.stat> last accessed on 20/09/2024.

[55] Radosevic, S., Yoruk, E.: Technology upgrading of middle income economies: A new approach and results, *Technological Forecasting and Social Change*, 129 2018, pp. 56-75.

[56] Organisation for Economic Co-operation and Development (OECD): International co-inventions indicator.

ing to De Beule et al.[57], a country occupies its place on the global innovation map only with indigenous inventions, but the one which came in cooperation with international partners from high-income economy. Global technology pool is a vital mechanism for accelerating industrial development and worker productivity[58]. Lack of international cooperation has left CEE countries with obsolete R&D capacities, less connected to high-quality, cutting-edge technology. Thus, indigenous CEE companies ended up with limited product range depending on foreign demand[59]. However, CEE well-developed scientific and engineering educational system combined with cheap labor presents an opportunity for developed countries to set their R&D operations there. Since recently, the trend of collaboration between foreign MNC (multi -national corporations) and local inventors has gained traction which can be visible with, still small, but growing number of international co-inventions in CEE countries[60].

Further acquisition of international knowledge presents one of the basic elements of CEE innovation strategy. Data from OECD database indicate that largest R&D financial patron in CEE countries is the government. CEE countries governments provide 60% of all investment in R&D, compared to 30% in western countries. According to Kozlowski et al.[61], in new market economy, CEE countries governments need to continue their function of financing education and basic research, however, they also need to provide financial assistance to all other R&D capacities that are active in the economic, domestic and international sector. Historically, due to prevailing public companies, CEE countries governments rely heavily on direct subsidy as primary instrument of support. However, with entering market economy and introduction of private companies this measure has questionable effectiveness on innovation activities[62]. According

[57] De Beule, F., Van Beveren, I.: Sources of open innovation in foreign subsidiaries: An enriched typology, *International Business Review*, 28(1) 2019, pp. 135-147.

[58] Goldberg, I. et al.: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

[59] Piech, K., Radosevic, S.: *The knowledge-based economy in Central and East European countries: countries and industries in a process of change*, London: Palgrave Macmillan, 2006.

[60] Organisation for Economic Co-operation and Development (OECD): International co-inventions indicator.

[61] Kozlowski, J., Radosevic, S., Ircha, D.: History matters: The inherited disciplinary structure of the post-communist science in countries of central and Eastern Europe and its restructuring, *Scientometrics*, 45(1) 1999, pp. 137-166.

[62] Tevdovski, D., Tosevska-Trpcevska, K., Disoska, E. M.: What is the role of innovation in productivity growth in Central and Eastern European countries?, *Economics of Transition*, 25(3) 2017, pp. 527-551.

to Masso and Vahter[63], Mateut[64] and Toshevska-Trpchevska et al.[65] positive effect of government subsidy on innovation activities is not questionable. Though, they find ambiguous findings of effectiveness of government funding on innovation output. Relationship between government subsidy and innovation activities was additionally complicated by Disoska et al.[66], whose research proves that effectiveness of government subsidy varies over time.

CEE governments have recognized lack of high added value technologies, and solution sees in international R&D partners. However, low level of R&D expenditure in CEE countries has disabled not only radical inventive activities, but also development of incremental technology necessary for the development of absorptive capacity and coupling of domestic and foreign know-how. Inadequate networking, weak administrative capacity and institutional coordination indicate absence of structured innovation policy, pushing away high value-added foreign companies. CEE governments try to compensate this deficiency with direct and indirect R&D funding. However, CEE governments cannot increase their contribution to overall R&D expenditure, given that they already are the largest R&D contributor, and their financial resources are limited due to a weak economic situation. Lack of government resources questions efficiency and comprehensiveness of invasive measures such as direct funding. It is expected that this government measure has limited effect on large international private R&D investors, largest contributor in production of high technology, according to Lööf and Heshmati[67], Lach[68], and Becker[69]. This is mostly because the costs of their projects go beyond available resources in the government's budget, and those funds are mostly directed towards the proj-

[63] Masso, J., Vahter, P.: Technological innovation and productivity in late-transition Estonia: econometric evidence from innovation surveys, *The European Journal of Development Research*, 20 2008, pp. 240-261.

[64] Mateut, S.: Subsidies, financial constraints and firm innovative activities in emerging economies, *Small Business Economics*, 50(1) 2018, pp. 131-162.

[65] Toshevska-Trpchevska, K. et al: The impact of a crisis on the innovation systems in Europe: Evidence from the CIS10 innovation survey, *European Review*, 27(4) 2019, pp. 543-562.

[66] Disoska, E. M. et al.: Evidence of innovation performance in the period of economic recovery in Europe, *Innovation: The European Journal of Social Science Research*, 33(3) 2020, pp. 280-295.

[67] Lööf, H., Heshmati, A.: The impact of public funds on private R&D investment: New evidence from a firm level innovation study. Commercialization and Transfer of Technology: Major Country Case Studies, *Nova Science Publishers*, 2007, pp. 77-96.

[68] Lach, S.: Do R&D subsidies stimulate or displace private R&D? Evidence from Israel, *Journal of Industrial Economics*, 50 2002, pp. 369-390.

[69] Becker, B.: Public R&D policies and private R&D investment: A survey of the empirical evidence, *Journal of economic surveys*, 29(5) 2015, pp. 917-942.

ects which would have been done anyway. Furthermore, government's focus on social and private profit return often indicates the mismatching of their end goals. Less invasive measures, such as tax incentive, do not put a heavy burden on the government's budget. This neutral instrument is non-discriminatory and embraces efficiently the public as well as the private actors. Finally, tax incentive creates positive investment environment for international companies. Thus, it is expected that CEE governments' R&D tax incentive will attract foreign R&D companies which are in search for quality innovation environment.

This paper immerses in understanding weather CEE countries' main innovation policy instruments, such as direct and indirect subsidy, stimulate cooperation with foreign partners.

4. METHODOLOGY

In order to get an answer to the research question, the authors chose a sample of seven CEE countries (Poland, Czech Republic, Slovak Republic, Slovenia, Lithuania, Latvia and Estonia) members of OECD for the time period 2000-2017. Selected countries have history of thirty years' in market economy, however, for the first decade of transition period they were concentrated on building macroeconomic stability and neglected the development of innovation policy. Thus, many of the observed countries still have not developed fiscal stimulus for innovation activities. To answer the question did government policy spur collaboration of local researchers and foreign inventors, we used data from OECD and World Bank database. In this research, the collaboration of local researchers and foreign inventors is the dependent variable and was presented with the variable "domestic ownership of inventions made abroad" (RDO). The variable can be found in OECD database, and presents the number of patents owned by resident(s) of country x (applicant) that have been invented by at least one foreign resident (inventor) from country y. To present government support, the independent variable, this research selected two major instruments for delivering public support, R&D tax incentives (IGS) and direct funding (BERD). The model was controlled with variables R&D personnel (PER) and gross domestic expenditure for R&D (GERD). Methodology used in this research was done using a panel vector autoregression approach that controlled for endogeneity and allowed determination of inter-linkages among variables.

Panel Vector Autoregressive (PVAR) model as explained in Bošnjak et al.[70], Sigmund and Ferstl[71] is a combination of vector autoregressive model and single equation dynamic panel model that allows analysis of dynamic causalities among variables under consideration (1)

$$\boldsymbol{y}_{i,t} = \mu_i + \sum_{l=1}^{p} \boldsymbol{A}_l \boldsymbol{y}_{i,t-l} + \boldsymbol{B}\boldsymbol{x}_{i,t} + \boldsymbol{C}\boldsymbol{s}_{i,t} + \epsilon_{\boldsymbol{i,t}} \quad (1)$$

Where μ_i, **y**, **x**, **s** and ϵ denote fixed effects, vector of endogenous variables, vector of predetermined variables, vector of strictly exogenous variables and residuals, respectively. Hayakawa[72] suggested forward orthogonal deviation as the preferred transformation to remove unobserved individual effects from panel data model. As suggested by Hayakawa, variables were transformed using forward orthogonal deviation. Afterwards, one-step Generalized Method of Moments (GMM) estimator was employed and the number of moment conditions was reduced by collapsing of instruments[73]. All of the variables analyzed in this paper were considered as endogenous.

Lagged variables in system enable dynamic or static dependencies that may potentially arise among countries under consideration while being suitable in case of heterogeneity in coefficient estimates for the variables under consideration (Koop and Korobilis[74], Ozcan et al.[75]). Lag selection was determined based on information criterion following Andrews and Lu[76]. Furthermore, to

[70] Bošnjak, M., Novak, I., Bašić, M.: Openness and inflation nexus: The case of European post-transition countries, in: Sever Mališ, S., Jaković, B., Načinović Braje, I. (eds.): *Proceedings of FEB Zagreb International Odyssey Conference on Economics and Business* (pp. 181-191), Zagreb: Faculty of Economics and Business, 2022.

[71] Ferstl, R., Sigmund, M.: Panel Vector Autoregression in R with the Package Panelvar. *SSRN: Social Science Research Network*, 2017.

[72] Hayakawa, K.: First difference or forward orthogonal deviation-which transformation should be used in dynamic panel data models?: A simulation study, *Economics Bulletin*, 29(3) 2009, pp. 2008-2017.

[73] Ferstl, R., Sigmund, M.: Panel Vector Autoregression in R with the Package Panelvar, *SSRN: Social Science Research Network*, 2017.

[74] Koop, G., Korobilis, D.: Model uncertainty in panel vector autoregressive models, *European Economic Review*, 81 2016, pp. 115-131.

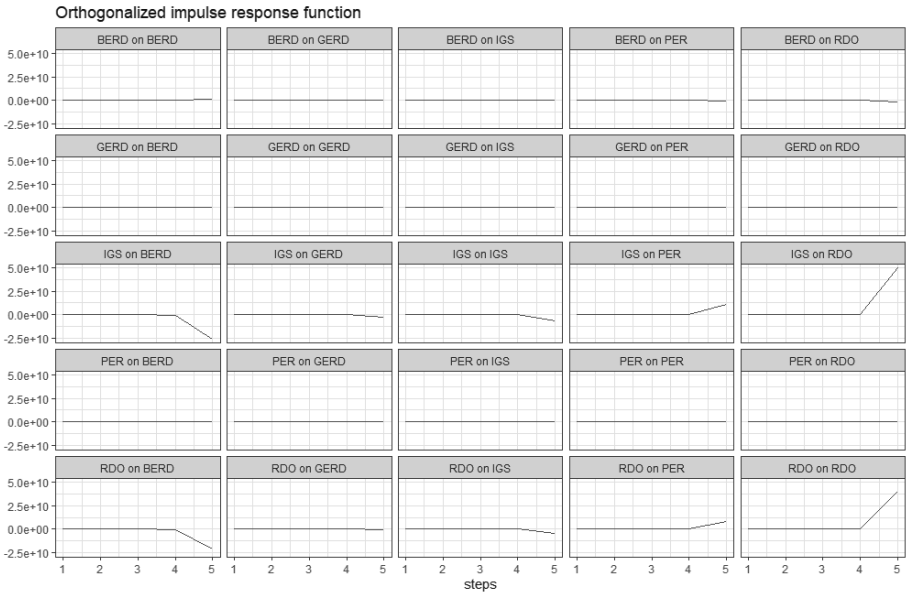
[75] Ozcan, B., Panayiotis G. Tzeremes, Nickolaos G. Tzeremes: Energy consumption, economic growth and environmental degradation in OECD countries, *Economic Modelling*, 84 (2020), pp. 203-213.

[76] Andrews, D. W., Lu, B.: Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models, *Journal of econometrics*, 101(1) 2001, pp. 123-164.

illustrate response among endogenous variable orthogonal impulse response functions from Lutkepohl[77] was estimated, together with forecast error variance decomposition.

Based on orthogonal impulse response function, no special effects were identified out of shocks in BERD, GERD and PER. The shocks in IGS negatively affected BERD. At the same time shocks in IGS positively affected PER and RDO while the effects on RDO were more prominent. Furthermore, RDO effected negatively BERD and IGS while effects on BERD were more sizable. No effects on GERD out of shocks in RDO were identified while effects on PER were positive. As illustrated in Picture 1 titled "Orthogonalized impulse response function" effects always appeared with four years of delay. Forecast error variance decomposition was calculated in addition and provided in the appendix of this paper.

Picture 1. "Orthogonalized impulse response function"



Results of this research indicate the following: Growth of direct subsidy by the government leads to lower collaboration of local researchers and foreign inventors. Growth of tax incentive by the government leads to growth of collaboration of local researchers and foreign inventors, Growth of collaboration

[77] Lütkepohl, H.: *New introduction to multiple time series analysis*, New York: Springer 2005.

leads to further growth of collaboration of local researchers and foreign inventors creating spiral effect. Using PVAR specification and GMM as an estimator technique, various econometric issue can be handled. While PVAR-GMM is a flexible and valuable approach there are some limitations as it is the case with any method. Based on the findings from previous research, the authors assumed the linear nature of the linkage between variables under consideration. Hypothetically, in case of nonlinear relationship among considered variables GMM would not be a desirable approach. Dynamic panel data and the method followed in this research is sensitive to lag selection, especially when short time periods are considered. However, in the research period between 2000 and 2017, the potential issue of lag selection was addressed, and the authors followed the approach from Andrews and Lu[78].

5. DISCUSSION

The results of this research indicate that the intensification of government direct subsidy program lowers the level of collaboration between local and foreign researchers. Direct government funding programs are designed to support the projects with the highest estimated social return[79]. Though philanthropic phenomena are emerging, profit stays in the main focus of private capital[80]. Incentives to private investors to support projects with high social return are still not sufficient to offset potential losses from knowledge spillovers, unavoidable in social projects.

Thus, projects with the social return continue relying on domestic public R&D sector, such as research institutes, public universities, agencies and other non-profit institutions. However, transition to market economy has overlooked detail transformation of CEE countries innovation system, keeping old habits of socialist public R&D sector, overemphasized basic research, neglecting the importance of commercialization. Furthermore, lack of financial resources and entrepreneurial spirit limit absorption and development of high-quality technology. Hence, CEE public R&D sector has been built on the shoulder of internal capacities, the acquisition of outdated technology of developed countries. This has trapped them in innovation loop of low-quality knowledge

[78] Andrews, D. W., Lu, B.: Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models, *Journal of econometrics*, 101(1) 2001, pp. 123-164.

[79] Bloom, N., Van Reenen, J., Williams, H.: A toolkit of policies to promote innovation, *Journal of economic perspectives*, 33(3) 2019, pp. 163-84.

[80] Roundy, P., Holzhauer, H., Dai, Y. Finance or philanthropy? Exploring the motivations and criteria of impact investors, *Social Responsibility Journal*, 13(3) 2017, pp. 491-512.

production, far from technology frontier and serious cooperation with technology advanced international partners. This is confirmed with a relatively small number of international co-inventions by universities and research institutes[81]. Thus, in search for projects with highest social return, government direct funding ends mostly in universities and research institutes, reinforcing accumulation of internal, low-quality innovations. This hinders absorptive capacity and potential collaboration with international partners with advanced technology. Furthermore, the results of this research indicate that growth of indirect government support, i.e. tax incentive for R&D programs, leads to growth of local researchers and foreign inventors' collaboration. Compared to government subsidy, tax incentive is a more widespread policy measure. The use of R&D tax incentives is worldwide and represents a sensible contribution to the reduction of R&D costs incurred by corporate sector[82]. Numerous authors, including Yang et al.[83], Dechezleprêtre et al,[84], Lokshin and Mohnen[85], Busom et al.[86], Bloom et al.[87], tested for the effectiveness of the instrument observing tax price elasticity. All of them indicated that each dollar forgone in tax credit for R&D stimulates additional expenditure of corporate sector on R&D. Thus, tax incentives take part in framing positive business climate for corporate sector. Statistical data indicate that foreign multinational companies appear to be making a significant contribution to inventive activity in the CEE region[88], i.e. foreign companies' local R&D operations, and generating a large fraction of the total patents emerging from CEE countries. Thus, tax incentive reinforces additional expenditure of foreign companies on R&D activities. Through their

[81] Organisation for Economic Co-operation and Development (OECD) Science, Technology and Patents [Data file], <https://stats.oecd.org/> last accessed on 17/06/2024.

[82] Corchuelo, M. B., Martínez-Ros, E.: Who benefits from R&D tax policy?, *Cuadernos de Economía y Dirección de la Empresa*, 13(45) 2010, pp. 145-170.

[83] Yang, C.-H., Huang, C.-H., Hou, T. C.-T.: Tax incentives and R&D activity: Firm-level evidence from Taiwan, *Research Policy*, 41 2012, pp. 1578-1588.

[84] Dechezleprêtre, A., Einiö, E., Martin, R., Nguyen K-T., Van Reenen, J.: Do Tax Incentives for Research Increase Firm Innovation? An RD Design for R&D, *NBER Working Paper* (w22405), 2016.

[85] Lokshin, B., Mohnen, P.: How effective are level-based R&D tax credits? Evidence from the Netherlands, *Applied Economics*, 44(12) 2012, pp. 1527-1538.

[86] Busom, I., Corchuelo, B., Martínez-Ros, E.: Tax incentives… or subsidies for business R&D?, *Small Business Economics*, 43 2014, pp. 571-596.

[87] Bloom, N., Van Reenen, J., Williams, H.: A toolkit of policies to promote innovation, *Journal of economic perspectives*, 33(3) 2019, pp. 163-184.

[88] Castellani, D., Perri, A., Scalera, V. G.: Knowledge integration in multinational enterprises: The role of inventors crossing national and organizational boundaries, *Journal of World Business*, 57(3) 2022, pp. 101290.

sponsorship of local inventors and inclusion in worldwide teams of researchers, foreign companies promote co-inventions. According to OECD database, more than half of total CEE patent grants originate from teams of inventors placed in more than one country. Finally, the results of this research indicate how growth of collaboration among local and foreign researchers will have spiral effect. CEE indigenous innovations often lag behind high-quality innovations from more developed countries (Radosevic[89], Tiits et al.[90]). Though highly skilled and well educated, decades of isolation prevent CEE inventors to pull out from innovation mediocracy and catch up with the global technological frontier. According to Dernis et al.[91], CEE countries' first significant encounter with contemporary technological achievements came from foreign companies after accepting market economy model. Multinational companies' sponsorship of domestic inventors and access to their world-wide R&D teams have enabled the development of absorptive capacity, necessary for successful coupling of foreign and domestic knowledge. Successful coupling of foreign and domestic knowledge secures domestic researchers to be locked in a loop of collaboration with a foreign partner.

6. CONCLUSION

Cutting through CEE countries' innovation system, this research indicates the most important innovation driving forces. Emphasizing the shortcomings of the system, a question is raised whether CEE countries can catch up with the leaders in the global innovation race? Three decades of system transformation have passed, but somehow a significant step toward technological frontier is missing. Access to foreign technology is available, however, historical heritage manages to slow down its adoption, keeping CEE countries' knowledge base on the verge of mediocracy. Lacking radical inventive activities, they find themselves comfortable with the acquisition of old outdated technology, hoping they develop necessary level of absorptive capacity for successful coupling of domestic and foreign know-how. This research emphasizes the importance of international collaboration in developing absorptive capacity and building

[89] Radosevic, S.: *The knowledge-based economy in Central and East European countries - an overview of key issues. Knowledge-based economy in Central and Eastern Europe: Countries and industries in a process of change*, London: Palgrave Macmillan, 2006.

[90] Tiits, M. et al: Catching up, forging ahead or falling behind? Central and Eastern European development in 1990-2005, *Innovation: The European Journal of Social Science Research*, 21(1) 2008, pp. 65-85.

[91] Dernis, H. et al.: World corporate top R&D investors: Innovation and IP bundles, *Joint Research Centre* (JRC94932), 2015.

technology base. According to Goldberg et al.[92] global technology pool is a vital mechanism for accelerating industrial development and reaching technological frontier. Previous and this research identify international collaboration inventions with high-quality technology. Thus, CEE countries' governments use a wide spectrum of instruments for improving innovation climate and attract international companies with high-quality technology. Using tax incentives and direct funding, governments encourage reinvesting of companies' funds in R&D. This research shows ambiguous effect of government support. While tax incentive supports international collaboration, direct subsidy obstructs it. In order to justify this opposite effect, this paper emphasizes how different types of government support target different actors. Hence, tax incentive prompts mostly large multinational corporations, the largest patent applicants in CEE countries, whose technology is a result of foreign and domestic researchers' collaboration. On the other hand, direct subsidy target projects with high social return, projects mostly conducted by internally oriented institutions, like universities, NGO (non-governmental organizations) and research institutes. These findings are important because they reveal that in spite increased efforts in creating positive innovation environment, CEE governments only partially succeed in reorienting innovation activities toward high-quality technologies. Governments need to invest more effort in separating public research institutions from old habits of self-sufficiency. Furthermore, this paper has additionally enriched the short list of papers focused on government support to revolutionize CEE countries' technology scene. There are some limitations in this research, which mostly reflects through a lack of data for the entire transition period. Consolidated data for the period since 1990-2000 is not available. However, the downside of this limitation is mitigated with the fact that this period of transition is often seen as a "lost decade" for innovation system.

This research focused on general tax incentive and their effect on international R&D collaboration. Future research could dive deeper in observing the effect of specific types of taxes, such as up-front tax credits for investments, reductions in capital gains taxes or tax rates on investments, and tax credits on international R&D collaboration.

[92] Goldberg, I. et al.: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

LITERATURE

1. Aghion, P.: Some Thoughts on Industrial Policy and Growth, in: Falck, O., Gollier, C., Woessmann, L. (eds.): *Industrial Policy for National Champions*, Boston: MIT press, 2011.
   - DOI: https://doi.org/10.7551/mitpress/9780262016018.003.0002
2. Ahn, J. M., Lee, W., Mortara, L.: Do government R&D subsidies stimulate collaboration initiatives in private firms?, *Technological Forecasting and Social Change*, 151 2020, pp. 119840
   - DOI: https://doi.org/10.1016/j.techfore.2019.119840
3. Andrews, D. W., Lu, B.: Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models, *Journal of econometrics*, 101(1) 2001, pp. 123-164.
   - DOI: https://doi.org/10.1016/S0304-4076(00)00077-4
4. Angué, K., Mayrhofer, U.: International R&D cooperation: the effects of distance on the choice of the country of partners, *Management*, 2010, pp. 1-37.
5. Appelt, S., Bajgar, M., Criscuolo, C., Galindo-Rueda, F.: R&D Tax Incentives: Evidence on Design, Incidence and Impacts, *OECD Science, Technology and Industry Policy Papers*, (32) 2016.
6. Basit, S. A., Kuhn, T., Ahmed, M.: The Effect of Government Subsidy on non-Technological Innovation and Firm Performance in the Service Sector: Evidence From Germany, *Business Systems Research Journal*, 9(1) 2018, pp. 118-137.
   - DOI: https://doi.org/10.2478/bsrj-2018-0010
7. Becker, B.: Public R&D policies and private R&D investment: A survey of the empirical evidence, *Journal of economic surveys*, 29(5) 2015, pp. 917-942.
   - DOI: https://doi.org/10.1111/joes.12074
8. Bloom, N., Van Reenen, J., Williams, H.: A toolkit of policies to promote innovation, *Journal of economic perspectives*, 33(3) 2019, pp. 163-184.
   - DOI: https://doi.org/10.1257/jep.33.3.163
9. Bošnjak, M., Novak, I., Bašić, M.: Openness and inflation nexus: The case of European post-transition countries, in: Sever Mališ, S., Jaković, B., Načinović Braje, I. (eds.): *Proceedings of FEB Zagreb International Odyssey Conference on Economics and Business* (pp. 181-191), Zagreb: Faculty of Economics and Business, 2022.
10. Bryan, K., Williams, H.: Innovation: Market Failures and Public Policies, *Handbook of Industrial Organization*, 5(1) 2021, pp. 281-388.
    - DOI: https://doi.org/10.1016/bs.hesind.2021.11.013
11. Busom, I., Corchuelo, B., Martínez-Ros, E.: Tax incentives… or subsidies for business R&D?, *Small Business Economics*, 43 2014, pp. 571-596.
    - DOI: https://doi.org/10.1007/s11187-014-9569-1

12. Castellani, D., Perri, A., Scalera, V. G.: Knowledge integration in multinational enterprises: The role of inventors crossing national and organizational boundaries, *Journal of World Business*, 57(3) 2022, pp. 101290.
    - DOI: https://doi.org/10.1016/j.jwb.2021.101290

13. Contractor, F. J., Dangol, R., Nuruzzaman, N., Raghunath, S.: How do country regulations and business environment impact foreign direct investment (FDI) inflows?, *International Business Review*, 29(2) 2020, pp. 101640.
    - DOI: https://doi.org/10.1016/j.ibusrev.2019.101640

14. Corchuelo, M. B., Martínez-Ros, E.: Who benefits from R&D tax policy?, *Cuadernos de Economía y Dirección de la Empresa*, 13(45) 2010, pp. 145-170.
    - DOI: https://doi.org/10.1016/S1138-5758(10)70027-X

15. Dai, X., Chapman, G.: R&D tax incentives and innovation: Examining the role of programme design in China, *Technovation*, 113 2022, pp. 102419.
    - DOI: https://doi.org/10.1016/j.technovation.2021.102419

16. De Beule, F., Van Beveren, I.: Sources of open innovation in foreign subsidiaries: An enriched typology, *International Business Review*, 28(1) 2019, pp. 135-147.
    - DOI: https://doi.org/10.1016/j.ibusrev.2018.08.005

17. Dechezleprêtre, A., Einiö, E., Martin, R., Nguyen K-T., Van Reenen, J.: Do Tax Incentives for Research Increase Firm Innovation? An RD Design for R&D, *NBER Working Paper* (w22405), 2016.
    - DOI: https://doi.org/10.3386/w22405

18. Dernis, H., Mafini, D., Hervas, F., Millot, V., Squicciarini, M., Vezzani, A.: World corporate top R&D investors: Innovation and IP bundles, *Joint Research Centre* (JRC94932), 2015.

19. Disoska, E. M., Tevdovski, D., Toshevska-Trpchevska, K., Stojkoski, V.: Evidence of innovation performance in the period of economic recovery in Europe, *Innovation: The European Journal of Social Science Research*, 33(3) 2020, pp. 280-295.
    - DOI: https://doi.org/10.1080/13511610.2018.1524288

20. European Commission: Convergence Report reviews Member States' preparedness to join the euro area and paves the way for Croatia's euro adoption on 1 January 2023, June 1 2022, <https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3312> last accessed on 20/10/2024.

21. European Investment Bank: Innovation Investment in Central, Eastern and South-Eastern Europe: Building Future Prosperity and Setting the Ground for Sustainable Upward Convergence. 2023, <https://www.eib.org.>, last accessed on 03/08/2024.

22. Feitosa, P. H. A., Salles-Filho, S., Bin, A., Juk, Y., Colugnati, F. A. B.: Does international R&D cooperation under institutional agreements have a greater impact than those without agreements?, *Science and Public Policy*, 50(5) 2023, pp. 831-841.
    - DOI: https://doi.org/10.1093/scipol/scad019

23. Ferstl, R., Sigmund, M.: Panel Vector Autoregression in R with the Package Panelvar. *SSRN: Social Science Research Network*, 2017.
    - DOI: https://doi.org/10.2139/ssrn.2896087

24. Gassmann, O., Von Zedtwitz, M.: New concepts and trends in international R&D organization, *Research policy*, 28(2-3) 1999, pp. 231-250.
    - DOI: https://doi.org/10.1016/S0048-7333(98)00114-0

25. Ghemawat, P.: Distance still matters: The hard reality of global expansion, *Harvard Business Review*, 2001, pp. 137-147.

26. Goldberg, I., Goddard, J., Kuriakose, S. Racine, J.: *Igniting innovation: rethinking the role of government in emerging Europe and Central Asia,* Washington, D.C.: World Bank Group.

27. Guo, D., Guo, Y., Jiang, K.: Government R&D support and firms' access to external financing: funding effects, certification effects, or both?, *Technovation*, 115 2022, pp. 102469.
    - DOI: https://doi.org/10.1016/j.technovation.2022.102469

28. Havrylyshyn, O.: Recovery and growth in transition: A decade of evidence, *IMF Staff papers*, 48(1) 2001, pp. 53-87.
    - DOI: https://doi.org/10.2307/4621690

29. Hayakawa, K.: First difference or forward orthogonal deviation-which transformation should be used in dynamic panel data models?: A simulation study, *Economics Bulletin*, 29(3) 2009, pp. 2008-2017.

30. Hong, J., Hong, S., Wang, L., Xu, Y., Zhao, D.: Government Grants, Private R&D Funding and Innovation Efficiency in Transition Economy, *Technology Analysis & Strategic Management* 27(9) 2015, pp. 1068-1096.
    - DOI: https://doi.org/10.1080/09537325.2015.1060310

31. Jiang, C., Zhang, Y., Bu, M., Liu, W.: The Effectiveness of Government Subsidies on Manufacturing Innovation: Evidence From the new Energy Vehicle Industry in China, *Sustainability*, 10(6) 2018, pp. 1692.
    - DOI: https://doi.org/10.3390/su10061692

32. Jiang, Z., Xu, C.: Policy Incentives, Government Subsidies, and Technological Innovation in New Energy Vehicle Enterprises: Evidence from China, *Energy Policy*, 177 2023, pp. 113527.
    - DOI: https://doi.org/10.1016/j.enpol.2023.113527

33. Kirankabeş, M. C., Erkul, A.: Regional knowledge production in Central and East European countries: R&D factor productivity and changes in performances, *Eastern Journal of European Studies*, 10(1) 2019, pp. 25-44.

34. Koop, G., Korobilis, D.: Model uncertainty in panel vector autoregressive models, *European Economic Review*, 81 2016, pp. 115-131.
    - DOI: https://doi.org/10.1016/j.euroecorev.2015.09.006

35. Kozlowski, J., Radosevic, S., Ircha, D.: History matters: The inherited disciplinary structure of the post-communist science in countries of central and Eastern Europe and its restructuring, *Scientometrics*, 45(1) 1999, pp. 137-166.
    - DOI: https://doi.org/10.1007/BF02458473

36. Kriaucioniene, M., Arminas R.: Transition via R&D: emerging forms and strategies of corporate R&D in the catch up countries (Lithuanian case), *IV Globelics Conference at Mexico City*, 2008, pp. 22-24.

37. Lacasa, I. D., Giebler, A., Radošević, S.: Technological capabilities in Central and Eastern Europe: an analysis based on priority patents, *Scientometrics*, 111 2017, pp. 83-102.
    - DOI: https://doi.org/10.1007/s11192-017-2277-2

38. Lach, S.: Do R&D subsidies stimulate or displace private R&D? Evidence from Israel, *Journal of Industrial Economics*, 50 2002, pp. 369-390.
    - DOI: https://doi.org/10.1111/1467-6451.00182

39. Le, T., Jaffe, A.: The Impact of R&D Subsidy on Innovation: Evidence From New Zealand Firms, *Economics of Innovation and New Technology*, 26 (5) 2017, pp. 429-452.
    - DOI: https://doi.org/10.1080/10438599.2016.1213504

40. Liping, D.: Analysis of the relationship between international cooperation and scientific publications in energy R&D in China, *Applied energy*, 88(12) 2011, pp. 4229-4238.
    - DOI: https://doi.org/10.1016/j.apenergy.2011.02.045

41. Lokshin, B., Mohnen, P.: How effective are level-based R&D tax credits? Evidence from the Netherlands, *Applied Economics*, 44(12) 2012, pp. 1527-1538.
    - DOI: https://doi.org/10.1080/00036846.2010.543083

42. Lööf, H., Heshmati, A.: The impact of public funds on private R&D investment: New evidence from a firm level innovation study. Commercialization and Transfer of Technology: Major Country Case Studies, *Nova Science Publishers*, 2007, pp. 77-96.

43. Lütkepohl, H.: *New introduction to multiple time series analysis*, New York: Springer 2005.
    - DOI: https://doi.org/10.1007/978-3-540-27752-1

44. Masso, J., Vahter, P.: Technological innovation and productivity in late-transition Estonia: econometric evidence from innovation surveys, *The European Journal of Development Research*, 20 2008, pp. 240-261.
    - DOI: https://doi.org/10.1080/09578810802060751

45. Mateut, S.: Subsidies, financial constraints and firm innovative activities in emerging economies, *Small Business Economics*, 50(1) 2018, pp. 131-162.
    - DOI: https://doi.org/10.1007/s11187-017-9877-3

46. Mickiewicz T, Radosevic S, Varblane U.: FDI in Central Europe: short-run effects in manufacturing, in: Fabry N. H., Zeghni S. H. (eds.): *Transition in Asia and Eastern and Central Europe: a closed door - two open windows?,* New York (US): Nova science, 2001. pp. 31-53.

47. Miotti, L., Sachwald, F.: Co-operative R&D: why and with whom?: An integrated framework of analysis, *Research policy*, 32(8) 2003, pp. 1481-1499.
    - DOI: https://doi.org/10.1016/S0048-7333(02)00159-2

48. Narula, R., Dunning, J. H.: Explaining international R&D alliances and the role of governments, *International Business Review*, 7(4) 1998, pp. 377-397.
    - DOI: https://doi.org/10.1016/S0969-5931(98)00019-5

49. Oh, D., Kim, Y., Ahn, H.: An analysis of international cooperation in the public research and development programs of Korea, *Asian Journal of Technology Innovation*, 18(2) 2010, pp. 43-67.
    - DOI: https://doi.org/10.1080/19761597.2010.9668692

50. Organisation for Economic Co-operation and Development (OECD) Science, Technology and Patents [Data file], <https://stats.oecd.org/> last accessed on 17/06/2024.

51. Organisation for Economic Co-operation and Development (OECD), International co-inventions indicator.

52. Organisation for Economic Co-operation and Development (OECD), R&D expenditure indicator, <OECD.stat> last accessed on 20/09/2024.

53. Organization for Economic Co-operation and Development (OECD), R&D Tax Incentives indicator, <https://www.oecd.org/en/topics/r%26d-tax-incentives.html> last accessed on 20/09/2024.

54. Ozcan, B., Panayiotis G. Tzeremes, Nickolaos G. Tzeremes: Energy consumption, economic growth and environmental degradation in OECD countries, *Economic Modelling*, 84 (2020), pp. 203-213.
    - DOI: https://doi.org/10.1016/j.econmod.2019.04.010

55. Peng, M. W., Heath, P. S.: The growth of the firm in planned economies in transition: Institutions, organizations, and strategic choice, *Academy of management review*, 21(2) 1996, pp. 492-528.
    - DOI: https://doi.org/10.2307/258670

56. Piech, K., Radosevic, S.: *The knowledge-based economy in Central and East European countries: countries and industries in a process of change*, London: Palgrave Macmillan, 2006.

57. Radosevic, S., Lepori, B.: Public research funding systems in central and eastern Europe: between excellence and relevance: introduction to special section, *Science and Public Policy*, 36(9) 2009, pp. 659-666.
    - DOI: https://doi.org/10.3152/030234209X475236

58. Radosevic, S., Yoruk, E.: Technology upgrading of middle income economies: A new approach and results, *Technological Forecasting and Social Change*, 129 2018, pp. 56-75.
- DOI: https://doi.org/10.1016/j.techfore.2017.12.002

59. Radosevic, S.: *The knowledge-based economy in Central and East European countries - an overview of key issues. Knowledge-based economy in Central and Eastern Europe: Countries and industries in a process of change*, London: Palgrave Macmillan, 2006.

60. Radosevic, S.: Transformation of science and technology systems into systems of innovation in central and eastern Europe: the emerging patterns and determinants, *Structural Change and Economic Dynamics*, 10(3-4) 1999, pp. 277-320.
- DOI: https://doi.org/10.1016/S0954-349X(99)00016-8

61. Rehman, N. U., Hysa, E., Mao, X.: Does public R&D complement or crowd-out private R&D in pre and post economic crisis of 2008?, *Journal of Applied Economics*, 23(1) 2020, pp. 349-371.
- DOI: https://doi.org/10.1080/15140326.2020.1762341

62. Roundy, P., Holzhauer, H., Dai, Y. Finance or philanthropy? Exploring the motivations and criteria of impact investors, *Social Responsibility Journal*, 13(3) 2017, pp. 491-512.
- DOI: https://doi.org/10.1108/SRJ-08-2016-0135

63. Sadraoui, T., Ali, T. B., Deguachi, B.: Economic growth and international R&D cooperation: a panel Granger causality analysis, *International Journal of Econometrics and Financial Management*, 2(1) 2014, pp. 7-21.

64. Solow, Robert M. A: Contribution to the Theory of Economic Growth. The Quarterly *Journal of Economics*, 70(1) 1956, pp. 65-94.
- DOI: https://doi.org/10.2307/1884513

65. Sterlacchini, A., Venturini, F.: R&D tax incentives in EU countries: does the impact vary with firm size?, *Small Business Economics*, 53(3) 2019, pp. 687-708.
- DOI: https://doi.org/10.1007/s11187-018-0074-9

66. Szücs, F.: Do research subsidies crowd out private R&D of large firms? Evidence from European Framework Programmes, *Research Policy*, 49(3) 2020, pp. 103923.
- DOI: https://doi.org/10.1016/j.respol.2020.103923

67. Teixeira, A. A., Santos, P., Oliveira Brochado, A.: International R&D Cooperation between low-tech SMEs: the role of cultural and geographical proximity, *European Planning Studies*, 16(6) 2008, pp.785-810.
- DOI: https://doi.org/10.1080/09654310802079411

68. Tevdovski, D., Tosevska-Trpcevska, K., Disoska, E. M.: What is the role of innovation in productivity growth in Central and Eastern European countries?, *Economics of Transition*, 25(3) 2017, pp. 527-551.
- DOI: https://doi.org/10.1111/ecot.12121

69. Tian, B., Yu, B., Chen, S., Ye, J.: Tax incentive, R&D investment and firm innovation: evidence from China, *Journal of Asian Economics*, 71 2020, pp. 101245.
- DOI: https://doi.org/10.1016/j.asieco.2020.101245

70. Tiits, M., Kattel, R., Kalvet, T., Tamm, D.: Catching up, forging ahead or falling behind? Central and Eastern European development in 1990-2005, *Innovation: The European Journal of Social Science Research*, 21(1) 2008, pp. 65-85.
- DOI: https://doi.org/10.1080/13511610802002254

71. Toshevska-Trpchevska, K., Disoska, E. M., Tevdovski, D., Stojkoski, V.: The impact of a crisis on the innovation systems in Europe: Evidence from the CIS10 innovation survey, *European Review*, 27(4) 2019, pp. 543-562.
- DOI: https://doi.org/10.1017/S1062798719000218

72. Van Beers, C., Berghäll, E., Poot, T.: R&D internationalization, R&D collaboration and public knowledge institutions in small economies: Evidence from Finland and the Netherlands, *Research Policy*, 37(2) 2008, pp. 294-308.
- DOI: https://doi.org/10.1016/j.respol.2007.10.007

73. Veugelers, R.: Research and innovation policies and productivity growth, *Bruegel Working Paper*, (8) 2021.

74. Wozniak-Jechorek, B.: Examining the European Transition: Central Eastern European Countries Two Decades post-EU Accession, *Revista Economia e Políticas Públicas*, 12(1) 2024, pp. 48-60.
- DOI: https://doi.org/10.46551/epp2024v12n0104

75. Wu, T., Yang, S., Tan, J.: Impacts of government R&D subsidies on venture capital and renewable energy investment-an empirical study in China, *Resources Policy*, 68 2020, pp. 101715.
- DOI: https://doi.org/10.1016/j.resourpol.2020.101715

76. Xu, J., Wang, X., Liu, F.: Government subsidies, R&D investment and innovation performance: analysis from pharmaceutical sector in China, *Technology Analysis & Strategic Management*, 33(5) 2021, pp. 535-553.
- DOI: https://doi.org/10.1080/09537325.2020.1830055

77. Yang, C.-H., Huang, C.-H., Hou, T. C.-T.: Tax incentives and R&D activity: Firm-level evidence from Taiwan, *Research Policy*, 41 2012, pp. 1578-1588.
- DOI: https://doi.org/10.1016/j.respol.2012.04.006

78. Yi, J., Murphree, M., Meng, S., Li, S.: The more the merrier? Chinese government R&D subsidies, dependence, and firm innovation performance, *Journal of Product Innovation Management*, 38(2) 2021, pp. 289-310.
- DOI: https://doi.org/10.1111/jpim.12564

79. Zuo, Z., Lin, Z.: Government R&D subsidies and firm innovation performance: The moderating role of accounting information quality, *Journal of Innovation & Knowledge*, 7(2) 2022, pp. 100176.
- DOI: https://doi.org/10.1016/j.jik.2022.100176

Appendix

FORECAST ERROR VARIANCE DECOMPOSITION:

$RDO

	RDO	IGS	BERD	PER	GERD
[1,]	1.0000000	0.0000000	0.0000000000	0.000000e+00	0.000000e+00
[2,]	0.3942094	0.6051561	0.0006163152	1.566077e-05	2.549050e-06
[3,]	0.4186773	0.5805946	0.0007263007	4.673014e-08	1.782188e-06
[4,]	0.3901135	0.6091530	0.0007310965	8.874809e-08	2.393650e-06
[5,]	0.3906707	0.6085929	0.0007339885	3.309008e-08	2.381508e-06
[6,]	0.3897988	0.6094647	0.0007341188	3.376973e-08	2.401868e-06
[7,]	0.3898102	0.6094532	0.0007342092	3.246253e-08	2.401634e-06
[8,]	0.3897832	0.6094802	0.0007342138	3.247465e-08	2.402266e-06
[9,]	0.3897834	0.6094800	0.0007342166	3.243452e-08	2.402263e-06
[10,]	0.3897825	0.6094808	0.0007342168	3.243462e-08	2.402283e-06

$IGS

	RDO	IGS	BERD	PER	GERD
[1,]	0.6107362	0.3892638	0.0000000000	0.000000e+00	0.000000e+00
[2,]	0.3831491	0.6162245	0.0003988040	2.259010e-04	1.614486e-06
[3,]	0.5067970	0.4925020	0.0007004493	6.810722e-08	4.543060e-07
[4,]	0.3903298	0.6089452	0.0007222202	4.128583e-07	2.385140e-06
[5,]	0.3932706	0.6059936	0.0007333954	3.391383e-08	2.321245e-06
[6,]	0.3898230	0.6094407	0.0007338372	3.782469e-08	2.401200e-06
[7,]	0.3898910	0.6093724	0.0007341891	3.251317e-08	2.399741e-06
[8,]	0.3897845	0.6094789	0.0007342049	3.259516e-08	2.402233e-06
[9,]	0.3897859	0.6094775	0.0007342159	3.243690e-08	2.402204e-06
[10,]	0.3897826	0.6094808	0.0007342165	3.243838e-08	2.402282e-06

$BERD

	RDO	IGS	BERD	PER	GERD
[1,]	0.1263414	0.8716182	0.0020404458	0.000000e+00	0.000000e+00
[2,]	0.3826769	0.6165177	0.0008016708	1.499868e-06	2.181705e-06
[3,]	0.3791203	0.6201392	0.0007379224	2.137764e-08	2.649182e-06
[4,]	0.3894868	0.6097753	0.0007354417	1.841301e-08	2.409381e-06
[5,]	0.3894473	0.6098159	0.0007343213	3.193546e-08	2.410150e-06
[6,]	0.3897710	0.6094923	0.0007342551	3.193483e-08	2.402565e-06
[7,]	0.3897720	0.6094914	0.0007342204	3.241442e-08	2.402530e-06
[8,]	0.3897821	0.6094813	0.0007342181	3.241766e-08	2.402294e-06
[9,]	0.3897822	0.6094812	0.0007342170	3.243264e-08	2.402292e-06
[10,]	0.3897825	0.6094809	0.0007342169	3.243284e-08	2.402284e-06

$PER

	RDO	IGS	BERD	PER	GERD
[1,]	0.4696355	0.00813272	0.0987442596	4.234875e-01	0.000000e+00
[2,]	0.2599428	0.73983014	0.0001698769	1.578228e-06	5.555877e-05
[3,]	0.3533037	0.64325904	0.0020254149	1.407596e-03	4.278673e-06
[4,]	0.1556133	0.84363364	0.0007410265	1.333326e-07	1.192264e-05
[5,]	0.3866832	0.61254714	0.0007661322	1.039552e-06	2.487386e-06
[6,]	0.3807753	0.61848558	0.0007364383	2.665067e-08	2.618392e-06
[7,]	0.3896250	0.60963740	0.0007352153	2.035218e-08	2.406327e-06
[8,]	0.3895003	0.60976300	0.0007342947	3.214905e-08	2.408909e-06
[9,]	0.3897757	0.60948763	0.0007342484	3.201381e-08	2.402454e-06
[10,]	0.3897737	0.60948968	0.0007342195	3.242163e-08	2.402491e-06

$GERD

	RDO	IGS	BERD	PER	GERD
[1,]	0.3421717	0.6576780	7.686293e-05	7.115254e-07	7.276306e-05
[2,]	0.4076424	0.4699822	2.355467e-02	9.876936e-02	5.134488e-05
[3,]	0.2339228	0.7658324	1.882603e-04	1.540317e-06	5.499488e-05
[4,]	0.3656979	0.6318460	1.651923e-03	8.005756e-04	3.601907e-06
[5,]	0.2026484	0.7965937	7.486282e-04	7.544946e-08	9.210884e-06
[6,]	0.3875682	0.6116707	7.580516e-04	5.169091e-07	2.463249e-06
[7,]	0.3830267	0.6162348	7.358820e-04	2.816464e-08	2.563449e-06
[8,]	0.3896679	0.6095948	7.349641e-04	2.311984e-08	2.405233e-06
[9,]	0.3895711	0.6096922	7.342748e-04	3.222523e-08	2.407246e-06
[10,]	0.3897775	0.6094858	7.342405e-04	3.211885e-08	2.402409e-06