American Research Journal of Humanities Social Science (ARJHSS)
E-ISSN: 2378-702X
Volume-04, Issue-06, pp-92-102
www.arjhss.com

Research Paper Open Access

A Systematic Literature Review on Public Research Institutes (PRIs) Practices and Strategies in Contributing to an Advancement Country's Research and Development

1. Danarsiwi Tri Lastiwi, 2. Prof. Chandra Wijaya, 3. Dr. Pantius D. Soeling
[1]doctoral student in the Faculty of Administrative Science, University of Indonesia.
Working at Indonesian Institutes of Sciences (LIPI)
[2] the Dean and lecturer in the Faculty of Administrative Science, University of Indonesia
[3] lecturer in the Faculty of Administrative Science, University of Indonesia

Abstract: In many developed countries, the Public Research Institutes (PRIs) are the main pillar of the country's research and development (R&D). Meanwhile, in many developing countries, research practices mainly done in R&D of industries. Some experts have studied PRIs either in developed or developing countries, but they researched PRIs as a single object. This study aims to investigate the research practices in many PRIs based on the journal literature. The researchers highlighted the PRIs in developed countries' activities and strategies so that they become good research institutions which are able to overcome problems in society, industry and add the stock of knowlegde. The researchers also emphasized on the success key matters in these PRIs how contribute to their countries' economic development. The method used in this study is content analysis by describing the research activities of PRIs based on research articles. The articles analyzed are amount of 26 articles. From those articles, the researchers found 10 developed countries and 2 developing countries discussed. The researchers then explored the research practices, the strategies and the contribution of the PRIs for those countries respectively. The study will produce recommendations for PRIs in developing countries to take some lessons from the developed PRIs' research activities and strategies to be succesful research institutions.

Keywords: Public Research Institutes, developing countries, developed contries, content analysis, research and development.

I. Introduction

Public Research Institutes (PRIs) perform research and experimental development as a primary economic activity and operate with the controlling of government (OECD, 2005). According to Frascati Manual 2015, research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge –including knowledge of humankind, culture and society – and to devise new applications of available knowledge (OECD, 2016). Therefore, PRIs do research for the development of economic of the countries, the solutions for many problems faced by the society and also for the stock of knowlegde.

Economic growth and Research and Development (R&D) activities are two things that can not be separated. If a country want to have a healthy economic growth, that country must have one of the drivers i.e. investment in R&D. It has been proven internationally that investment in R&D is an important driver for economic growth. The investment are used to make innovation to support increased productivity. As a result, production performance in the country will be good and encourages economic growth.

PRIs in developed countries, generally, are good in organization structure, supported by government (fund, policy and environment of research). They can support the increasing economy of their countries (Băzăvan, 2019), (Heindl & Liefner, 2019), (Min et al., 2020). Meanwhile PRIs in developing contries are still improving their performance to be a capable R&D institution.

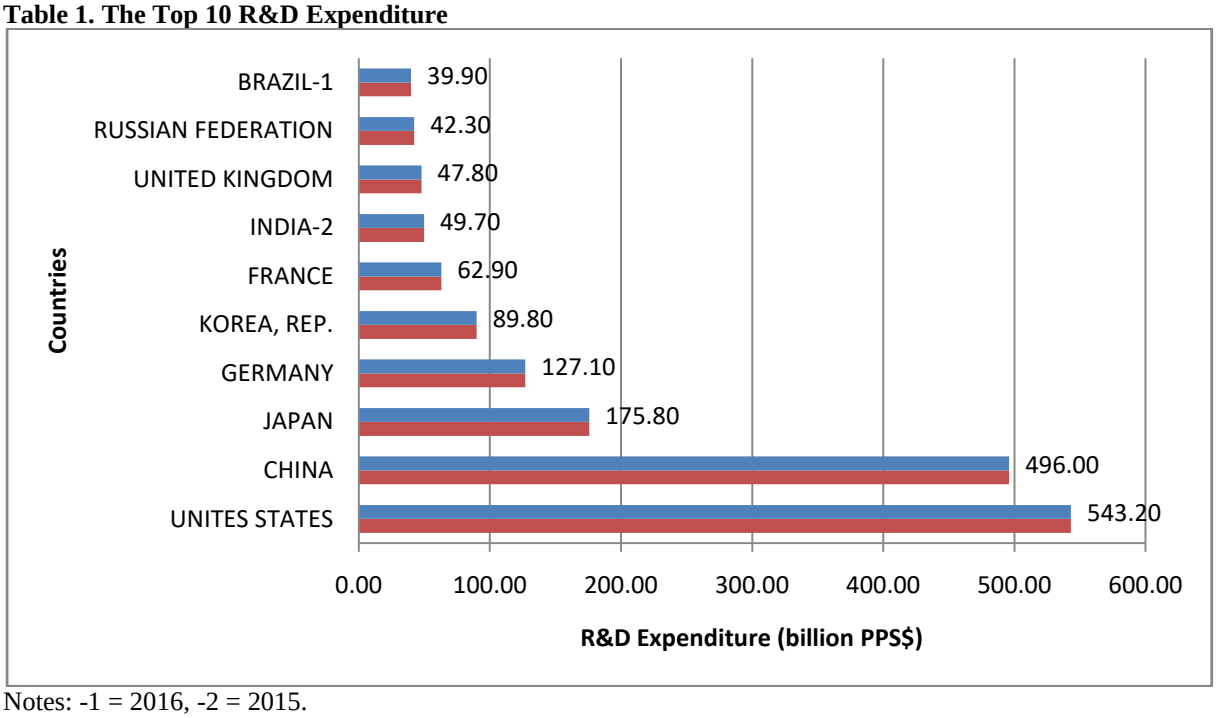
In 2009, the United Nations Statistical Commission started a revision to the System of National Accounts to treat R&D spending as an investment, rather than as an intermediate input. This reclassification has

had a positive effect on GDP, which increased by 3.5 percent on average for the European Union (Peter Van De Ven, 2015). In Germany, the Public Research Institution (Fraunhofer) has contributed to an increase in productivity in the economy by 0.55% (Comin, Licht, Pellens & Schubert, 2019). Korean government and research institutes alike have exerted their concentrated efforts to develop world-class technologies by carefully examining future economy, market outlook, technological trends, and the current level of science and technology (Lee & Song, 2007).

In South Korea the collaboration between PRI and industry has a positive effect on the creation of technology licenses for industry (Son et al., 2019). While in France, industries that collaborate with PRIs are more likely to develop service innovations (Giannopoulou et al., 2019). Study about 5 PRIs in developed countries (ITRI- Taiwan, Fraunhover – Germany, AIST- Japan, CSIRO- Australia and NIST -USA) has concluded that the factors in failure or success of the PRIs are funding, researchers, geography matters, setting research agenda, performance evaluation and governance (Intarakumnerd & Goto, 2018).

Furthermore, based on the experience of Massachusetts Institute of Technology and other US universities, in the case of the formation and sustainability of biotechnology company clusters, the origin of a cluster and sustainable health depends on government funding of science in universities and institutions (Nelsen, 2005). From the figure below we can see the world's top leader in R&D invesment in the year of 2017 or the latest year available (2015 for India and 2016 for Brazil).

Table 1. The Top 10 R&D Expenditure



Notes: -1 = 2016, -2 = 2015.
Source: UNESCO Institute for Statistics, June 2019.

The most commonly-used indicators to monitor resources devoted to R&D worldwide are Gross Domestic Expenditure on R&D (GERD) expressed in Purchasing Power Parity (PPP$) and R&D intensity (percentage of Gross Domestic Product (GDP) devoted to R&D activities). From the table 1, we can compare the investments expense for the fund in doing research in the top ten countries. USA is the most financing country for its R&D. But the researchers only found 1 article about the USA's PRIs in the targeted database (that written togehter with PRIs from other countries). Other countries could not find in the articles studied are Russia, Brazil, UK and France. Suitable with the method done by the researchers, the countries emerged from the articles gathered are: China, Japan, Germany, Korea, which all can be classified as developed countries. Then added with Taiwan, Italy, Singapore and Belgium from the articles' data. So, there are 10 developed countries. India and Nigeria which emerged in articles classified as developing country. Comparing between the expenditure and the contribution of R&D to GDP is explored from the literature found (on the result of this study). As an initial understanding that the country with a big investment in R&D will get better results than the ones which not enough investments in R&D. To know how the PRIs' efforts to contribute to their countries'

economy, the researchers mapped the publications about the PRIs found. This research aims to draw the points of success key factors and strategies done by the PRIs in developed countries which will be lesson learned for the developing countries in improving their PRIs to be good institutions. Moreover those PRIs can contribute in developing R&D in those countries.

II. Materials and Methods

Content analysis was chosen as a methodological approach of this study. Ann Dutton Ewbank and Ja Youn Kwonhave been used an exploratory content analysis to describe the current landscape of school library advocacy literature in the United States. This study wants to describe the current landscape of PRIs based on research articles. The stage of analysis in this study adopt from those scholars(Ewbank & Kwon, 2015). The first stage of the study was conducted bysearching of scholarly journal literature related to PRIs. Searching was done in the Science Direct and Springerlink databases by using term 'public research institutes' in title. Term of 'public research units' and 'public research organizations' emerged from the databases.

The research about PRIs, found in the database, treated PRI as a single object study. How the practices and srategies doing in those PRIs. While, in this study researchers gathered PRIs from literature to be reviewed and compared one another. From the review, will be resulted the key matters which make a successfull PRI.

43 publications were found at the Science Direct database and 4 were found at the Springerlink database. Analysis only conducted for publications using English language, while the researchers found 1 article written in Spanish and 1 in French (they are excluded from the analysis). Then the researchers scrutinize the articles which are suitable with the purpose of the study. The articles related with the PRIs and R&Dare selected to be analyzed. This selection was done based on journal title within the articles are exist. The following is the title of publication selected and the quantity of the articles respectively :

Journal title

1. ☑ Research Policy (7)
2. ☑ Technovation (7)
3. ☑ Technological Forecasting and Social Change (5)
4. ☑ European Economic Review (2)
5. ☐ Drug Discovery Today (1)
6. ☐ Acta Astronautica (1)
7. ☐ Expert Systems with Applications (1)
8. ☐ Information Systems (1)
9. ☐ Surface and Coatings Technology (1)
10. ☑ Regional Science and Urban Economics (1)

The check list shows the articles which are further analyzed. Meanwhile from Springerlink database only 4 articles found and all will be analyzed. Therefore, the total of 26 publications were eligible for further analyzed. Then, each article was mapped to identify the PRIs of country origin, the research focus , and the PRIs' practices in doing research.

The researchers only used the articles emerged from the databases with the keyword "public research institutes" in title. Most of the articles found are about developed countries and only two articles found about developing country (India and Nigeria). The classification of developed and developing countries based on the United Nations Conference on Trade and Development (UNCTAD, 2018).

III. Results and Discussion

The articles classified by the country origin, the research focus and the results of the PRIs studied can be seen in this following table:

Table 2. PRIs'country, Research Focus and Findings

Country and Citation	Research Focus	Research Findings

Germany: (Grimpe, 2012): (Beise & Stahl, 1999); (Falck et al., 2019).	Funding strategies(Grimpe, 2012). Technology transfer and industrial innovation (Beise, 1999). Collaboration between firm and PRIs through IRGC (Innovative Regional Growth Cores) program (Falck et al., 2019).	All funding processes are meritocratic and based on past scientific achievements needs qualification (Grimpe, 2012). Public research may transfer technology successfully to industrial companies (Beise & Stahl, 1999). No indication that the IRGC discernibly affected aggregate regional prosperity (Falck et al., 2019).
South Korea: (Lee & Song, 2007); (Chung, 2001); (Min et al., 2019); (Min et al., 2020); (Yang & Jung, 2016).	‘‘Technology Cluster Analysis,’’ as a method for selection and focusing research areas (nano tcchnology) in increasing Korea national competitiveness (Lee & Song, 2007) Science and technoligy integration of South and North Korea (Chung, 2001) Success factors of the commercialization of technologies transferred (Min et al., 2019) Technologies transfer from PRIs & universities to companies (Min et al, 2020). Research network around PRIs (Yang & Jung, 2016).	Three clusters of nanotechnology (nano material, nano device and nano bio) can be government research area focus (Lee & Song, 2007). The unification of S & T Korea should be guided by South Korea framework, though South Korea system still should be improved. The system must be efficient, flexible, mobile and competitive (Chung, 2001). The success of technology transfer will be determined by strategic management of the companies and their partnership (Min et al., 2019). Commercialization of technology (resulted by researchers/academician) strongly influenced by effective partnership (Min et al., 2020). Structural improvement plans for networks inside PRI (Yang & Jung, 2016).
China: (M.Hu & Phillips, 2011); (Lu & Lazonik, 2001); (Kroll & Schiller, 2010).	The development of biofuel industry (the material supply and the technology become the focus of China’s public policy) (M. Hu & Phillips, 2011). China’s state role of the integration of investment and organizational learning in industry (Lu &Lazonik, 2001). The mismatch between solutions supplied by the public sector and the needs of Chinese firms (Kroll &	Technology interdependence and knowledge diffusion as national innovation capabilities (M. Hu & Phillips, 2011). China national inovation system support indigenous innovation capabilities (Lu & Lazonick, 2001). A new structural framework between PRIs and

	Schiller, 2010).	enterprises to support Chia national innovation system (Kroll & Schiller, 2010).
Taiwan: (Hsu et al, 2005); (M.C.Hu, 2008).	Policy tool on the formation of new firms (Hsu et al, 2005). Knowledge flows and innovationcapability (M.C.Hu, 2008).	Technology and human capital as the main focus in Taiwan (Hsu et al., 2005) Taiwan has internalised external knowledge from the US and Japan on specific core technologies (M. C. Hu, 2008).
Japan: (Kumaresan & Miyazaki, 1999); (Okamuro et al, 2011); (Ishibashi & Matsumara, 2006).	Analyzing Japan innovation system in robotics industries (Kumaresan &Miyazaki, 1999). The determinants of R&D cooperation start-ups business (Okamuro et al, 2011). Investigate a welfare-maximizing public research institute competes against profit-maximizing private firms (Ishibashi & Matsumara, 2006).	The innovation system transformation is identified and changing structural setups (Kumaresan & Miyazaki, 1999). Founder-specific characteristics are important in determining R&D cooperation with universities and PRIs (Okamuro et al., 2011). The PRIs' R&D expenditure from the viewpoint of social welfare, therefore the government should control the PRIs properly (Ishibashi & Matsumura, 2006).
Italia: (Coccia & Rolfo, 2008).	Strategic change in PRIs (Coccia & Rolfo, 2008).	PRIs operate as research units market-oriented and researchers focus on applied activity and consultancy (Coccia & Rolfo, 2008).
Singapore: (Cheah & Ho, 2020), (Ho et al., 2016).	Examines the implementation of industrial policy through PRIs and development funding impacts the innovation collaboration between PRIs and firms (Cheah & Ho, 2020). The using of PRIs' manpower scheme to assist the technology upgrading of Small-and-Medium-sized Enterprises (SMEs) (Ho et al., 2016).	Project funding significantly influences the innovation collaboration outcome (Cheah & Ho, 2020). The T-Up (Technology Upgrading) secondment (i.e. a temporary placement of manpower in a different organization) had positive impact on the technological capabilities, innovation performance and growth of participating companies (Ho et al., 2016).
Belgium: (Moray & Clarysse, 2005).	Study PRI (IMEC, Belgium) in technology transfer and science-based entrepreneurial firms set up (Moray & Clarysse, 2005).	Changing the venturing policies have an effect on the type of companies created (Moray & Clarysse, 2005).

Germany, Taiwan, Japan, Australia, US (Intarakumnerd & Goto, 2018).	Investigate the roles of five prominent PRIs in the world whose mission is to support technological development of industry in their national innovation systems (Intarakumnerd & Goto, 2018).	Key factors determining success and failure of PRIs : funding, researchers, setting research agenda, peformance evaluation, geography matters, governance (Intarakumnerd & Goto, 2018).
India: (Mohan & Rao, 2005).	Highlight the partnership process between PRIs and industries and develop a model of the partnership (Mohan & Rao, 2005).	Proposed model comprises of five steps: 1. Attracting potential industrial partners 2. Understanding industry's needs 3. Selection of the partners hip structure 4. Management of the partnership (Mohan & Rao, 2005).
Nigeria: (Oyelaran-Oyeyinka & Sampath, 2007).	The learning possibilities through inter-organisational interactions in biotechnological systems of innovation (Oyelaran-Oyeyinka & Sampath, 2007).	Lack of interactions between industry and PRIs. Interactions between the various PRIs are also weak result in lack of information amongst researchers to content oneself in joint research. PRIs also do not much collaborate with traditional medicine practitioners and hospitals. The critical aspects for biotechnological systems of innovation to develop are sufficient funding and collaboration between various actors to generate interactive learning (Oyelaran-Oyeyinka & Sampath, 2007).

After exploring the content of the articles, the researchers made a conceptual matrix suitable with the purpose of this study i.e. identify the PRIs' activities and strategies, emphasize on the success key matters in these PRIs how contribute to their countries' economic development. The study will produce recommendation for PRIs in developing countries to take some lessons from the developed PRIs' research activities and strategies to be succesful research institutions. According to Ahlstrand (Ahlstrand, 1999) strategy is the mediating force between the organization and its surroundings, focusing on decisions and actions that come naturally. Strategy formation is not limited to intentional processes, but can occur as a pattern of actions formalized or otherwise. Other definition, strategy is the theory of the firm on how to compete successfully. It also considers performance as a factor influenced by strategy, as it can be considered that to compete successfully means having a satisfactory performance (Barney & Peng, 2001). Based on those definitions, the researchers identified the strategies done by the PRIs in achieving the succesfull research oganizations.

Table 3. Conceptual Matrix

Country/ PRIs – Country	Research Practices	Strategies	Contribution for the Country
Germany	The joint ventures of technology-oriented research which comprise partners from European countries.	The public research financed not only determined by scientist productivity (patent and publication) but also application or consulting oriented research.	The implementation of the European Research Area, which can compete with US and Japan.
South Korea	The intensity of market competition as factor to moderate the partnership on the successful commercialization.	Technology transfer and commercialization.	2,61 % Gross National Product
China	China Technology does application oriented and highly intertwined with industries.	Clarify the PRIs focus, which on basic and which on applied science. The PRIs financed by industrial revenue. This will force the researchers adopt their output, gain substantial premiums, raising their motivation.	China has become the fourth largest applicant patent. China is the third largest bioethanol producer in the world. Produce 9246 of biofuel patents.
Taiwan	Providing big capital for research with the risk of investment to expand manufacturing capacity.	Facilitating external knowledge internalization and build endogenous capabilities of innovation.	HannStar (Taiwan) is no.2 for patents in TFT-LCD (transistor-liquid crystal display -LCD)/TV and computer's screen manufacturing.
Japan	Government control PRIs appropriately. They concerned about the cooperation between PRIs and entrepreneurs to support national innovation system.	Innovation system in Japan based on science, technology, market and the linkages among them.	In the case of robot industrial, Japan is the major exporter with holds around 60% world's stock.
Italy	Researchers actively giving consultancy and doing applied activity.	Government obliged the researchers in PRIs to have collaboration with firms and external institutions for funding.	Short run effect in applied activity of economic system.
Singapore	PRIs' top management role in implementing industrial policy to enhance open innovation outcomes.	Identify external sources for collaboration. Develop specialization types of industries.	Mediate project funding with collaborative outcome.

Belgium	Technology transfer activities.	Researchers–entrepreneurs are coached in the development of the company's business model and commercial strategy.	Improve the value of science-based entrepreneurial firm.
Fraunhofer-Germany ITRI- Taiwan AIST- Japan CSIRO-Australia NIST-US	PRIs as intermediary, supporting National Innovation System. Doing knowledge transfer both for high-technology industries and SMEs.	PRIs strategy covers research agenda setting, finance, managing researchers, intermediating role and performance evaluation.	Fraunhofer : spin-off firms (around 200 until 2012) and licensing revenues (117 million Euro). ITRI : conducts mostly applied research to serve customer needs. AIST : conducts long term research, creating new industries, for example carbon fibre. CSIRO : more than 150 start-ups have been created. NIST : research for producing 'public goods' (ex: setting measurement and industrial standards). an intermediary nationwide network of more than 1,200 technical experts.
India	PRIs and industry partnership.	Develop mutual trust between PRIs and industry. Smoothen adaptation the innovation process/product to market.	Partnership will develop commercially potential technology.
Nigeria	Innovation system in biopharmaceutical industry.	Partnerships between all stakeholders within and outsideNigeria.	Policy intervention in innovation of biotechnological system – firms, universities, traditional medicinal practitioners, and hospitals.

Based on our analyzes, we conclude that researchers in developed countries do research both for academic purposes (publication and patent) and also for practical benefits (transfer technology, collaboration with industries, and innovation). The most strategy conducted by developed countries is linkage with industries. In India, that still classified as developing countries, but shows as country that consent in R&D development (can be seen from the R&D investment – number 7 world wide) the research has been done by mutual partnership between PRIs and industries. Smoothen the adaptation of technology from the PRIs to marketable product/process.

PRIs in India divided into 2 classification related with the market. The first is Classic model, where the researchers do not concern with the needs of industry in doing research. The second is Market model where the researchers decide the direction of their research based on the needs of the industries. Most of the PRIs projects in India classified as Market model (from 44 projects, only 7 that act as classic model). It showed that India, though classified as developing country, has develop mutual relationship between researchers and industries. It was emerged after the growing awareness of the PRIs that their researchers not really concern with market needs. They focused on long-term innovation processes. So the PRIs need to have linkage with industry to avoid unrealistic expectations about market potential.

In Nigeria, research has been done by replication (i.e. innovation) from developed countries. PRIs has done inter-organizational interactions (formal and informal linkages), contacts of various agents (firms, universities, traditional medicine practitioners, hospitals and other external agencies). But Nigeria's PRIs are still facing obstacles in implementing linkage with industries, lack of financing (90% comes from international sources), lack of policy coordination from the level of government policies until practices (researchers were not even aware the similar activities in other PRIs), weak private sector, lack of adequate incentives for researchers and lack of technological facilities.

Based on the two articles analyzed about PRIs in developing countries above, we can concluded that there is country still facing obstacles in the basic element. From the fund, human resources, facilities, weak of private sector, not adequate collaboration, weak lingkage with local industries that still compounded by the less robust industries. So that it need not only take some lessons from PRIs in developed countries, but also need the favor from various elementer aspects.

IV. Conclusion

The development individual capacity might be an incremental process, but the accumulation of development capacity, based the literature discussed, can be the construction of the institutional and innovation for developing a nation's innovation system as a whole. Understanding the articles about PRIs in developed countries, the researchers concluded that most of the PRIs have done technology transfer, absorbing the external knowledge and technology, industrial innovation and also technology commercialization. PRIs in developed countries are ready to transfer knowledge both to high-technology industries and SMEs. PRIs conduct strategies in industries collaboration with patent commercialization, company's business model and product/process of innovations.

In each article that we analyzed, we conclude that the most strategy that every PRIs in developed country runs is linkage with industries/ firms and commerzialisation.

Some lessons learn can be drawn for developing countries which somehow the innovation process still face obstacles. Lack of technological capabilities makes implication in collaboration with either local or foreign institutes. Low level of entrepreneurship and poor institutional capacity are also be the hindrance. The overlapping institutions, the overwhelming tasks, the lack of coordination among institutions are other problems faced by developing countries. Therefore, PRIs can focus on commercial orientation of research through increasing collaborative research with industries and translation research into innovative products.

Acknowledgement

We thank Ministry of Research and Tecnology/National Research and Innovation Agency Indonesia (Kementerian Riset dan Teknologi/Badan Riset dan InovasiNasional) for funding the publication of this article.

REFERENCES

[1]. Ahlstrand, B. (1999). Strategy safari: a guided tour through the wilds of strategic management. *Choice Reviews Online*, *36*(06), 36-3419-36–3419. https://doi.org/10.5860/choice.36-3419.

[2]. Barney, J. A. Y. B., & Peng, M. (2001). Resource-Based " View " a Useful Is the Resource-Based Perspective for Strategic Perspective for Management Management Research ? Yes. *Review Literature And Arts Of The Americas*, *26*(1), 41–56.

[3]. Băzăvan, A. (2019). Chinese government's shifting role in the national innovation system. *Technological Forecasting and Social Change*, *148*. https://doi.org/10.1016/j.techfore.2019.119738.

[4]. Beise, M., & Stahl, H. (1999). *Public research and industrial innovations in Germany*.

[5]. Cheah, S. L. Y., & Ho, Y. P. (2020). Effective industrial policy implementation for open innovation: The role of government resources and capabilities. *Technological Forecasting and Social Change*, *151*(December 2019), 119845. https://doi.org/10.1016/j.techfore.2019.119845.

[6]. Chung, S. (2001). Unification of South and North Korean innovation systems. *Technovation*, *21*(2), 99–107. https://doi.org/10.1016/S0166-4972(00)00025-0.

[7]. Coccia, M., & Rolfo, S. (2008). Strategic change of public research units in their scientific activity. *Technovation*, *28*(8), 485–494. https://doi.org/10.1016/j.technovation.2008.02.005.

[8]. Comin, Licht, Pellens & Schubert. Do Companies Benefit from Public Research Organizations? The Impact of Fraunhofer Society in German.

[9]. Ewbank, A. D., & Kwon, J. Y. (2015). School library advocacy literature in the United States: An exploratory content analysis. *Library and Information Science Research*, *37*(3), 236–243. https://doi.org/10.1016/j.lisr.2015.04.005.

[10]. Falck, O., Koenen, J., & Lohse, T. (2019). Evaluating a place-based innovation policy: Evidence from the innovative Regional Growth Cores Program in East Germany. *Regional Science and Urban Economics*, *79*, 103480. https://doi.org/10.1016/j.regsciurbeco.2019.103480.

[11]. Giannopoulou, E., Barlatier, P. J., & Pénin, J. (2019). Same but different? Research and technology organizations, universities and the innovation activities of firms. *Research Policy*, *48*(1), 223–233. https://doi.org/10.1016/j.respol.2018.08.008.

[12]. Grimpe, C. (2012). Extramural research grants and scientists' funding strategies: Beggars cannot be choosers? *Research Policy*, *41*(8), 1448–1460. https://doi.org/10.1016/j.respol.2012.03.004.

[13]. Heindl, A., & Liefner, I. (2019). Technology in Society The Analytic Hierarchy Process as a methodological contribution to improve regional innovation system research : Explored through

comparative research in China. *Technology in Society*, *59*(August), 101197. https://doi.org/10.1016/j.techsoc.2019.101197.

[14]. Ho, Y. P., Ruan, Y., Hang, C. C., & Wong, P. K. (2016). Technology upgrading of Small-and-Medium-sized Enterprises (SMEs) through a manpower secondment strategy – A mixed-methods study of Singapore's T-Up program. *Technovation*, *57–58*, 21–29. https://doi.org/10.1016/j.technovation.2016.07.001.

[15]. Hsu, Y. G., Shyu, J. Z., & Tzeng, G. H. (2005). Policy tools on the formation of new biotechnology firms in Taiwan. *Technovation*, *25*(3), 281–292. https://doi.org/10.1016/S0166-4972(03)00078-6.

[16]. Hu, M. C. (2008). Knowledge flows and innovation capability: The patenting trajectory of Taiwan's thin film transistor-liquid crystal display industry. *Technological Forecasting and Social Change*, *75*(9), 1423–1438. https://doi.org/10.1016/j.techfore.2008.04.005.

[17]. Hu, M., & Phillips, F. (2011). *Technological Forecasting & Social Change Technological evolution and interdependence in China ' s emerging biofuel industry*. *78*, 1130–1146. https://doi.org/10.1016/j.techfore.2011.02.013.

[18]. Intarakumnerd, P., & Goto, A. (2018). Role of public research institutes in national innovation systems in industrialized countries: The cases of Fraunhofer, NIST, CSIRO, AIST, and ITRI. *Research Policy*, *47*(7), 1309–1320. https://doi.org/10.1016/j.respol.2018.04.011.

[19]. Ishibashi, I., & Matsumura, T. (2006). R&D competition between public and private sectors. *European Economic Review*, *50*(6), 1347–1366. https://doi.org/10.1016/j.euroecorev.2005.04.002.

[20]. Kroll, H., & Schiller, D. (2010). Establishing an interface between public sector applied research and the Chinese enterprise sector: Preparing for 2020. *Technovation*, *30*(2), 117–129. https://doi.org/10.1016/j.technovation.2009.10.003.

[21]. Kumaresan, N., & Miyazaki, K. (1999). An integrated network approach to systems of innovation - The case of robotics in Japan. *Research Policy*, *28*(6), 563–585. https://doi.org/10.1016/S0048-7333(98)00128-0.

[22]. Lee, Y. G., & Song, Y. Il. (2007). Selecting the key research areas in nano-technology field using technology cluster analysis: A case study based on National R&D Programs in South Korea. *Technovation*, *27*(1–2), 57–64. https://doi.org/10.1016/j.technovation.2006.04.003.

[23]. Lu, Q., & Lazonick, W. (2001). The organization of innovation in a transitional economy: Business and government in Chinese electronic publishing. *Research Policy*, *30*(1), 55–77. https://doi.org/10.1016/S0048-7333(99)00082-7.

[24]. Min, J. W., Kim, Y. J., & Vonortas, N. S. (2020). Public technology transfer, commercialization and business growth. *European Economic Review*, *124*, 103407. https://doi.org/10.1016/j.euroecorev.2020.103407.

[25]. Min, J. W., Vonortas, N. S., & Kim, Y. J. (2019). Commercialization of transferred public technologies. *Technological Forecasting and Social Change*, *138*(October 2018), 10–20. https://doi.org/10.1016/j.techfore.2018.10.003.

[26]. Mohan, S. R., & Rao, A. R. (2005). Strategy for technology development in public R&D institutes by partnering with the industry. *Technovation*, *25*(12), 1484–1491. https://doi.org/10.1016/j.technovation.2005.05.007.

[27]. Moray, N., & Clarysse, B. (2005). Institutional change and resource endowments to science-based entrepreneurial firms. *Research Policy*, *34*(7), 1010–1027. https://doi.org/10.1016/j.respol.2005.05.016.

[28]. Nelsen, L. L. (2005). The role of research institutions in the formation of the biotech cluster in Massachusetts: The MIT experience. *Journal of Commercial Biotechnology*, *11*(4), 330–336. https://doi.org/10.1057/palgrave.jcb.3040134.

[29]. OECD. (2005). Oslo Manual. In *OECD and Eurostat Publication: Vol. Third edit*. https://doi.org/10.1787/9789264013100-en.

[30]. OECD. (2016). Frascati Manual 2015. In *Frascati Manual 2015*. https://doi.org/10.1787/9789264268111-ko.

[31]. Okamuro, H., Kato, M., & Honjo, Y. (2011). Determinants of R&D cooperation in Japanese start-ups. *Research Policy*, *40*(5), 728–738. https://doi.org/10.1016/j.respol.2011.01.012.

[32]. Oyelaran-Oyeyinka, B., & Sampath, P. G. (2007). Learning through inter-organisational interactions: Public research institutes in the Nigerian biopharmaceutical system of innovation. *European Journal of Development Research*, *19*(1), 174–193. https://doi.org/10.1080/09578810601144483.

[33]. Peter Van De Ven. (2015). New standards for compiling national accounts: what's the impact on GDP and other macro-economic indicators? *OECD Statistics Brief*, *20*.

[34]. Son, H., Chung, Y., & Hwang, H. (2019). Do technology entrepreneurship and external relationships

always promote technology transfer? Evidence from Korean public research organizations. *Technovation*, *82–83*, 1–15. https://doi.org/10.1016/j.technovation.2019.02.005.

[35]. UNCTAD. (2018). *WORLD INVESTMENT REPORT; Foreign Direct Investment Inflows in Malaysia*. www.unctad.org/diae.

[36]. Yang, H., & Jung, W. S. (2016). Structural efficiency to manipulate public research institution networks. *Technological Forecasting and Social Change*, *110*, 21–32. https://doi.org/10.1016/j.techfore.2015.12.012.