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Designing Simulation of Indonesia National Innovation Capability Model Using the Dynamic System

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Abstract : *Indonesia urgently needs to have a comprehensive model of Indonesia national innovation capability to become a reference in determining policies to enhance national innovation capability. The national innovation capability will be the success key for the country in the future. The purpose of this study is to design a simulation model that can represent related stakeholder behavior in national innovation capability. Interaction among stakeholders in the model of the Indonesia national innovation capability is very dynamic and complex. Thus, the use of dynamic system methodology in this study is very appropriate. Dynamic systems are able to analyze a system dynamically and change over time. Output indicators used to measure the increase in the Indonesia national innovation capability is the number of publications, number of patents, and the value of exports of high technology products. The input data is used as the baseline is data in 2011. These data are as follows: Government Research and Development (R&D) funding IDR 7,000 billion, the number of publications 1,281, the number of patent 533, and high-tech exports USD 5,728 million. The model is determined to run for 20 times. At the end point the number of publications becomes 20,220, the number of patents becomes 4,526, and exports of high technology products USD 4,847 million. Then the model is performed by five simulation scenarios. The findings in this study show the significant result in theIndonesia national capability innovation model is in the fifth scenario. It shows that the number of publications increased by 51%, patents increased by 89%, and exports of high technology products increased by 528 %. However, the limitation of this study is to only analyze the involvement of stakeholders at the central level on improving national innovation capabilities. Variable input is limited to the rate of increase of R&D funding from the Government, the level of collaboration and the level of competence of the researchers.*

Keywords *-National Indonesiainnovationcapability, dynamic system, collaboration, stakeholder, R&D*

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I. Introduction

AccordingGlobal Economic Forum (2017), Indonesia's competitiveness rose from 2016-17, from 41 to 38. Nevertheless, Indonesia's position has not shown an increase if compared to the ranking in 2013-14. In addition, according to INSEAD(2017), the ranking of Indonesia innovation index rose to 87 from 88th compared to 2016. However, it decreased, when compared to the year 2013 which reaches 85th rank.Therefore, Indonesia needs to enhance the level of competitiveness and step into the Efficiency Driven stage. One of the main factors that needs to be done is to enhance the capability of national innovation.

The development of the global economy in the 21st century, have become more dependent on the production, diffusion, and dissemination of knowledge. So, that innovation based on knowledge and information has become an important role to maintain a competitive advantage (Malerba, 2005). Freeman (1995), proposed the concept of a national innovation system, which is a complex interactive relationship between the individual elements of the knowledge innovation system. The theory of a national innovation system is further expanded and becomes a conceptual tool and method for analyzing national innovation capabilities, establishing innovation policies, developing innovation environments and appraising innovation performance.

Porter (2004) defines national innovation capabilities as the potential of a country to produce a stream of commercially relevant innovations. He analyzed the determinants of national innovation capabilities in the context of global competitiveness. Innovation capability is not only the level of innovation realization but also aims to measure the fundamental conditions that create an innovative environment in a country. A thorough strategic analysis of determinants of national innovation capabilities that can formulate strategic objectives at the macro level, depending on internal and external conditions. Also, The concept of innovation capability has been introduced by Suarez-Villa (1990), which is to measure the level of invention and national innovation potential. The size of the innovation capability can provide important information about the dynamics of the invention and economic activity. It is used by policymakers, or academics to understand changes in the invention, technology, and competitiveness.

National innovation capability can be broadly defined as the potential ability of a country to maintain innovation activities through the implementation of a national innovation system. The criteria applied to measure national innovation abilities vary according to the national conditions of each level of analysis. Experts believe that national innovation capabilities can be measured through various aspects such as human resources, knowledge creation, knowledge dissemination and innovative financing (Commission of the European Communities, 2003). The national innovation system includes six sub-systems, namely science and technology policy, innovation strategy, human technical support service, technical support services, financial resource mobilization and international cooperation (Kayal, 2008).

Innovation capability plays an important and largely determines who can develop quickly in the era of globalization. For companies, innovation has the power to build a competitive advantage in relation to globalization. For a country, innovation capability is the source of prosperity and economic growth (Belitz, et al., 2008). According to Gans and Stern (2003), National innovation capabilities depend not only on the technical and scientific achievement but also focus on the economic application of a new technology. Innovation capabilities not only the level of innovation but aim to measure the underlying condition that creates an environment for innovation. Innovation capabilities depend on the ability of technology and manpower in the fields of engineering and science. Innovation capabilities also reflect policy choices and investment by the government and businesses that affect the incentives for research, development, and commercialization of a country.

National innovation capabilities will be key to the success of Indonesia in the future.Thus, Indonesia is very necessary to have a model of national innovation capabilities to be a reference in determining the policy of increasing the national innovation capability. The interaction between stakeholders in the national innovation capability model is dynamic and complex. Therefore, the dynamic system approach in this study is very appropriate. Dynamic systems are able to analyze a system dynamically and change over time.

The objectives of the study are: (1) To produce a simulation model that can represent behavior related to the improvement of national innovation capability by using a dynamic system model; (2) to design planning scenarios for national innovation capability with some changes in input variables; and (3) to develop the implications of planning scenarios for national innovation capability.

II. Material And Methods

The study was conducted from April 2015 to January 2018. Data and information used are primary and secondary data. Primary data is obtained through direct interviews with experts who can provide input for the preparation of Indonesia national innovation capability models. Experts come from 4 groups: Government, Private, Universities and Research Institutions. Secondary data were obtained from the Ministry of National Development Planning, Ministry of Research, Technology and Higher Education; Ministry of Justice and Human Rights, and Worldbank.

This research methodology uses a dynamic system approach. Dynamic systems are able to analyze a system dynamically and change over time. According to Richardson and Pugh (1986), this methodology focuses on policymaking, then how it can determine the behavior of problems that can be modeled by system dynamically. Dynamic systems are a strategic approach for analyzing complex system problems (Morecroft, 2007). The dynamic system is a combination of theory, methodology and philosophy that analyzes system behavior in almost all fields of study. This system is useful in the areas of knowledge, health, law, education, and other fields of study. In addition, this system will help whenever we need to know the system changes every time (Harris & Williams, 2005).

The system approach is a rational-to-intensive methodology that solves problems in order to achieve certain goals. A system approach is an integrated approach that views a problem as a system, where the nature of the problem is complex and may be interdisciplinary (Eriyatno, 2003). According to Muhammadi and Soesilo (2001), the system can be interpreted as the overall interaction between elements of an object within certain environmental boundaries that work towards the goal.

In dynamic systems, feedback and delays lead to dynamic system behavior as a consequence of the system structure. All human actions and all changes in the world occur through the feedback loop network. Feedback controls whatever changes over time. According to Forrester, the meaning of feedback in social systems is that decisions taken from the current situation lead to changes in the current situation. This change also changed the decision later (Forrester, 2009). Lane (2001) states that empirical research without theory is blind and we must consider the dynamic system as a modeling approach that has several assumptions. The assumption is about how human agents use information and how empirical data is used for: modeling, model testing and how the model is used practically.

Morecroft (2007) describes a dynamic system is a method of problem analysis involving the time aspect as an important factor, studying the changes in the outside world that affect the system. If a change in one part of the system will affect the other parts of the system and vice versa. Furthermore, Sterman (2000) explains that dynamic systems are related to the behavior of a time-changing system, with the aim of explaining and understanding how information feedback influences the behavior of the system so that it can design the information feedback structure and appropriate control policies through simulation and optimization system using qualitative models and quantitative models.

The research stages started from literature studies and expert interviews to identify problems. The next step is to develop aIndonesia National Innovation Capacity Model using a dynamic system. Building a dynamic system begins with the identification of stakeholders and constraints. Then design a causal loop diagram models, develop relationships and formulation of the model, analyze and test the model parameters. Then, the model is analyzed through five scenarios with some changes to the input variables.

Identify Stakeholders and Constraints

Identify stakeholders to identify the roles and problems faced in model of Indonesia national innovation capabilities. There are several stakeholders involved, namely the Government, R&D institutions, universities, and industry.

Determine Causal Loop Diagram Model

Indonesia National innovation capabilities measured by how much the output of innovation that includes publications, patents and export of high technology products. Each stakeholder has role is to generate innovation outputs (publications, patents, and exports of high technology products). The Government provides funding for R&D. R&D institutions and universities conduct R&D and produce publications and patent. The industry conducts R&D to produce patents and export of high technology products. For more details can be seen in Figure 1.

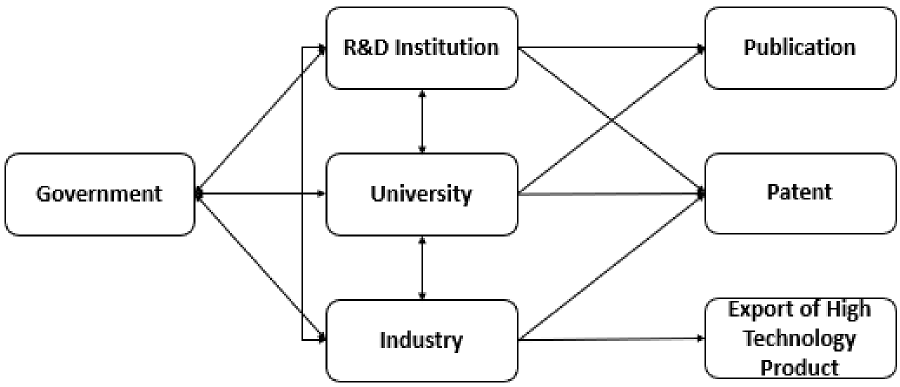

Figure 1 The process flow of stakeholders produces an innovation ouput (publications, patents, exports of high-tech products)

Relationship and Formulation Model

Government R&D funding increase depending on the rate of R&D funding increase per year. The budget increase is dependent upon government revenue derived among others such as from tax and non-tax. R&D funds are then used to conduct R&D in the R&D Institutions, Universities, and Industry. R&D institutions and universities generate publications and patents, while Industry generatepatents and export of high technology products. In addition, the number of publications will be influenced by the number of doctoral graduates. Every doctorgraduate is required to produce publication since 2012. The process of R&D in all three institutions will be affected by the level of collaboration among researchers and the level of researcherscompetence. The relationship between variables can be seen in Figure 2.

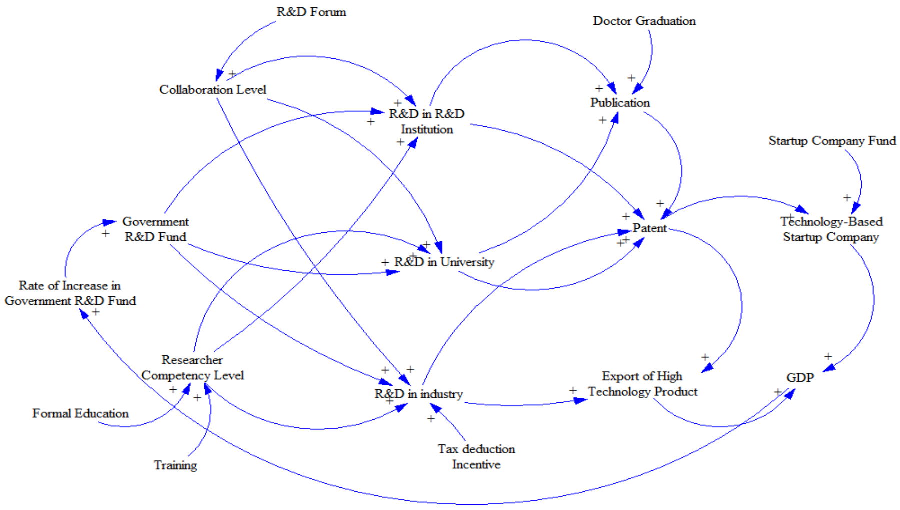

Figure 2 Model of CausalLoop diagrams Indonesia National Innovation Capability

Testing Model

Mean Absolute Percentage Error (MAPE) is one of the testing tools to perform modeling validation. MAPE compares the behavior of models with real systems. This test is used to determine the conformity of estimation data with actual data.

$$\text{MAPE} = \frac{1}{n}\sum\frac{|X_m - X_d|}{X_d} \text{ x } 100\%$$

Description :

X_m = data of simulation result

X_d = actual data

n = period/number of times

The criteria of model accuracy with MAPE test are:

MAPE < 5% : very precise

5 < MAPE < 10% : exact

MAPE > 10% : not correct

III. Result

Model Parameters

The data used as the Baseline in Model testing can be seen in Table 1. These data are R&D funds allocated by the Government, number of doctoral graduates, number of publications, number of patent applications, and export value of high technology products. Source of R&D funddatasare obtained from the Government Work Plan. Data on the number of patents, number of publications, and the value of exports of high-tech products using data from Worldbank. Meanwhile, the data of doctoral graduates are obtained from the Ministry of Research, Technology and Higher Education.

Table 1 R & D Funds, Doctoral Graduates, Publications, Patent, and Export of High Technology Product

Tahun	**R&D Fund (IDRBilion)** [1]	**Doctoral Graduate (person)**[2]	**Publication**[3]	**Patent**[3]	**Export of High Technology Product (USD Milion)** [3]
2011	7,000	2,634	1,281	533	5,728
2012	7,320	3,233	1,769	600	4,962
2013	7,900	3,435	1,992	663	4,818
2014	8,100	3,591	2,928	702	4,981
2015	8,800	3,955	5,071	1,058	4,410
2016	9,005	4,003	7,728	1,595	3,947

Source : [1]Government Work Plan, [2] Ministry of Research, Technology and Higher Education,
[3] The Worldbank

MAPE Testing

MAPE for R&D funds is 1.01 percent (<5 percent), so it is stated very precisely. Similarly, MAPE for doctoral graduates is 4.76 percent (<5 percent). MAPE for publication is 9.74 percent (<10 percent, so it is stated appropriate. Meanwhile, MAPE for patent is 7.67 (<10 percent), so it is stated appropriately.MAPE for the export of high technology products is 4.68 percent (< 5 percent), so it is statedvery precisely.

Dynamic System Model

In dynamic system models, variable inputs used to perform scenario model changes is the rate of increase of R&D funding, the level of collaboration, and the level of competence (Figure 3). R&D funds are funding sourced from the State Budget. The level of competence is the ability possessed by the researchers that can be improved through education, training, internships and so on. Meanwhile, the level of collaboration among researchers is how far the cooperation between researchers in conducting R&D. The level of collaboration among actors innovation can be strengthened through research forums, funding scheme of R&D collaboration, and invite industry to cooperate in R&D.

Output indicators used to measure the increase in the Indonesia national innovation capability is the number of publications, number of patents, and the value of exports of high technology products. From the model can display output indicators in the form of graphs and data.

Point first year of the model is in 2011. So that the input data used as the baseline is data in 2011 for government R & D funding, the number of publications, number of patents and export of high technology products as in Table 1. These data are as follows: Government R&D funding IDR 7,000 billion, the number of publications 1,281, the number of patents 533, export of high-tech product USD 5,728 Million. Research costs are assumed to be IDR 0.4 billion per proposal.

Baseline Simulation

The model is determined to run for 20 times. If it is assumed that R&D funding increases by 5 percent per year, the R&D funds of the Government continue to increase by Rp. 18.5 trillion in the 20th year. Although R&D funds continue to increase, the number is still relatively small compared to the total State Revenue Expenditure Budget. The three outputs of publications, patents, and exports of high technology products continue to increase. At the end point the number of publications becomes 20,220, the number of patents becomes 4,526, and exports of high technology products USD 4,847 million. Everything shows a sharp increase compared to the starting point.

Simulation Scenario

In this model five simulation scenarios are performed: (1) The first scenario is a change in the rate of increase in R&D funds from 5 percent to 10 percent; (2) The second scenario is the increase in the level of collaboration to 30 percent; (3) The third scenario, is the increase in the competency level to 30 percent; (4) The fourth scenario is the increase in the level of collaboration and the competency level of each to 30 percent; and (5) The fifth scenario is the increase of R&D funds to 10 percent, the increase of the collaboration rate to 30 percent, and the increase in the competency level to 30 percent.

In the first scenario, the rate of increase in R&D funding was changed from 5% to 10% per year, without changing the other input variables. The model runs 20 times. The results are different from the results of the simulation model. All output at the endpoint show an increase, the number of publications increased 19% to 24,136, patents increased by 24% to 5,633, and the export of high technology products increased 235% to $ 16,259 million.

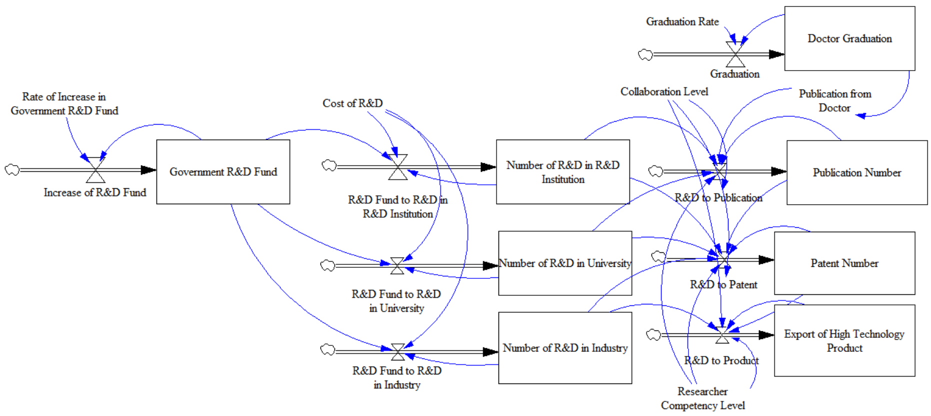

Figure 3 Dynamic System Model of Indonesia National Innovation Capability

In the second scenario, the collaboration rate is increased by 30%, while the other input variables are fixed. Then the model runs 20 times. All output showan increase compared to the baseline simulation, the number of publications increased by 18% to 22,984, patents increased by 14% to 5,334, and exports of high-tech products increased 82% to USD 8,806 million. Without an increase in R&D funds, increased levels of collaboration can increase the output of innovation. Collaboration has a major impact on product development processes from technology transfer or product development in industrial R&D. According to Sawang (2010), collaboration can enhance the role of actors in the exchange and sharing of knowledge, experience, and expertise. Collaboration between public actors and industry actors will create better and more effective products and services.

In the third scenario, the competency level of the researcher is increased by 30%, while the other input variables are fixed. Then the model runs 20 times. All outputs show an increase, the number of publications increased by 11% to 22,541, patents increased 14% to 5,140, and exports of high technology products increased 37% to USD6,637 million.

Next is the fourth scenario, the level of collaboration and the level of competence of researchers each raised to 30%. While the rate of increase in R&D funding remains at 5%. Then, the model is run 20 times .. All output show an increase, the number of publications increased 17% to 23,738, patents increased by 25% to 5,663, and exports of high technology products increased 119% to $ 10,605 million

In the fifth scenario, the level of increase in R&D funding increased to 10%, the level of collaboration and the level of competence of researchers each increased to 30%. Then, the model is run 20 times and the results can be seen in Figure 4, Figure 5 and Figure 6. All output showan increase, the number of publications increased 51% to 30,537, patents increased by 89% to 8,533, and exports of high technology products increased 528 % to USD 33,281 million.

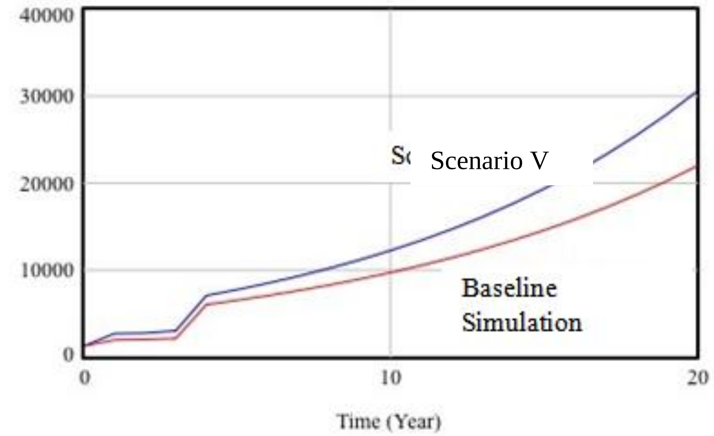

Figure 4 Graph of Number of Publications on the Fifth Scenario

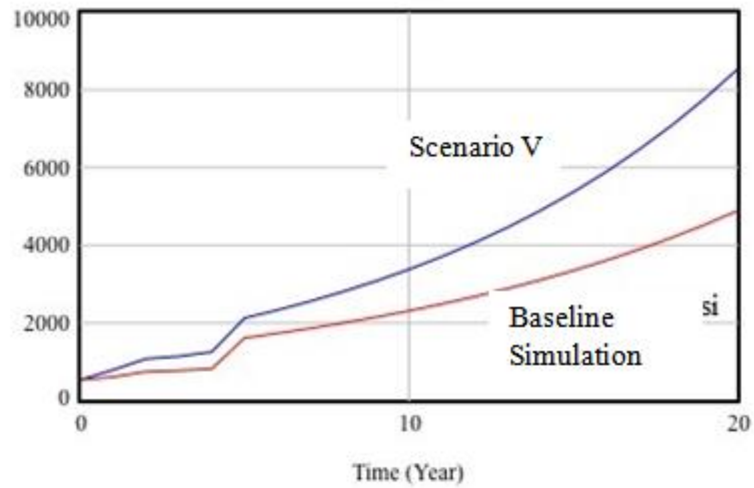

Figure 5 Graph of Number of Patents on the Fifth Scenario

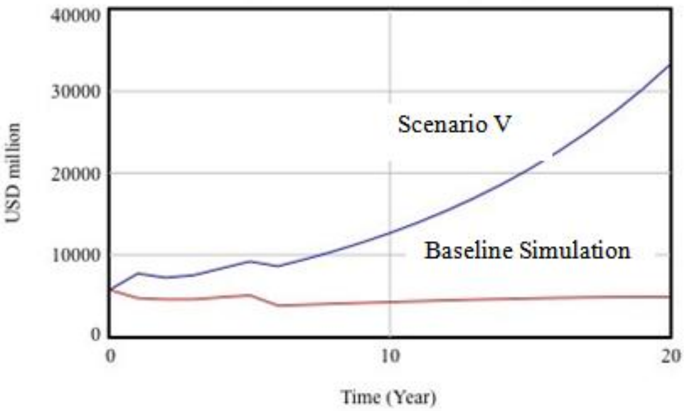

Figure 6 Graph of High Technology Product Export in the Fifth Scenario

The five scenarios show an increase in the output of different innovations. The greatest increase occurred in the fifth scenario by changing the R&D increase from 5 percent to 10 percent, the collaboration rate by 30 percent, and the competency level 30 percent. Table 2 is a comparative summary of the five scenarios.

Table 2 Value of Innovation Output in 5 Scenarios

No.	Skenario	Output Innovation at the 20th point					
		Publication		Patent		Export of High Technology Product	
		Unit	Change	Unit	Change	Milion USD	Perubahan
1.	BaselineSimulation	20,220		4,526		4,847	
2.	Scenario I	24,136	0.19	5,633	0.24	16,259	2.35
3.	Scenario II	22,984	0.14	5,334	0.18	8,806	0.82
4.	Scenario III	22,541	0.11	5,140	0.14	6,637	0.37
5.	Scenario IV	23,738	0.17	5,663	0.25	10,605	1.19
6.	Scenario V	30,537	0.51	8,533	0.89	33,281	5.28

Description :
Scenario I : Increase in R & D funds from 5% to 10%
Scenario II : Increase of collaboration rate by 30%
Scenario III : Increase of research competency level by 30%
Scenario IV : Increase the level of collaboration and the level of competence of researchers each of 30%
Scenario V : Increase in R & D funds to 10%, increase the level of collaboration and research competence of each of 30%

IV. Discussion

In the first scenario, the rate of increase in R&D funding was changed from 5% to 10% per year, without changing the other input variables. This shows that the amount of research funding is very influential on all of the output of innovation, particularly exports of the high-tech product increased enormously. According to Fan (2008), Financial investment and human resources in R&D as an important input factor to build Indonesia national innovation capability. One of the main focuses on reforming R&D is to integrate the business sector with knowledge and provide incentives for innovation activities.

For the second scenario, the collaboration rate is increased by 30%, while the other input variables are fixed. Without an increase in R&D funds, increased levels of collaboration can increase the output of innovation. Collaboration has a major impact on product development processes from technology transfer or product development in industrial R&D. According to Sawang (2010), collaboration can enhance the role of actors in the exchange and sharing of knowledge, experience, and expertise. Collaboration between public actors and industry actors will create better and more effective products and services. According to Zheng (2006), the national innovation system refers to a nation's innovation network where there is an interaction between institutions to enhance innovation that includes economic, scientific and technological organizations.

Then, in the third scenario, the competency level of the researcher is increased by 30%, while the other input variables are fixed. The level of competence plays an important role in optimizing R&D financing. Increased competence of researchers, positively influenced the increased output of innovation, but the increase is smaller than the increase in collaboration. According to Belitz, et al. (2008), in order for a country to be innovative, the country needs a national innovation system is functioning properly. The national innovation system refers to companies, research institutions, and the surrounding conditions that influence the process by which innovation grows. This system ensures that qualified individuals, new knowledge, and adequate capital unite in the innovation process

Furthermore, in the fourth scenario, the level of collaboration and the level of competence of researchers each raised to 30%. While the rate of increase in R&D funding remains at 5%. It shows that increased levels of collaboration and increased levels of competence simultaneously increase the output of innovation better than if individual input variables change. According to Matheus and Hu (2007), Innovation capabilities not only focus on one aspect of innovation performance but from a variety of sustainable sources. Beside that, according to Belitz, et al. (2008), Innovation capability of a country considered as the ability of people and companies to create and transform knowledge into a new, viable products and services sold and efficient process.In the fifth scenario, the level of increase in R&D funding increased to 10%, the level of collaboration and the level of competence of researchers each increased to 30%. The level of collaboration and research competence level will simultaneously increase innovation output significantly. There is even a high increase in exports of high-tech products.

Increased R&D fund sourced from the Government can significantly increase the number of publications, patents, and high technology exports. Therefore, the Government must commit to continuously improve R&D funding to R&D institutions, universities, as well as to industry.

However, with the availability of a limited budget, the Government can optimize the efforts to encourage continued collaboration between researchers or stakeholders. The interaction between the stakeholders is very influential in accelerating Indonesia national innovation capability. The government should continue to encourage and support the formation of R&D collaboration forums initiated by R&D institutions, universities, and industry. In addition, the Government can continue to develop a collaborative R&D funding scheme involving industry as a technology user.

Meanwhile, increasing the competence of researchers is also very important to improve the ability of researchers in conducting research and development. Increased competence can be done either through formal education or non-formal education, such as training, workshops, courses and other forms of training.

V. Conclusion

Stakeholders involved in the Indonesia National Innovation Capacity Model are Government, Research and Development Institutions, Universities, and Industries. Every stakeholder has behaviors that interact with each other. The government allocates R&D funds to R&D institutions, universities and industries. Research and Development Institutions, Universities, and Industries conduct R&D to produce innovation output in the form of publication, patent, and export of high technology products. Output Innovation is a measure of national innovation capability, where the greater the value, the higher the level of national innovation capability.

The input variables used in the national innovation capability are the level of R&D fund increase, the level of R&D collaboration, and the level of competence of the researcher. In this model, simulation of five scenarios with different input variable composition is employed. The increase in R&D fund from 5% to 10% has an effect on the improvement of all innovation output, particularly the export of high technology products which increased by 2.35 times. The 30% increase in collaboration rate showed a large increase in the export of high technology products by 82%. Increase in the competency level of researchers by 30% indicates an increase in the output of innovation, but smaller than the increase in the level of collaboration. Unlike when both input variables are raised simultaneously, where all the output of innovation increases sharply, particularly on the export of high-tech products. Increased output of innovation is greater by making changes to all input variables, that are R&D fund increase from 5% to 10%, 30% collaboration rate, and 30% research competency level. The output of innovation generated is the number of publications increased 51%, 89% patent, and exports of high-tech products 52%.

To further develop the model, it is necessary to examine the addition of input variables in addition to the rate of increase in R&D funds, the competency level of the researcher, and the level of collaboration. Thus, further research will increase the input variable composition in the model simulation.

This study is limited to innovation output indicators that are a measure of Indonesia national innovation capability. Therefore, it is necessary to further examine how big the impact of innovation output, such as the impact on the increasing number of technology-based start-up companies.

The model in this study is aimed to improve the ability of decision makers in enhancing Indonesia national innovation capabilities. Therefore, it is necessary to have a commitment from the Government to use the model to allocate the R&D funding, develop collaborative policies among researchers or stakeholders, and improve the ability of researchers.

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