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The International Research Collaboration, Learning and Promoting Innovation Capability in Indonesia Medical Sectors

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FOREWORD by EDITOR-in-CHIEF

We are pleased to present to the readers with the fifth issue of the Journal of Science, Technology and Innovation Policy and Management. In this issue, we continue to publish the results of interdisciplinary scientific researches in various aspects of STI Policy and Management. This issue, prior issues, and other resources are available at www.stipmjournal.org.

We thank the reviewers and editorial boards for taking their precious time to ensure the quality of the articles through the double-blind peer review process. The seven articles in this volume cover a wide range of topics in STI policy and R&D governance and management. In this issue, we introduce a special topic on *Original Concept Formation.* This is a new focus and scope of STI Policy and Management Journal. A concept formation in technology policy (TP) and management of technology (MOT), including proven soft technology concept based on rigorous data, cumulatively published references, and long experiences in the academic sphere. The original concept formation should deal with soft technology problems, policy context for problem-solving, concept formation, and its effective implementation.

M. Nawaz Sharif presents an original concept formation entitled *Technology for Development: Ten True Stories Revealing the Complexity of Replicating South Korean Success*. The essay comprises ten true stories presented to highlight personally observed problems encountered by Asian developing country leadership who tried to replicate South Korean success in fostering technology innovation induced sustainable economic growth strategy without paying robust attention to the crucial role of creating an "innovation climate/culture" as a necessary foundation for myriad development efforts.

The subsequent articles revealed research findings on the various issue of STI policy and R&D governance and management. First article is presented by Erwiza Erman entitled *Changing Stages of System Innovation at the Ombilin's Coal Mines of Sawahlunto: From Ghost Town to World Heritage.* This paper examines system innovation, a transition from one socio-technical system to another by transforming the historical and cultural area into a world heritage city. The objective of this study is to reconstruct the changing stages of system innovation in achieving the World Heritage status at the Ombilin coal mines site of Sawahlunto.

The second article is composed by Rachmini Saparita and Savitri Dyah, entitled *Mechanism of Implementing Technology in the Community of Eastern Indonesia (Case Study in Belu Regency, Nusa Tenggara Timur Province).* This paper focuses on the mechanism of technology implementation to increase society's welfare. The study also evaluated technology implementation activities in the period 2003 to 2019, using meta-synthesis. The analysis found that there are five types of technology transfer mechanisms carried out by researchers at LIPI.

The third article is composed by Budi Triyono, Ria Hardiyati, and Aditya Wisnu Pradana, entitled *Lack of Contribution of the Indonesian R&D Program to Economic Sector: Learning from the RPJMN Implementation*. Through a review of the National Medium-Term Development Plan (RPJMN) documents on the S&T Sector period of 2015–2019, this article attempts to analyze various obstacles related to the minimal contribution of Indonesian R&D Programs in supporting Indonesia's economic sector and national competitiveness.

Wati Hermawati presents an article entitled *Key Success Factors in Managing and Implementing Public Funded R&D Projects in Indonesia*. In this paper, she mentioned that the role of public-funded R&D institutions in supporting innovation and economic performance of MSMEs (micro, small and medium enterprises) is still very small. Therefore, the success factors in managing and implementing R&D projects at R&D institutions should be identified, particularly in providing solution for MSMEs' problems. Through the two case studies, this article provides key success factors and lessons learned to improve R&D project activities at PRCs.

The fifth article is presented by Trina Fizzanty, Kusnandar, Sigit Setiawan, Radot Manalu, and Dini Oktaviyanti, entitled *The International Research Collaboration, Learning and Promoting Innovation Capability in Indonesia Medical Sectors.* This article presents the case of eight international collaborative research projects in medical research in Indonesia. The research found that International research collaboration has opened the opportunity for Indonesian researchers to learn and upgrade their capability and contribute to the scientific arena. However, none of international research projects reached the commercialization stage yet, but some of which were at the beginning of clinical trial stage.

Finally, Budi Harsanto presents an article entitled *Eco-innovation Research in Indonesia: A Systematic Review and Future Directions*. The article analyzes the recent development of eco-innovation research in Indonesia and provides some potential avenues for future research. The analysis was carried out using Systematic Literature Review (SLR) techniques to synthesize knowledge development of a scientific field in a structured, transparent, and reliable manner.

The editor of STIPM Journal are dedicated to working with scholars in existing and emerging STI issues and produce high-quality papers to expand knowledge in the field of STI Policy and R&D Governance and Management. We believe that all the papers published in this issue will greatly influence on the STI Policy and Management for Sustainable Development.

The STIPM Journal is indexed by Google Scholar, ISJD, IPI, DOAJ, BASE, SINTA, and OCLC World Cat. This makes the journal dissemination wider.

The editor-in-chief acknowledge and are very grateful to the authors, the editorial board, the section editors, the designer, the staff of the LIPI Press Publishing Office, and everyone who has contributed to the publication of the STIPM journal. We are also very grateful to our future readers. By inviting the readers to publish your research results articles in this journal, we believe in the meaningfulness and future collaboration as well as to provide a higher scientific platform for the authors and the readers, with a comprehensive overview of the most recent STI Policy and Management research and development at the national, regional, and international level.

Happy New Year 2021 to all of you!

Jakarta, 15 December 2020

Editor-In-Chief

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The International Research Collaboration, Learning and Promoting Innovation Capability in Indonesia Medical Sectors

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ABSTRACT

Research collaboration across countries is known as a promising strategy to enhance science and technology capacity. This strategy becomes more popular for researchers as it contributes to research productivity. In the context of a developing economy like Indonesia, the goal of international research collaboration is to increase the researchers' scientific capacity. However, limited references were discussed on how international research collaboration projects could leverage innovation capacity in a developing economy. This paper aims to reveal research results to fill the literature gape, in the context of a developing economy and medical research. Several case studies consisting of eight international collaboration research projects in medical research were utilized, in which Indonesian researchers worked collaboratively with foreign researchers. The research found that the International Research Collaboration (IRC) has opened opportunities for Indonesian researchers to learn and upgrade their capability and contribute to scientific knowledge. Collaborative medical research in requires long-term research and significant funding support. Based on the case studies, none of international research projects had reached the commercialization stage, but some of which were at in the beginning of the clinical trial stage. Funding is needed for clinical research to enhance innovation.

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I. INTRODUCTION

Research collaboration has been known as one possible strategy to enhance science and technology capacity. This strategy becomes more popular for researchers (Schubert & Sooryamoorthy, 2010) since it has contributed to research productivity. In the early twentieth century, scientific papers from collaboration were 10%, but by the end of twentieth century it increased to 50% (Frenken, Oort, & Verburg, 2007). For example, "international collaboration connects distant knowledge bases that generally have less overlap than knowledge bases within a single country. The costs involved in international projects (travel costs, co-ordination costs) generally exceed the costs of national project, other things being equal. This could mean that in order to legitimate these higher costs, the expected returns must also be higher." (Kusnandar et al., 2013) Therefore, promoting innovation through IRC could be a strategy for a developed economy to ensure their innovative products are accepted in the developing economy, while the IRC aims to increase the scientific and innovative capacity.

This interesting phenomenon has attracted more researchers, especially in the field of science and technology management, to study the phenomena of research collaboration. Some researchers used bibliometric as indicators for research collaboration to study some factors which influence, such as the field of discipline (Qin, Lancaster, & Bryce, 1997), geographical (Ponds, Oort, & Frenken, 2007), and also to measure the degree of collaboration (Liao & Yen, 2012). The researchers are also interested in the impact of research collaboration to enhance the quality of research output measured by paper quality which was revealed by He, Geng and Campbell-Hunt (2009) and Frenken, Oort and Verburg (2007), also in nanotechnology research by Tang and Shapira (2012). The deeper analysis conducted by Rigby and Edler (2005), found that research collaboration with stronger network produces higher quality of output.

Research collaboration not only has positive impact on research output, but also on the researcher as an individual. Ynalvez and Shrum (2011) revealed that research collaboration has positive impact on output productivity of researcher. Priest et al. (2011) found that research collaboration could increase researcher capacity through sharing knowledge. This issue also studied by Niu and Qiu (2014) who explained that researchers can obtain not only formal scientific knowledge, but also micro-organizational capabilities, social and technical skills.

In addition to scientific impact, the research collaboration is expected to enhance innovation. Therefore, international research collaboration is now an emerging area of innovation studies (Chen, Zhang, & Fu, 2019). To increase innovation, some researchers collaborate with industries and this phenomenon also becomes an interesting issue. Okubo and Sjöberg (2000) and Abramo et al. (2009) mapped the collaboration between academics and industries in European Countries. Freitas, Marques and Silva (2013) studied the role of university-industry collaboration for innovation development on mature and emerging industries in Brazil. They found that the collaboration has no impact for mature industries, but for emerging industries, the collaboration has an impact on developing new product and process, and increasing workers capacity through training. This finding was supported by Kang and Park (2012) who studied the role of the government's R&D institution in small medium enterprises (SMEs) innovation in Korea. They found that SMEs which collaborated with R&D institution had better innovation output.

The increasing awareness that research collaboration provides many benefits has encouraged researchers to study how it can be successful. Many studies focus on factors that determine the success of research collaboration. Ubfal and Maffioli (2011) pointed out that, based on the resource-based view, funding is one of the factors that determined the success of research collaboration. Meanwhile, Bammer (2008) asserted that the fundamental principle of research collaboration is integrating different perspectives among actors to achieve the goal. Smith and Malina (1999) revealed that power imbalance can be a barrier in this process, while Nummela (2003) found that commitment is the important factor in research collaboration.

Some research suggested that one of the important aspects of research collaboration is learning process among actors (Sargent & Waters, 2004; Priest et al., 2011; Niu & Qiu, 2014). However, it could not exist because of several factors. Kim and Park (2008) found that network structure became one of the important factors in the learning process. Meanwhile, Leung (2013) revealed that network ties, communication and actors reputation are the determinant factors of that process.

Research collaboration is within the social context, concerning human behaviors between two or more actors, where every actor conducts the role and function required to achieve the goal (Sonnenwald, 2007). All actors interact with each other during collaboration, where this process is influenced by the environment that is influenced by the process. Therefore, research collaboration is a non-linear, dynamic process with complex system characteristics (Wood & Grey, 1991).

A wider study of the success of research collaboration was conducted by Butcher and Jeffrey (2007). From their personal perspective, the determinant factors were trust and personal relationship, motivation, interests and need, commitment and expertise. The success factors from the management side are clearly objective, agreement on the role, monitoring, communication, funding, size of organization, working time management and leadership. Meanwhile, Sargent and Waters (2004) built a framework for research collaboration. The framework consists of three factors, namely personal factors of actors (trust, communication, and attraction), phase of research collaboration process (initiation, clarification, implementation, and completion) and environmental factors (institutional, national and international). All factors were interrelated and determined the success of research collaboration.

There are similar factors of success between research collaboration for scientific output and research collaboration for innovation output which involved industry actors. Some studies revealed that personal factors (commitment, interests, network, trust, reputation) and management factors (objective definition, mutual benefit agreement, organization) are the important factors for the success of the collaboration between academic and industry (Barnes, Pashby, & Gibbons, 2002; Carise, Cornely, & Gurel, 2002; Valentin, Sanchez, & Martin, 2004). But, there are some significant factors in this collaboration. Jansen et al. (2008) explained that the initial period when individual, institution and administrative need to be synchronized is the crucial phase of the academic-industry collaboration. Meanwhile, Boehm and Hogan (2013) asserted that the process continuity is the key factor to achieve innovation through academic-industry collaboration. Drivers of IRC, IRC patterns, IRC effects, IRC networks and IRC measurement (Chen et al., 2019). In the context of a developing economy, the role of IRC to scientific outputs has been studied, for example, by the international research collaboration in Indonesian Research Organization (Fizzanty et al., 2012), while its contribution to innovation especially in developing economy has not been studied. The question is how the international research collaboration could promote innovation in the context of a developing economy? This paper aims to present the results the international research collaboration process contributing to the innovation of a developing economy and the implications for innovation policy.

II. METHODOLOGY

The case study method by Yin (2003) was utilized to examine international research collaboration on medical innovation in Indonesia. The case study is international research collaboration, on innovation related to tropical medical problems, which are eight international collaborative research projects that facilitated collaboration between public research institutes, industries, universities, donors and government institutions as seen in Table 1. The primary information was gathered from a series of interviews with project coordinators or principal investigators from Indonesia. The secondary information was collected from the Ministry of Research and Technology, project document and digital information.

Interviewing respondents required a minimum of three hours. For each case study, at least two respondents were interviewed to obtain

Table 1.
The Case Studies of International Research Collaboration

No	Research Project	Actor		Project Term
		Local (Indonesia)	Foreign	
1	Stem Cell	Research Center (RC) in University O	University Hospital in Singapore	since 1988
		Regional Public Hospital P	University A in Australia	
		National Public R&D Q	University B in UK	
		State Owned Pharmaceutical Company R	University C in Japan	
2	Dengue	Research Center (RC) in University O	University D in Japan	since 1986
		University S	Private Biotechnology Company in Australia	
3	Hepatitis	Research Center (RC) in University O	University D in Japan	2010–2014
		Ministry of RT	University E in Japan	
			MEXT Japan	
4	HIV	Research Center (RC) in University O	University D in Japan	2010–2014
		State-owned pharmaceutical company T		
		University S		
		Ministry of RT		
5	Rotavirus	Research Center in University U	Research Institute F in Australia	since 1976
		State-owned pharmaceutical company V		
6	Cough Recorder	Research Center in University U	University G in Australia	since 2009
7	TB and Dengue	University W	International Research Institute H in Singapore	since 2007
		Research Institute X		
8	Dengue	University W	International Foundation I	since 2009
		Research Institute X	Multinational Company J	
			University K in Netherland	

Source: Kusnandar et al. (2013)

qualitative information 'process of collaboration'. They are one principal investigator or project coordinator from Indonesia and minimum one local research collaborators working in hospital or companies or R&D institutions or other universities and also the Indonesian Ministry of Research and Technology (Kemenristek). The snowballing technique was applied to obtain information on who were involved in the international research collaboration. So, the total number of respondents for this study was 20 respondents. Due to limited access to interview international partners, a secondary information was collected from project documents and internet research particularly to obtain information on collaboration process from international partners.

The cross-case study analysis was employed to obtain a pattern of collaboration process. In order to obtain Indonesian perspectives on the issues of international research collaboration in medical/health, LIPI arranged a one-day workshop entitled "Opportunities and Challenges in International Research Collaboration in Supporting Innovation in Medical Sector". There were 35 participants from various institutions discussing the issues of international collaboration. Several resource persons from Indonesia in this workshop are representatives from the Ministry of Research and Technology, faculty of medicine from universities, R&D institutes, pharmaceutical companies and facilitated by the research team from LIPI.

III. ANALYTICAL FRAMEWORK OF INTERNATIONAL RESEARCH COLLABORATION FOR IMPROVING INNOVATION CAPABILITY

Two bodies of literature examined in this study were the research collaboration, medical research and innovation system. The literature gave input to the theoretical framework of this study.

1. Research Collaboration

Research collaboration was defined as the co-operation of researchers in scientific activity to achieve a common goal (Katz & Martin, 1997). Amabile et al. (2001) defined research collaboration as people with different interests who work together to achieve a common purpose through interactions, information sharing and activities coordination. Meanwhile, Sonnenwald (2007) asserted that research collaboration lies within a social context, involving human behavior between two researchers or more, sharing knowledge and completing tasks to achieve a common goal. In line with those definitions, Bammer (2008) stated that research collaboration can be viewed as using various perspectives and skills to deal with the issue of interest. According to those definitions, we concluded that research collaboration was characterized by three important factors, namely a common goal, existing of scientific activities and involving actors with various perspectives.

Although there are some definitions of research collaborations, sometimes people are confused in distinguishing whether a certain actor is a part of the collaboration or not. In this study, we use criteria suggested by Katz and Martin (1997). A certain actor could be called as a part of the collaboration if they were included in at least one of the following activities

a) those who work on the collaboration from start to the end of project, or for a large part of it, or who make frequent or substantial contributions;
b) those whose names appear in the original research proposal;
c) those who are responsible for one or more of the main elements of the project, e.g., the experimental design, construction of research equipment, execution of the experiment, data analysis and interpretation;
d) those who are responsible for a key step;
e) those who propose initial projects and/or provide funding. The success factors are associated with to research collaboration.

Although many studies have proved that there were many benefits from research collaboration, there is no guarantee that every research collaboration will achieve the goal and give equal benefit to all actors. There are several factors affecting the success of research collaboration. Those factors can be divided into three elements, namely personal and team characteristics, process of collaboration, and environment (Amabile et al., 2001; Sargent & Waters, 2004).

The first element, personal and team characteristics, motivation becomes the fundamental element for every actor to form and collaborate. Melin (2000) stated that the main reason behind the collaboration is the need of a researcher that can be categorized into material, knowledge, and social needs. However, the actor of collaboration may not only researchers, but also industries and governments. So, they also have motivations in doing research collaboration. Autio, Hameri and Nordberg (1996) divided the motivations of research collaboration in six categories; technological, epistemic, financial, educational, political and strategic. Those motivations are different among researchers, industries, and governments. The main motivation for researcher is scientific improvement, for industries is innovation and business improvement, and for governments is national capacity enhancement in science, technology, and industry (Autio et al., 1996).

Because of the various motivations among actors, the most important thing that must exist in research collaboration is trust (Amabile et al., 2001; Sargent & Waters, 2004). Trust is the fundamental element which should be owned by every actor in collaboration. Trust can be defined as the willingness to rely on another party and to take an action which can make another party vulnerable (Doney, Cannon, & Mullen, 1998). In the context of research collaboration, trust is related to researchers' integrity, expertise, positive personal characteristics and time management capacity (Boehm & Hogan, 2013). Trust cannot be owned instantly, it requires time to build and maintain through work relationship (Leung, 2013). Previous experience and repeated cooperation could foster mutual trust and confidence (Beaudry & Schiffauerova, 2011).

The second element is the process of collaboration. One of the important factors was the effective communication—that can be

achieved by frequent meetings (Amabile et al., 2001). In addition, they also stated that being well-organized was the determinant factor in the effective process of collaboration. Therefore, the planning step does not only examine the process, but also the initiation process (Sargent & Waters, 2004). Thomson and Perry (2006) stated that collaboration is a continuum process of three stages; negotiation, commitment, and implementation. They also explained that those stages are not a linear process, but iterative and cyclical. For the research collaboration process, Sargent and Waters (2004) provided the framework used in this study. Based on that framework, research collaboration consists of four stages which happened in a cyclical process.

a) *Initiation phase* focused on actors' motivation to be involved in collaboration. This can be divided into instrumental and intrinsic. Instrumental is related to complementary skills, knowledge and data access opportunities. The intrinsic motivation involves the enjoyment of working with other person and building a long-term relationship and networking.
b) *Clarification phase* that researchers clarify the goal of collaboration and any properties of collaboration such as the scope, duration, number and kinds of actors who will be involved.
c) *Implementation phase* that collaborators play a role in conducting the research project according to the previous plan.
d) *Completion phase* where outcome and the likelihood of collaboration in the future will be evaluated.

The elements of personal and team characteristics and process of collaboration are influenced by the last element that is environment. Sargent and Waters (2004) categorized the environmental factors into three types; institutional support, resources, and climate. Institutional support will influence the time and resources to a collaboration project (Amabile et al., 2001). The other contribution of the institution is administration process (Sargent & Waters, 2004) which was important because the success in collaboration not only needs social capacity to build a relationship, but also administrative capacity through coordination and element of hierarchy (Thomson & Perry, 2006). For the resources factor, the most important is funding because it can determine the project's scope and duration (Sargent & Waters, 2004). Funding also becomes the factor that attracts researchers and also industries to interact with each other (Rigby & Edler, 2005). Meanwhile, climate factors are defined as policies and strategies of institutions and nation regarding research collaboration (Sargent & Water, 2004).

2. Innovation in Medical Sector

Based on Schlich and Tröhler (2006), medical innovation can be defined as the process of introducing a new medical technique or drug. Medical innovation can be divided into three types; drugs, medical devices and surgical procedures (Gelijns & Halm, 1991). We defined those three types from the U.S. Food and Drug Administration (U.S. FDA). Drug is any substance, other than food, which is used to diagnose, cure, mitigation, treatment, or prevention of disease, and it could affect the structure or any function of human or animals body. Medical device is defined as an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related object used for diagnosis, treatment, or prevention of disease which did not affect the body through chemical action. Meanwhile, surgical procedure is defined as a clinical procedure carried out under direct visualization.

The characteristics of the innovation process in the medical sector are different from other sectors due to the risk associated with the product. The risk becomes the most important factor in medical innovation because it directly affects the human body (Gelijns & Halm, 1991; Schlich & Tröhler, 2006; Coccia, 2012). Sometimes, it is difficult to fully understand how the disease works in the body, therefore the clinical procedure does not need a solid understanding of the disease but adopted from the recursive application (Tomás & Consoli, 2012). Innovation in the medical sector not only has short-term direct risks, but also side effect risk in the long term, either moderate or severe (Coccia, 2012). That is why, it needs the experimental step to the new technology in the

medical sector to prove that the product is safe for human (Yaqub & Nightingale, 2012).

Based on its types, product innovation in the medical sector can be divided into two, pharmaceuticals and diagnostical. Pharmaceutical aims to develop drugs to influence the human body structure or function (FDA, 2010). Medical diagnostic is diagnostic devices used in the medical sector. Both medical innovations have a similar process in research commercialization (Figure 1).

1) Pre-discovery phase

   Researchers are working to understand the basic characteristics of certain problems (causes of disease, etc.) which will be used for the next research stage.

2) Exploratory phase or pre-clinical trial

   The output of discovery is reviewed more intensively and tested at laboratory scale. The two testing are in vivo (testing at the outside of the body) and in vitro (animal testing).

3) Proof of concept or clinical trial

   Once the lab testing is passed, the next stage is testing the output of the project. Clinical trial is testing at the human body consists of three phase; phase-1 safety test of new drugs, phase-2 testing on volunteers in a large sample and phase-3 testing at community.

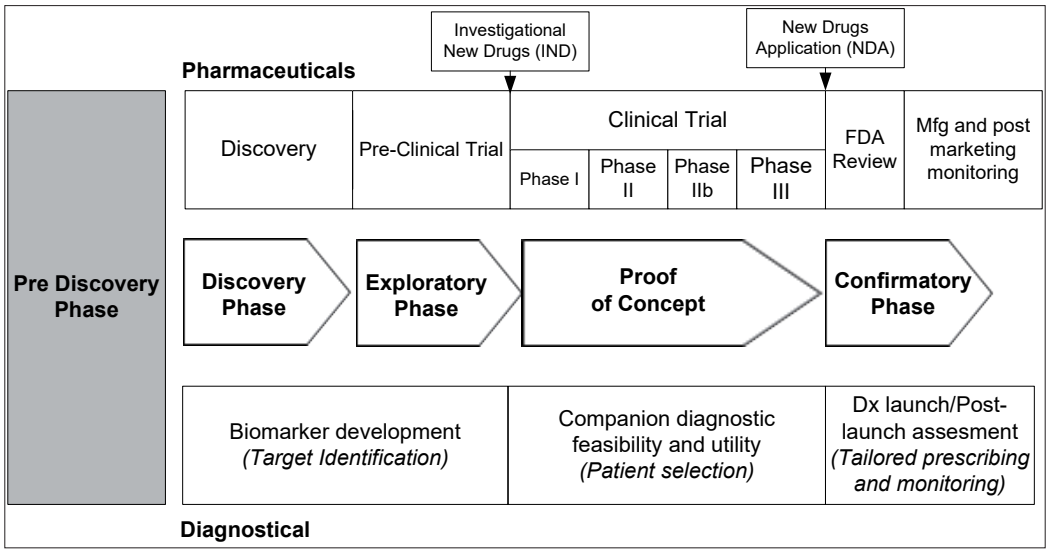
4) *Confirmatory phase*

   The passed concept is then tested in larger samples to convince than the output is effective. The last is manufacturing and post marketing monitoring. The official institution will review the innovation, followed by manufacturing of new products and market monitoring for at least four years.

3. Analytical Framework: Research Collaboration, Learning and Innovation Capacity

This study described the relationship between research collaboration, learning process and innovative capability hypothetically. Collaboration could lead to innovation if the relationship is based on trust, commitment, implementation capability, and mutual benefit and supported by knowledge absorptive capability and learning process and the ability achieve the highest outputs of the project.

The analytical framework used in this research (Figure 2) was modified from combining the four stages of collaboration process, namely initiation, clarification, implementation and completion (Sargent & Waters, 2004) and three



Source: Kusnandar et al. (2013) (constructed from Roche (2013), Ernst & Young (2000) and Innovation.org (2007))

Figure 1. Commercialization Process of Medical Research Outputs

stages of collaboration process such as negotiation, commitment and implementation (Ring & van de Ven, 1994). The modified framework suggested four stages of cyclical collaboration process, including initiation and negotiation (stage-1), clarification and commitment (stage-2), implementation (stage-3) and output and outcome (stage-4).

Every actor has their own motivation and expectations of the research collaboration, depending on the person's problems, institution and collaborative environment. At the initial process of collaboration, negotiation among actors are commonly practiced. Hence, the initiation and negotiation process should be in the first stage. This is an important stage in collaboration to ensure that all parties discussed the contribution and benefits shared by all actors. Once the consensus is achieved, all actors are expected to contribute and committed to reach the end goals. The output of research collaboration is publication, patent, knowledge transfer, human resource capacity, etc. When every actor shares resources and applies a learning process to improve their capacity, the project is expected to achieve its objective, and the results are potentially utilized. The impact of research collaboration could improve scientists' career, promote innovation for industry or community, transfer knowledge to support learning process, and increasing researchers' capacity and competency. The relationship between actors, collaborative process, output and impact, and collaboration environment are described in Figure 2 as the analytical framework of this study.

IV. RESULTS AND DISCUSSION

1. Result

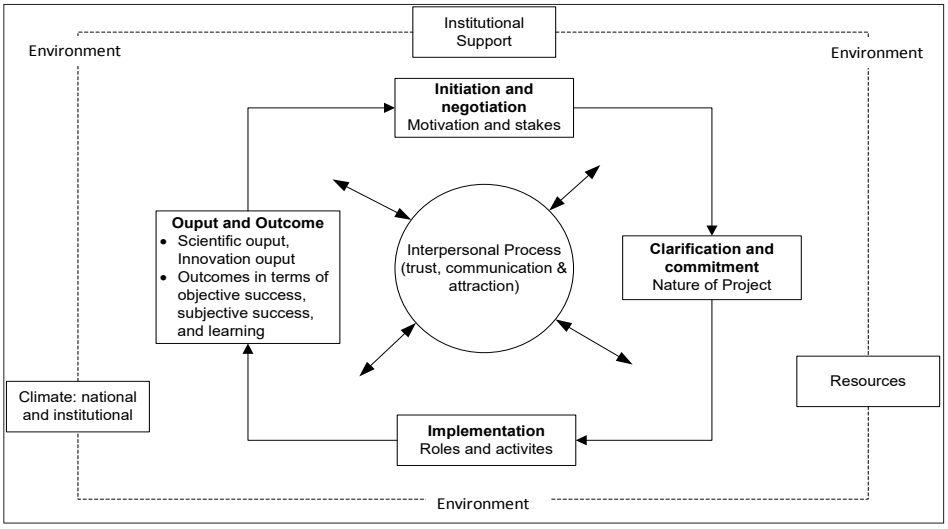
Characteristics of International Research Collaboration Projects

The two types of medical innovation products are pharmaceutical and diagnostic. Eight collaborative projects were examined and found that none of the collaborative projects reached the commercialization stage. Three international research collaboration projects in pharmaceuticals were still at the pre-discovery stage, two projects in diagnostic tools were at the pre-clinical trials (cough recorder and hepatitis) and three projects have reached the clinical trials, such as collaborative research projects in rotavirus, stem cell and dengue (Table 2).

Process and Management of International Research Collaboration

Pre-discovery

At this stage, only academia were involved in the collaboration. Research topics or themes were normally a part of the negotiation process



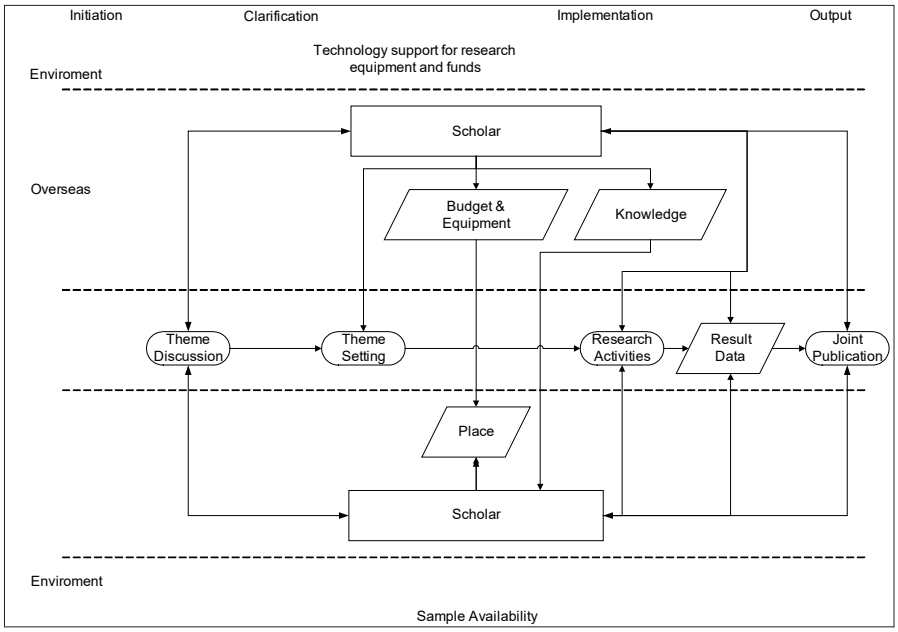
Source: Kusnandar et al. (2013) (modified from Sargent and Waters (2004) and Ring and van de Ven (1994))

Figure 2. Analytical Framework of Research Collaboration

Table 2.
Cluster of Study Cases based on Research Objectives and Innovation Stages

Pre Discovery	Pharmaceuticals		
	Discovery	**Pre-Clinical Trial**	**Clinical Trial**
1. TB dan Dengue (Case Study 7) 2. HIV (Case Study 4) 3. Dengue (Case Study 2)			1. Rotavirus (Case Study 5)
			2. Stem Cell (Case Study 1)
			3. Dengue (Case Study 8)
	Diagnostics		
	Biomarker Development		***Companion Diagnostic Feasibility and Utility***
	1. Cough Recorder (Case Study 6)		
	2. Hepatitis (Case Study 3)		

Source: Kusnandar et al. (2013)



Source: Kusnandar et al. (2013)

Figure 3. Actors, Interaction and the Environment of International Research Collaboration in Indonesia at Pre-discovery Stage

of all collaborators. However, this was not the case in the eight international projects. Foreign partners performed significantly in determining the theme of collaborative research projects. It was comprehensible, as both partners have a gap in innovation capacity and foreign partners took a role as a main funding source and research infrastructure provider for the projects. The knowledge transfer from foreign researchers to Indonesian partners was commonly practiced. The research was mostly located in Indonesia, and both partners made co-publication (Figure 3).

Diagnostic Case at Pre-clinical Stage/ Biomarker Development

The case studies were identified at the stage of biomarker development. All academics were engaged at this stage, and each actor had different competence. At the negotiation process, the project theme was proposed by foreign researchers and discussed with Indonesian researchers to come with consensus. The project aimed to produce diagnostic kits which have potential innovation in the future. At the clarification process, foreign partners agreed to provide funding and

research equipment, while Indonesian researchers provided the sample data. Unfortunately, all parties did not have legal standing support to ensure all parties have mutual benefit from the project outputs.

At the implementation stage, the projects were conducted through joint activities. In this process, knowledge transfer from foreign researchers to local partners mostly raised in terms of training and learning by doing. However, at this moment none of all case studies of biomarker development have produced diagnostic kits, only joint publication (Figure 4), since the project was not completed.

Clinical Stage for Pharmaceutical Case

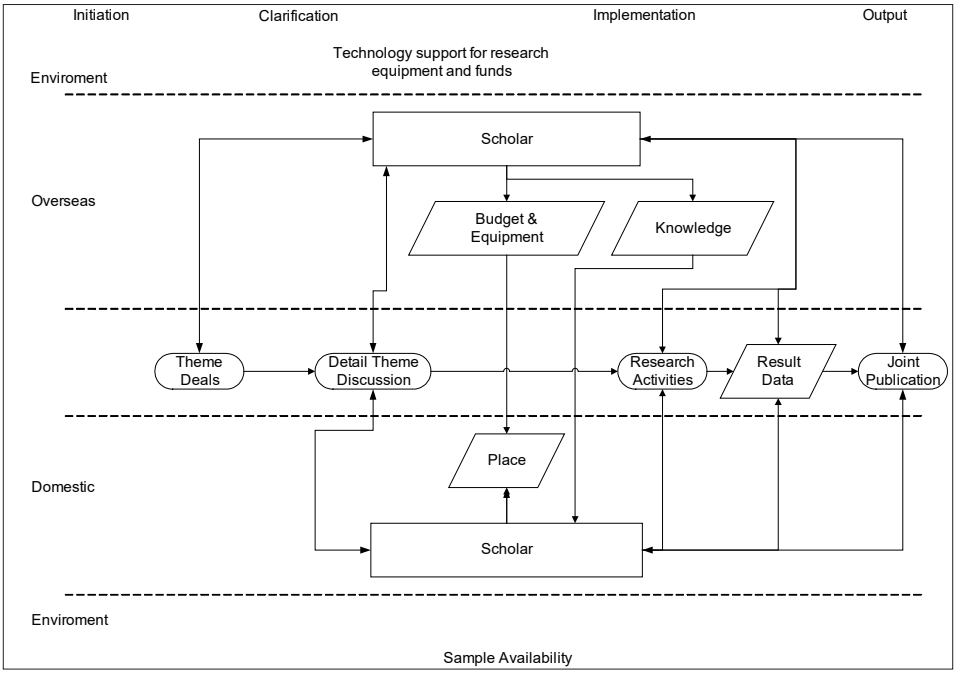
In the case of pharmaceuticals, both academia and industrialists were involved in the clinical stage. At the beginning, academia with various competencies made decisions on project theme who have various competences. Contrary to the previous case, both actors in this case determined the project theme, since all actors have equal and complement capacity in research. All actors conducted collaborative research and knowledge sharing in two ways.

Industrialists were interested in making a partnership after the project had shown market potential and ready to have a clinical test. Academia were still took a role at this stage. It takes a long period (more than ten years normally) for pharmaceutical research to do the clinical trial and reach the commercialization stage, as it requires a large amount of funding. Therefore, the involvement of business or industry is essential (Figure 5). Once the clinical trial has been completed, industrial R&D could use the result for product development.

2. Discussion

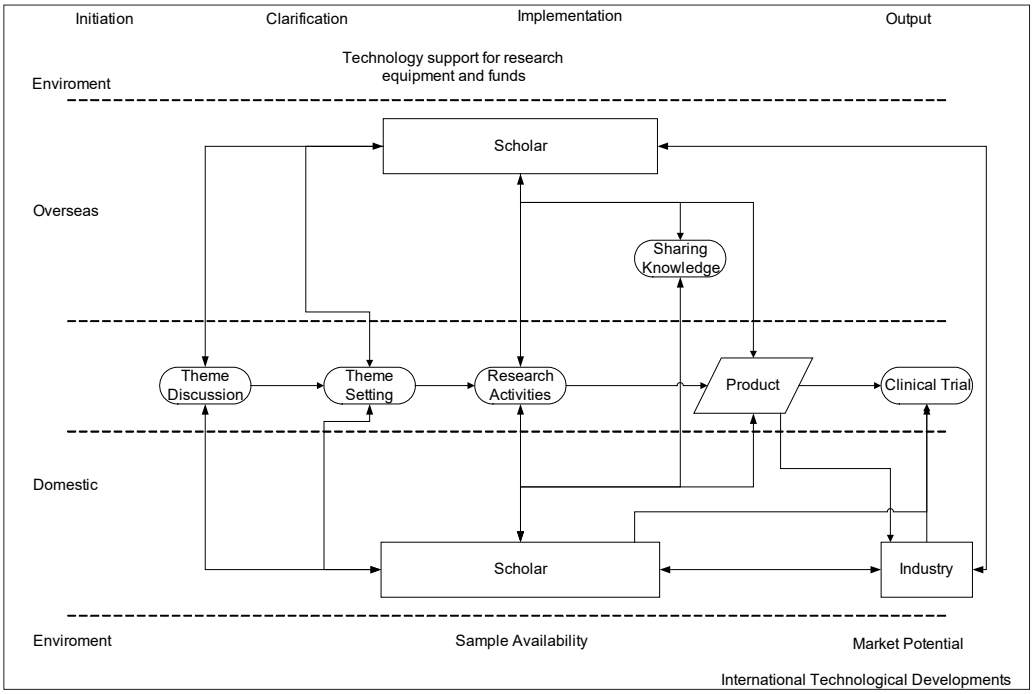
The Basic Principles of International Research Collaboration

Scientific competence and network were found essential as the basis for international research collaboration and building trust among collaborators. The researchers' competence was usually the main reason behind the collaboration. Scientific meetings and scientific publications are the best way for researchers to know their partners' reputation in science. Competence-based trust was the basis for collaboration (Sargent & Waters, 2004). In addition, network had a significant role



Source: Kusnandar et al. (2013)

Figure 4. Actors, Interaction, and the Environment of International Research Collaboration on Diagnostic Pre-clinical Stage or Biomarker Development



Source: Kusnandar et al. (2013)

Figure 5. Actors, Interaction and the Environment of International Research Collaboration on Pharmaceutical Case at Clinical Trial Stage

in international research collaboration. It was established through alumni network and previous experience in collaboration. The network will provide a recommendation for future collaboration. Ring and van de Ven (1994) suggested that collaboration emerges from individual interactions through formal and informal activities, followed by developing rules and structure of partnerships to ensure all parties will obtain mutual benefits.

In addition, resources ownership or accessibility was also an essential factor in establishing IRC. The cases of international collaborative projects have shown that better access to financial and research equipment were the main reasons to create partnerships with researchers in advanced economies. Meanwhile, foreign researchers were interested in working collaboratively with Indonesian researchers for several reasons, especially because the access to Indonesian bioresources and many cases of human diseases were easily found in Indonesia. The gap in scientific knowledge, funding and facility between the developing economy (Indonesia) and its foreign partners influenced how resources and activities were distributed among team members. For example, at the pre-discovery stage, partners of Indonesia were responsible for collecting the data or samples in Indonesia, while foreign partners provided funding, and research equipments as well as knowledge transfer to Indonesian partners.

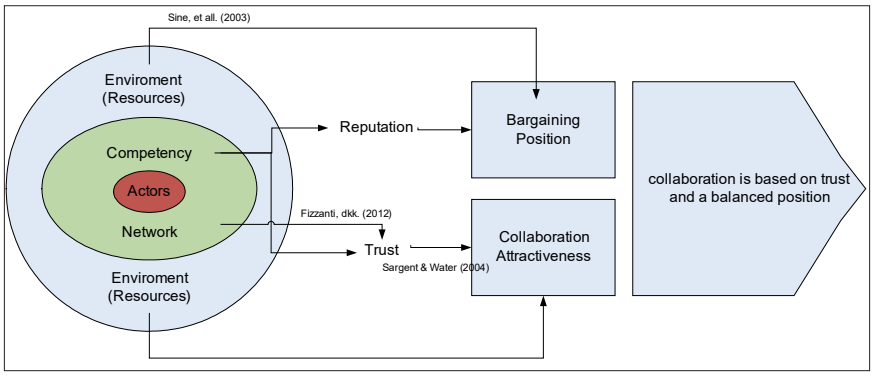
The gap of resource ownership among collaborators will likely determine the bargaining position of each partner. The higher gap of resources among collaborators, the higher gap of benefits will occur. Within this situation, a certain cost is being applied to promote collaboration (Snowden, 2002). As a consequence, collaborator with lower bargaining level may have less opportunity to obtain higher benefit, which is also known as the halo effect (Thorndike, 1920). Every collaborator will examine their partners' prestige such as competence, authority and resources, and track record (Sine et al., 2003). The initiative stage is therefore critical for the success of collaboration and share mutual benefits to all collaborators. At this stage, the collaborators discussed the research project in terms of the research theme, job allocation and research outputs and utilization.

Case studies in Indonesia medical research projects confirmed that the capacity of collaborator in funding provision and research infrastructure contributed to the successful negotiating process. Funding is the main resource for research collaboration as it defines the project scope, time frame and research depth (Sargent & Waters, 2004). The fact was limited research funding in Indonesia was scattered in various research institutions. At a given condition, the bargaining position of Indonesian researchers in international research partnerships could be at risk, particularly in scientific ownership and innovation.

Scientific reputation was the main contributor to successful international research collaboration. To some extent, Indonesia shall have bargaining position in related to scientific data from natural reseources and socio-cultural. Without any access to the data, the research projects cannot be succeed. Indonesian collaborators frequently considered that scientific data obtained from Indonesian natural resources was not always the basis or instrument for researchers in negotiation with their international partners. In fact, scientific reputation was the most influencal factor in negotiating projects of international scientific collaboration. Reputation is not given, but deserved recognition due to their contribution to scientific and acknowledged by scientific community. When both partners were balanced in scientific reputation, such as the case study in the clinical trial, both partners determined the project and when the project could reach innovation stage. The principles of scientific collaboration are described as follow (Figure 6).

The case studies have shown that the objective and time frame of research collaboration were likely to detemine the achievement of the collaboration. The outputs of collaboration in the case studies were mostly scientific publications, since the objective of collaborative projects was conducting basic research over a short term period. Meanwhile, the innovation is resulted when the collaboration intended to create a new product or process, such as a new vaccine, medicine, or method and to build long-term partnerships from the research plan until the trial process.

Additionally, the outputs from basic research collaboration were not only scientific publication, but also promoting new knowledge. The new understanding or new knowledge sometimes is unpredictable. Sharing knowledge among research collaborators was an opening to the possibility of new findings. As Antonelli and Ferraris (2011) suggested that promoting innovation requires knowledge from various actors, no organization or individual could produce innovation on its own. The competence of researcher is an accumulated process. The impact of collaboration is not only focused on the result, but also on a learning process among actors, which will provide long-term benefits for them (Sargent & Waters, 2004). The greater capacity output of the learning process will result in scientific outputs as indicated by their scientific reputation within the international academic community (Cooke, 2005). The continuing learning process and their consistency in particular research fields is a necessary condition to reach knowledge accumulation. Capacity development and scientific reputation



Source: Kusnandar et al. (2013)

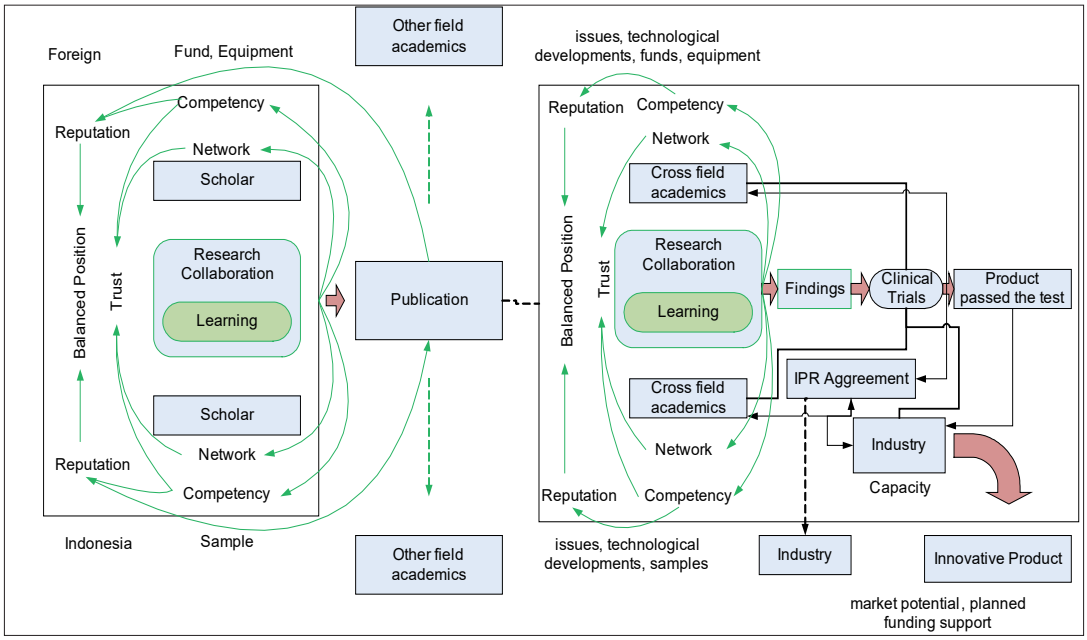
Figure 6. The Principles of International Research Collaboration on Pre-discovery Stage Knowledge Sharing and Multi-disciplinary Team

were essential to attract different competent actors involved in a collaboration to solve certain problems or organize applied research. This finding is also confirmed by Fizzanty et al. (2012) in which one key of successful collaboration in innovation is building multi-disciplinary or inter-disciplinary research teams. Furthermore, the applied research could be implemented due to technology advancement. For example, research on developing a method for spatial dengue repellent can be completed since the formula for mosquitos' killer has been found.

New products were resulted from accumulated basic knowledge and actors' collaboration. Once the research collaboration could produce something, the industry is being more interested in commercializing it. However, in the case of health products, it follow the medical standard, must conduct clinical trials that took a longer period and a large amount of funding. Consequently, there must be planning to fund the research collaboration in promoting innovation in health products. Government funding is not adequate to fund the clinical trial, since the fund is only available for a short period and the government funding is often not sustainable (funding may cut off in the middle of the economy calendar). Therefore, a funding institution would be involved in order to fund the clinical trial.

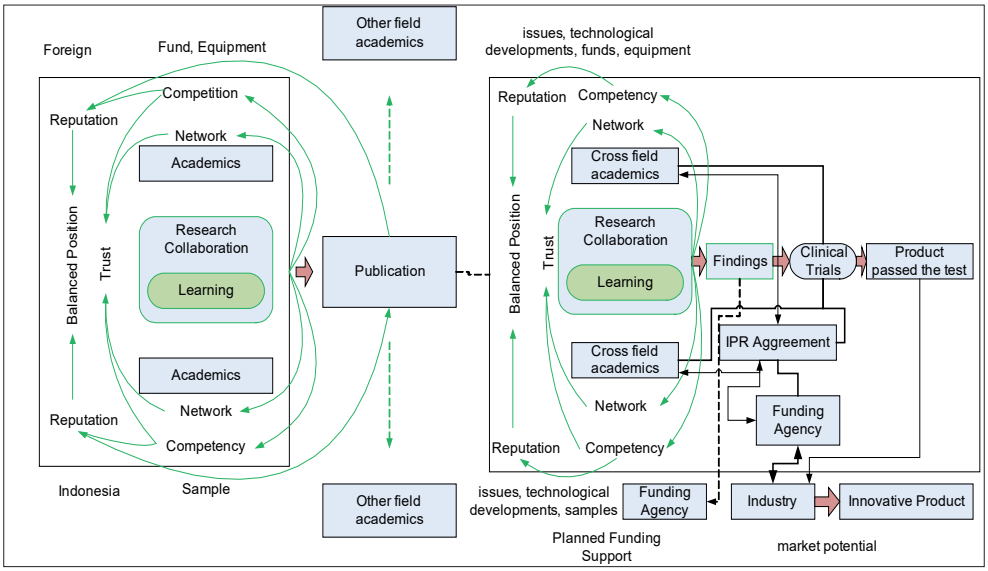
Two modes can be applied in ensuring the successful collaboration at the clinical trial stage. The first mode is involving a business or a firm to fund the clinical trial stage. Nevertheless, the firm has a right to be the producer or marketer for the new product. All of the process relies on intellectual property rights of all actors in the collaborative project. The second mode is engaging with funding institution that can provide a long-term funding where the institution and academia agree on intellectual property rights of the innovation. One day, when a business or a firm is interested to manufacture the innovation, it can buy the rights from the funding institution. The international research collaboration aims to promote innovation is presented in Figure 7 and Figure 8.

A business or a firm normally will decide to produce a new product from a research after calculating its market potential. Accordingly, the industry will evaluate its financial capability and technological capability to produce a new product. In summary, the research collaboration towards innovation requires a system which is complex and adaptive.



Source: Kusnandar et al. (2013)

Figure 7. Mode-1: The System of International Research Collaboration to Promote Innovation



Source: Kusnandar et al. (2013)

Figure 8. Mode-2: The System of International Research Collaboration to Promote Innovation

The Environment of International Research Collaboration to Promote Innovation

Research collaboration is an iterative process in which actors interact with their own competence and both are interested in particular issues. Consequently, the research institution should create an organizational environment in which the actors will likely interact with international partners. The interaction can be achieved through direct meetings, such as a conference, workshop and indirect mode (e.g., international publication). Therefore, the management of research organizations should facilitate the funding and encourage the members to participate actively in the activities.

The collaboration generally occurs when the collaborators begin their partnership with informal relationships. A formal agreement could not guarantee the collaboration. Fizzanty et al. (2012) suggested that many international research collaborations were not sustainable due to a research theme that was not a part of researchers' interest and trust among collaborators at implementation level was not established. The management of the organizations could promote the international research collaboration by providing support for researchers to participate in international meetings, bring the individual collaboration to institutional partnerships and many other issues that could support the collaboration to be succeeded.

To proceed with discovery or applied research, various competences would be essential in its collaborative projects. To conduct a product innovation research in Indonesia, a collaboration with international partners is necessary, but it is not sufficient. Strengthening collaboration among related stakeholders in Indonesia is essential to create a more open environment for organizations, reduce institutional egoism, and facilitate actors' collaboration across institutions.

In the health sector case, to bring research into innovation requires particular and long-term processes especially in facilitating the clinical trial. As a consequence, a large amount of a long-term funding should be provided. Whereas, the government funding system with a short-term period and annual output evaluation is not compatible with the characteristics of research and innovation. The government funding for bringing research to innovation was also limited especially for the clinical trial. Whereas, the clinical trial is a critical stage in commercializing innovation in health, but most innovation failure occurred in this stage.

To solve the funding issue in promoting innovation in medical research in Indonesian context, partnerships between industries and public to support funding in the clinical trial is essential. The business would get the benefit to produce

and market the innovation. However, Indonesian industries only utilize existing technologies for producing products, and lack of concern and vision to take a role in R&D. Accordingly, the industry is dominated by small-scale firms with limited financing and market share. Meanwhile, R&D activities require a big investment and high risk for small businesses. Case studies in this research confirmed that only large businesses, such as state-owned companies were involved in research collaboration.

Progress in regulation has been made in promoting partnerships between academia and industries in Indonesia. In 2013, when this research was conducted, the regulation of intellectual rights in Indonesia was still absent. Accordingly, no clear rules on how the industry is able to buy technology from the research collaboration, and how the benefit will be shared between researchers and inventors. Without this, researchers would have less incentive to conduct the best research practices and innovation.

Since 2015, the Indonesian Ministry of Finance (No. 72/PMK.02/2015) has launched a regulation to stipulate reward to inventor from royalty patent as nontaxable state income. The regulation has explicitly stated reward tariff from the total amount of royalty. For example, with a total income less than Rp100 million, inventors will receive 40% of royalty and smaller proportion of it when they receive a larger amount of income from the invention.

The Law of National Innovation System on Science and Technology was just officially launched on August 13th, 2019. The new law aims to strengthen the national innovation system and promote the utilization of innovation in Indonesia. In order to promote innovation, some initiatives were promoted, for example, government incentive (tax deduction 300%) for business whom investing in R&D, and human resource mobilization between academia and business, public procurement or demand to create a market for local innovation.

Meanwhile, the law also regulates permit for international research organizations and researchers in conducting research, development, assessment and application of collaboration in Indonesia. Promoting technology transfer from international partners to local partners provide a clear benefit to solve problems in Indonesia and involve S&T human resources who are competent to implement international projects. Meanwhile, the law also regulates the Material Transfer Agreement and the obligation of storing the primary data of research from international collaboration in Indonesia.

In summary, the Law of National System in S&T will force the international research collaboration to provide a balance and fair authority for each partners. It may reduce Indonesia collaboration in international research consortium, whilst, opening the possibility for local inventors to commercialize their innovation to national or local government and business. Designing thoughtful policy implementation is important to reduce counter-productive promotion of innovation by tapping into international research collaboration.

V. CONCLUSION AND POLICY IMPLICATIONS

1. Conclusion

a) Competence in research and research support, such as the access to research samples, the availability of research funding and equipment could be attractive factors in research collaboration. However, scientific competence is the main attribute to be a trusted partner and have an equal position in international research collaboration.

b) International research collaboration could be utilized to increase scientific capacity and competence through the learning process among collaborators. In the long term, the international research collaboration can produce innovations if working in multidisciplinary research.

c) In conducting the research, the international partners mostly provided funding, equipment, and research experts. Whereas, Indonesia, as a developing economy, provided sample and research experts

d) To produce innovations in the medical, research, the success of clinical trials needs

a large and long-term funding support. This research found that none of international medical research projects had reached the commercialization stage, but some of which were in the beginning of a clinical trial stage. Hence, engaging with industries is essential to support funding towards innovation. As a benefit, the industry will obtain the right to produce and market the innovative products based on the agreement contracts with academia.

2. Policy Implications

a) The most effective strategy to promote international research collaboration is through bottom-up strategy, that is begun with personal relationships and move toward formal or institutional partnerships. Hence, R&D leaders should support and facilitate researchers in their institution to interact and make partnership with international researchers.

b) In order to bring research into innovation, international collaboration could be a key strategy for Indonesia. On top of that, strengthening national collaboration among R&D organizations in Indonesia is essential to promote innovation.

c) Evaluating the ministry regulation on royalty patent is a priority to ensure an effective regulation to motivate researchers to bring their research outputs to innovation.

d) Designing thoughtful implementation of the Law of S&T National System is necessary to minimize the counter-productive promotion of innovation by tapping into international research collaboration.

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REFERENCES

Abramo, G., D'Angelo, C.A., Di Costa, F., & Solazzi, M. (2009). University–industry collaboration in Italy: A bibliometric examination. *Technovation*, *29*(6–7), 498–507.

Amabile, T.M., Patterson, C., Mueller, J., Wojcik, T., Odomirok, P.W., Marsh, M., & Kramer, S.J. (2001). Academic-practitioner collaboration in management research: A case of cross-profession collaboration. *The Academy of Management Journal*, *44*(2), 418–431.

Antonelli, C. & Ferraris, G. (2011). Innovation as an emerging system property: An agent based simulation model. *Journal of Artificial Societies and Social Simulation*, *14*(2), 1. DOI: 10.18564/jasss.1741

Autio, E., Hameri, A.P., & Nordberg, M. (1996). A framework of motivations for industry-big science collaboration: A case study. *Journal of Engineering and Technology Management*, *13*(3–4), 301–314.

Bammer, G. (2008). Enhancing research collaborations: Three key management challenges. *Research Policy*, *37*(5), 875–887

Barnes, T., Pashby, I., & Gibbons, A. (2002). Effective university–industry interaction: A multi-case evaluation of collaborative R&D projects. *European Management Journal*, *20*(3), 272–285.

Beaudry, C. & Schiffauerova, A. (2011). Impacts of collaboration and network indicators on patent quality: The case of Canadian nanotechnology innovation. *European Management Journal*, *29*(5), 362–376.

Boehm, D.N. & Hogan, T. (2013). Science-to-Business collaborations: A science-to-business marketing perspective on scientific knowledge commercialization. *Industrial Marketing Management*, *42*(4), 64–579.

Butcher, J. & Jeffrey, P. (2007). A view from the coal face: UK research student perceptions of successful and unsuccessful collaborative projects. *Research Policy*, *36*(8), 239–1250.

Carise, D., Cornely, W., & Gurel, O. (2002). A successful researcher-practitioner collaboration in substance abuse treatment. *Journal of Substance Abuse Treatment*, *23*(2), 157–162.

Chen, K., Zhang, Y., & Fu, X. (2019). Internasional research collaboration: An emerging domain of innovation studies. *Research Policy*, *48*(1), 149–168.

Coccia, M. (2012). Driving forces of technological change in medicine: Radical innovations

induced by side effects and their impact on society and healthcare. *Technology in Society*, *34*(4), 271–283.

Cooke, J. (2005). A framework to evaluate research capacity building in health care. *BMC Family Practice*, *6*(1), 44.

Doney, P.M., Cannon, J.P., & Mullen, M.R., (1998). Understanding the influence of national culture on the development of trust. *Academy of Management Review*, *23*(3), 601–620.

Ernst and Young, (2000). *In a field of force: Trend shaping the health industry.* Ernst & Young LLP

FDA. (2010, January 5). *Federal food, drug, and cosmetic act (FD&C Act)*. USA: FDA.

Fizzanty, T., Kusnandar, Manalu, R., Oktaviyanti, D., Rosaira, I., & Hermawati, W. (2012). *Typology and effectiveness of research collaboration in Indonesia: Case studies of internasional collaborative research projects at LIPI*. Lembaga Ilmu Pengetahuan Indonesia, Jakarta.

Freitas, I.M.B., Marques, R.A., & Silva, E.M.P. (2013). University–industry collaboration and innovation in emergent and mature industries in new industrialized countries, *Research Policy*, *42*(2), 443–453.

Frenken, K., Oort, F.V., & Verburg, T. (2007). Related variety, unrelated variety and regional economic growth. *Journal Regional Studies*, *41*(5), 685–697.

Gelijns, A.C. and Halm, E.A., (Eds.). (1991). *The changing economics of medical technology*. Washington DC: National Academic Press.

He, Z., Geng, X., & Campbell-Hunt, C. (2009). Research collaboration and research output: A longitudinal study of 65 biomedical scientists in a New Zealand university. *Research Policy*, *38*(2), 306–317.

Innovation.org. (2007). Drug discovery and development. Retrived on 26 July 2013 from http:\\ www.innovation.org.

Jansen, E., Hocevar, S.P., Rendon, R., & Thomas, G.F. (2008). *Interorganizational collaborative capacity: Development of a database to refine instrumentation and explore patterns* (NPS-AM-08-148). Naval Postgraduate School, Monterey, CA.

Kang, K.N. & Park, H. (2012). Influence of government R&D support and inter-firm collaborations on innovation in Korean biotechnology SMEs. *Technovation*, *32*(1), 68–78.

Katz, J.S. & Martin, B.R. (1997). What is research collaboration? *Research Policy*, *26*(1), 1–18.

Kim, H. & Park, Y. (2008) The impact of R&D collaboration on innovative performance in Korea: A Bayesian network approach. *Scientometrics*, *75*(3), 535–554.

Kusnandar, Fizzanty T., Manalu R., Setiawan, S., & Oktaviyanti, D. (2013) *Analysis of internasional research collaboration system in supporting innovation: Case studies in health sector* (Technical report, Pappiptek-LIPI, Jakarta).

Liao, C.H. & Yen, H.R. (2012) Quantifying the degree of research collaboration: A comparative study of collaborative measures. *Journal of Informetrics*, *6*(1), 27–33.

Leung, R.C. (2013). Networks as sponges: International collaboration for developing nanomedicine in China. *Research Policy*, *42*(1), 211–219.

Melin, G. (2000). Pragmatism and self-organization: Research collaboration on the individual level. *Research Policy*, *29*(1), 31–40.

Niu, F. & Qiu, J. (2014). Network structure, distribution and the growth of Chinese international research collaboration. *Scientometrics*, *98*, 1221–1233. https://doi.org/10.1007/s11192-013-1170-x

Nummela, N. (2003). Looking through a prism: Multiple perspectives to commitment to international R&D collaboration. *Journal of High Technology Management Research*, *14*(1), 135–148.

Okubo, Y. & Sjöberg, C. (2000). The changing pattern of industrial scientific research collaboration in Sweden. *Research Policy*, *29*(1), 81–98.

Ponds, R., Oort, F.V., & Frenken, K. (2007). The geographical and institutional proximity of research collaboration. *Papers in Regional Science*, *86*(3), 1539–1550.

Priest, H., Roberts, P., Dent, H., Hunt, T., Weston, D., Chell, A., Blincoe, C., & Armstrong, C. (2011). Preparing for collaborative working in mental health: an interprofessional education project with clinical psychology trainees and nursing students. *The Journal of Mental Health Training, Education and Practice*, *6*(1), 47–57.

Qin, J., Lancaster, F.W., & Bryce, A. (1997). Types and Levels of Collaboration in Interdisciplinary Research in the Sciences. *Journal of the American Society for Information Science*, *48*(10), 893–916.

Rigby, J. & Edler, J. (2005). Peering inside research networks: Some observations on the effect of the intensity of collaboration on the variability of research quality. *Research Policy*, *34*(6), 784–794.

Ring, P.S. & van de Ven, A.H. (1994). Development processes of cooperative interorganizational relationships. *Academy of Management Review*, *19*(1), 90–118.

Roche. (2013). Research & development overview. Retrieved on 25 July 2013 from http://www.roche.com/research_and_development/r_d_overview.htm.

Sargent, L. & Waters, L. (2004). Careers and academic research collaborations: An inductive process framework for understanding successful collaborations. *Journal of Vocational Behavior*, *64*(2), 308–319.

Schlich, T. & Tröhler U., (Eds.). (2006). *The risks of medical innovation: Risk perception and assessment in historical context*. Abingdon, UK: Routledge.

Schubert, T. & Sooryamoorthy, R. (2010). Can the centre-periphery model explain patterns of international scientific collaboration among threshold and industrialised countries? The case of South Africa and Germany. *Scientometrics*, *83*(1),181–203.

Sine, W.D., Shane, S., & Gregorio, D.D. (2003). The halo effect and technology licensing: The influence of institutional prestige on the licensing of university inventions. *Management Science*, 49(4), 478–496.

Smith, M.E. & Malina, D. (1999). Cross-cultural collaborative research: Toward reflexivity. *Academy of Management Journal*, *42*(1), 76–86.

Snowden, D. (2002). Complex acts of knowing: paradox and descriptive self-awareness. *Journal of Knowledge Management*, *6*(2), 100–111.

Sonnenwald, D.H. (2007). Scientific collaboration. *Annual Review Of Information Science and Technology*, *41*(1), 643–681.

Tang, L. & Shapira, P. (2012) Effects of Internasional collaboration and knowledge on China's nanotechnology research impacts. *Journal of Technology Management in China*, *7*(1), 94–110.

Tomás, D.B. & Consoli, D. (2012). Whatever works: Uncertainty and technological hybrids in medical innovation, *Technological Forecasting and Social Change*, *79*(5), 932–948.

Thomson, A.M. & Perry, J.L. (2006). Collaboration processes: Inside the black box. *Public Administration Review*, *66*, 20–32.

Thorndike, E.L. (1920). A constant error in psychological ratings. *Journal of Applied Psychology*, *4*(1), 25–39.

Ubfal, D. & Maffioli, A. (2011). The impact of funding on research collaboration: Evidence from a developing country, *Research Policy*, *40*(9), 1269–1279.

Wood, D. & Grey, B. (1991). Toward a comprehensive theory of collaboration. *Journal of Applied Behavioral Science*, *17*(2), 139–162.

Valentin, E.M.M., Sanchez, A.M., & Martin, L.A.G. (2004). Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Research Policy*, *33*(1), 17–40.

Yaqub, O. & Nightingale, P. (2012). Vaccine innovation, translational research and the management of knowledge accumulation. *Social Science & Medicine*, *75*(12), 2143–2150.

Ynalvez, M.A. & Shrum, W.M. (2011). Professional networks, scientific collaboration, and publication productivity in resource-constrained research institutions in a developing country. *Research Policy*, *40*(2), 204–216.

Yin, R.L. (2003). *Case study research: Design and methods* (2nd ed.). California: Sage Publications.