The Impact of Education on National HRST Performance

Elmi Achelia, Indri Juwita Asmara, Maulana Akbar, and Muhammad Tasrif

***Abstract*—The economic growth of a country is influenced by the state of human resources in science and technology (HRST). Based on the definition proposed in Canberra Manual, HRST includes people who have completed third-level education in the field of science and technology (based on ISCED) and or people who employed in S&T occupation where the above qualifications are normally required (based on ISCO). We refer the developed HRST model, the employed based classification is the demand side and the education classification is the supply side, with the relationship between the two sides which aims at achieving HRST stock. In this paper, we will focus on the supply side of HRST. HRST stock at the supply side is determined by the potential supply coming from third-level education graduation majoring science and technology. In this case, it's affected by the number of students studying in universities and the education period. However, in certain circumstances, policies in the field of education can also influence the supply side. We run scenarios using Indonesia's HRST historical data that shows conditions which indicate the impact of education policy to national HRST stock. Furthermore, the scenarios also include technology in simulation. This study shows the impact of policy and also technology on HRST performance driving the national economic growth.**

***Index Terms*—System dynamics, human resources, science and technology, education capacity, supply-demand.**

I. Introduction

The economic growth of a country is influenced by the state of human resources in science and technology (HRST). Generally stated, education drives economic development. From the history, education had important role in economic development through its capacity to promote productivity, income, human capital, and trade competitiveness [1]. Specifically, economic development supported by higher education. Based on the analysis provided by the World Bank, higher education promotes income growth, enlightened leaders, expanding choices, and increasing relevant skills which are all benefits lead to economic development [2]. Pillay also mention that higher education play important role in economic growth, technological absorption, and knowledge economy [3]. Most countries with high enrolment ratios in higher education became 'leaders' in technology, with high levels of achievement in technology. So that increasing tertiary education may be important in promoting faster technological catch-up and improving a country's ability to maximize its economic output [3].

Based on review above, it is recognized that higher education graduates promotes economic growth. We can also describe the higher education graduates who specifically promote economic growth as Human Resources in Science and Technology (HRST). Based on the definition proposed in Canberra Manual, Human Resources in Science and Technology includes people who have completed third-level education in the field of science and technology (based on ISCED) and or people who employed in S&T occupation where the above qualifications are normally required (based on ISCO) [4]. Since HRST delivered from certain educational level, it shows the importance of education institution as the producers of potential HRST stock. HRST on education comprises ISCED category 5, 6, and 7 on S&T fields of study, i.e. natural sciences, engineering and technology, medical sciences, agricultural sciences, social science, humanities, other fields [5]. ISCED category 5 describes education at the tertiary level, first stage, of the type that leads to an award not equivalent to a first university degree. ISCED category 6 describes education at the tertiary level, first stage, of the type that leads to a first university degree or equivalent. And ISCED category 7 describes education at the tertiary level, second stage, of the type that leads to a postgraduate university degree or equivalent.

Discussing the education, we refer to two main focuses, there are quality and quantity. In term of quality, it is related to education policy, teacher quality, and incentives which lead to student and teacher performance. From the study, Hanushek and Wößmann conclude that educational quality has powerful effects on individual earnings, on the distribution of income, and on economic growth [6]. On the other side, quantity defined as the educational institution ability to open enrollment and admits a number of students in certain period. Related to HRST stock, the ability of educational institution to produces HRST determines education capacity to influence the supply side of HRST model.

Since 2012, Indonesia has had a demographic bonus as mentioned in MP3EI (Master plan for Acceleration and Expansion of Indonesia's Economic), which is large proportion of productive age population (age range 15-64 years) compared to non-productive age (0-14 years and 65 years and over) as shown in Fig. 1 below. In comparison, Fig. 2 shows dependency ratio for countries. Demographic bonus is a reflection of the number of dependence, in the period 2020-2030 decreased dependency ratios is below 1, where two people of productive age bear only one non-productive age. The conditions need to be utilized optimally, the demographic bonus can be useful when if the productive age workforce is already employed, but will be a burden on the state or a liability if the productive age is not prepared correctly.

The Indonesian school system is immense and diverse. It is the third largest education system in the Asia region and the fourth largest in the world, behind China, India and the United States [7]. Unfortunately Indonesia is still left behind in terms of enrollment to higher education as shown in Fig. 3.

Manuscript received December 20, 2016; revised May 1, 2017.

The authors are with Lembaga Ilmu Pengetahuan Indonesia (LIPI), Indonesia (e-mail: elmiachelia@gmail.com).

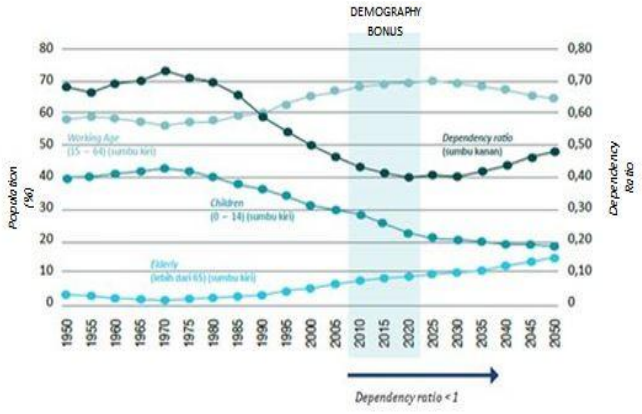

Fig. 1. Indonesia's demographic bonus.

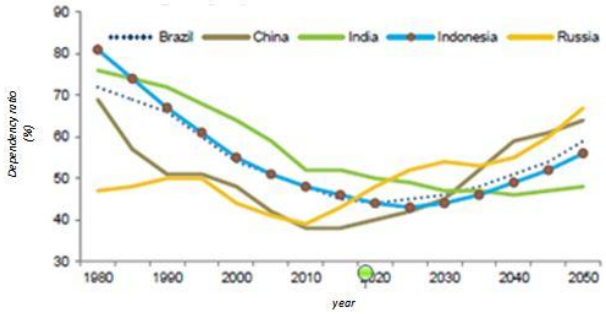

Fig. 2. Dependency ratio by countries.

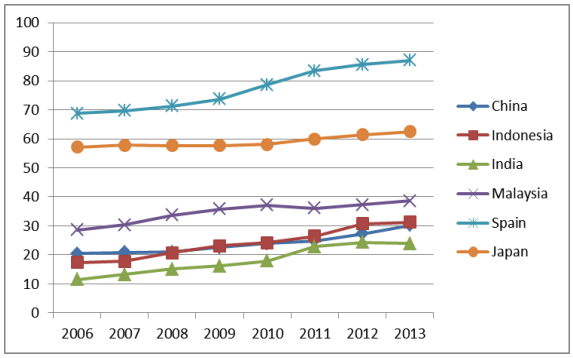

Fig. 3. Enrollment rate to tertiary education (ISCED 5 to 8).

Potential HRST created by the demographic bonus needs to be accompanied with education to become HRST supply. It can be seen from the enrollment rate into higher education in. According to The World Bank as compared with other countries in figure above, enrollment rate in Indonesia increased in years, but still lower than Malaysia as seen in Fig. 3. Indonesia and Malaysia has geographical proximity, influence each other for HRST supply and also play a role in Southeast Asia.

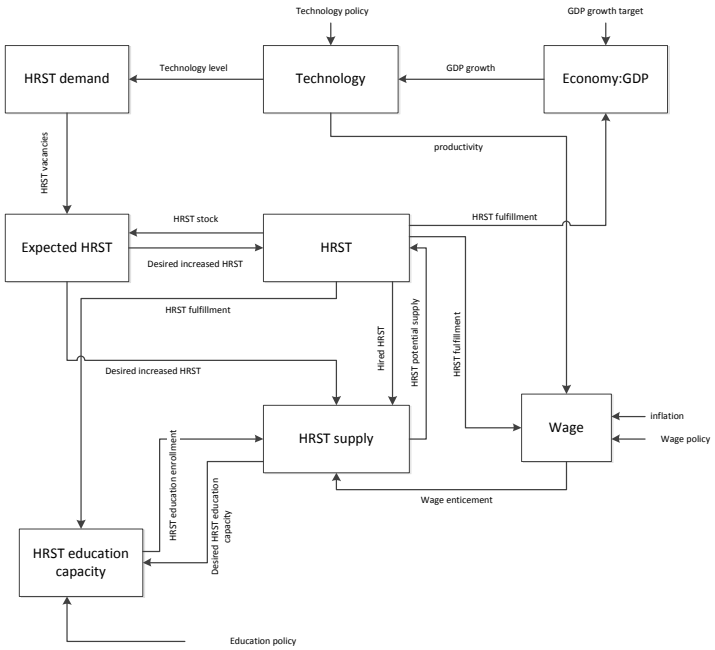

Fig. 4. Big picture of national HRST model.

ASEAN Free Trade Area (AFTA) and liberalization open the labor market in Southeast Asia. Nowadays, national HRST stock is not only depending on the supply of national higher education graduates but also from a global talent. Although it is not significant numbers of foreign worker in Indonesia, or vice versa. This becomes an opportunity and a challenge for Indonesia. Demographic bonus and an increase in tertiary education enrollment rate to be beneficial for Indonesia to build up the production of potential HRST which will be future supply for national demand and potential sources of HRST export to the regional or global markets.

This study explains the impact of education capacity and policy in producing national HRST stock. With understanding of current conditions and opportunities in the future, the government will be able to determine the appropriate policy regarding human resources, especially HRST.

II. Research Objective and Model Overview

This paper aims to explain the impact of education on national economic through national HRST. National HRST production developed by relationship between the HRST education capacity, the HRST education graduates, the potential supply of HRST, and the education policy. HRST stock by further influencing economy and technology which may generates feedback to HRST supply. The result is an input as consideration in determining government policy of human resources management, specifically HRST.

Many papers have been published on the use of system dynamics method in various education issues. A paper describe extending model of the Planning, Resourcing and Budgeting section [8]. A paper discusses academic definition of system dynamics on education [9]. Another paper emphasizes critical importance of the fields of system dynamics [10]. System dynamics also used in modeling US education system through a case study on the US state of Rhode Island [11]. The Brazilian higher education system also have been analyzed using system dynamics [12]. Also other hundreds paper of system dynamics used in field of education. It shows that system dynamics is a powerful method to use in various education issues.

We used the developed dynamics HRST model to describe the implication of education on economic [13]. The model structure shows the employed based classification is the demand side and the education classification as the supply side, with the relationship between the two sides which aims at achieving HRST stock.

Job vacancy created by HRST demand will determine number of expected HRST. The Expected HRST is fulfilled from stock and a number of not fulfilled HRST become desired increase of HRST. The number of Desired Increase HRST needs adjustment, it comes from HRST supply. Whereas, HRST supply created by the capacity of education and influenced by student interest in a particular field of science. In this study, we assume that the interest is driven by the wage to be received by the graduates at a job that matches their majoring field. Within the understanding, we describe the business process of HRST stock by a big picture.

The diagram below describes the big picture of national HRST model. We define 8 subsystems, as in Fig. 4, i.e. subsystem of HRST, subsystem of HRST demand, subsystem of expected HRST, subsystem of HRST supply, subsystem of HRST education capacity, subsystem of technology, subsystem of economy, and subsystem of wage.

Subsystem of HRST supply defines HRST on education. HRST stock on subsystem of HRST creates feedback to subsystem of expected HRST. HRST Stock also determine HRST fulfillment. HRST fulfillment indicates hired HRST performance impact on achieving GDP target which is indicator of economic development. Economic growth then determines technology level and generates further feedback on HRST supply and demand.

III. Description of the Model

The national HRST model developed by using system dynamics method. System dynamics is a methodology and mathematical modeling technique. System Dynamic is chosen for several reasons. First, it can handle dynamic complexity when the real world is not so simple, System Dynamics emphasizes multiple loop, multiple state, nonlinear character of the feedback system in which we live [14]. The system dynamics create a model of the phenomenon. The phenomenon is analyzed to form a structure of the system. The study constructs structure or element and the linkages between elements in HRST. This structure can then be tracked and identified the enforced functions or patterns behavior.

To understand the details of supply side of the model, we breakdown the subsystem of HRST supply and subsystem of HRST education capacity then analyze relationship between the subsystems.

A. Supply Side

Subsystem of HRST supply explains relationship between HRST education enrollments, HRST on education, HRST graduates, HRST potential supply, and hired HRST. HRST education enrollment shows numbers of student candidate interested in HRST education. The accepted candidates then became stock of HRST on education (HRSTE) and need to accomplish the education at certain period to be graduated. After graduation, they became a job seeker which is HRST potential supply to HRST stock. Subsystem of HRST supply described in Fig. 5.

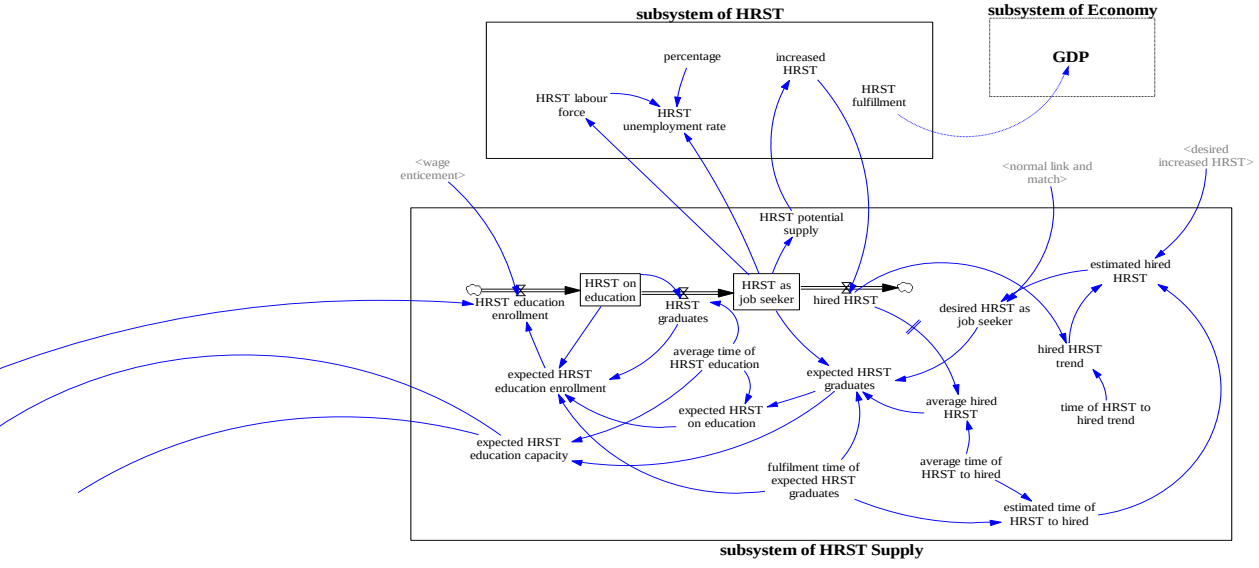

Fig. 5. Subsystem of HRST supply.

Using numbers of HRST as job seeker, we can also count HRST labor force and unemployment rate. HRST as job seeker connects subsystem of HRST supply and subsystem of HRST. On this subsystem, we also observe expected HRST education enrollment, fulfillment time of expected HRST graduates, and time of HRST to hire. This subsystem receives feedback from subsystem of HRST education capacity and subsystem of HRST. This subsystem also influenced by "wage enticement" and "link and match", and we remain this as external variable for this case. The term 'wage enticement' is used to describe attractiveness of salary of a position, offered by company to graduates, as a driver to prospective student to choose study field in tertiary education that fits the position's requirement. The term 'Link and match' used to describe suitability between the qualification of the graduates with the qualification required in certain position in the company.

Subsystem of HRST supply does not connected directly to subsystem of economy but connected via subsystem of HRST, specifically HRST fulfillment.

B. Education Capacity Impact on HRST Supply

Education capacity shows the number of student admission in tertiary education. Subsystem of HRST education capacity explains HRST availability by determines capacity on HRST education, as described in Fig. 6. This subsystem consist of HRST education capacity as a stock counted by number of person, increased and decreased HRST education capacity, time to increase HRST education capacity, and establishment of HRST education as age of educational institution from the first opened until closed or inactive.

This subsystem is influenced by two scenarios. The first is scenario on policy of HRST education, to simulate the impact when education capacity is increased or not increased. The second is changing technology elasticity, to simulate the impact when technology advancement occurs on decreased education capacity.

IV. Model Analysis

A. Analysis of Base Behavior

The developed HRST model validation is done by comparing generated trend to historical data. In result, we found GDP trend and GDP history have similar trend as describe in Fig. 7 and Fig.8. We also validate HRST trend to HRST history, and found the similarity. We can conclude that this model is valid to be used in scenario simulation.

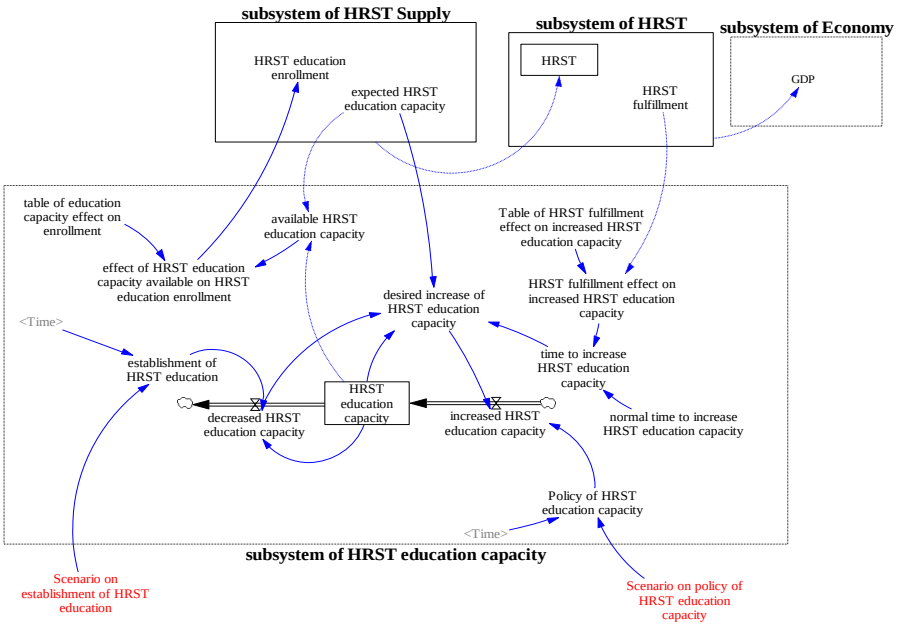

Fig. 6. Subsystem of HRST education capacity.

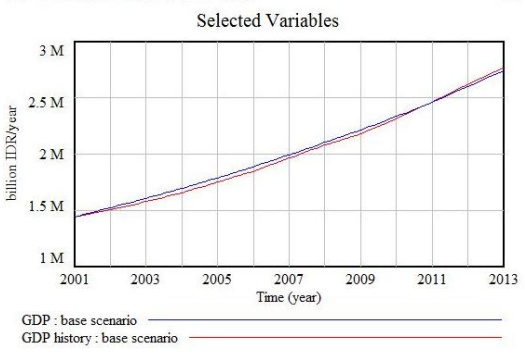

Fig. 7. Model validation result on GDP variable.

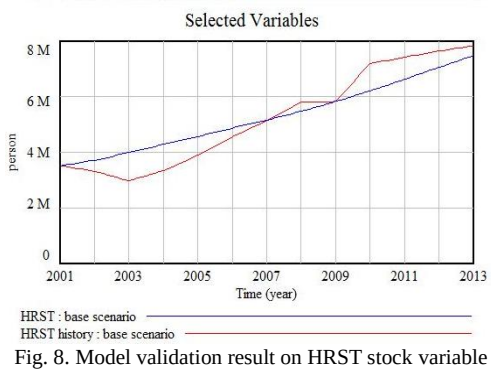

Fig. 8. Model validation result on HRST stock variable

B. Base Scenario

To perform a simulation with various scenarios, it is necessary to determine the basic scenario that will be used as a comparison. We define base scenario, it is created with GDP growth 5.4%, technology elasticity 0.3, inflation 5%, fulfilled wage policy, Link and match for 1 year (normal), HRST education capacity is increased as needed, and establishment of HRST education institution for 25 years (normal).

In the base scenario condition we have positive trends on HRST, GDP, HRST education capacity, and HRST on education. We also compare following trends, i.e. GDP, HRST, technology advancement, and HRST education capacity, see Fig. 9. This comparison may determine relation between HRST education capacity and economic growth in by GDP

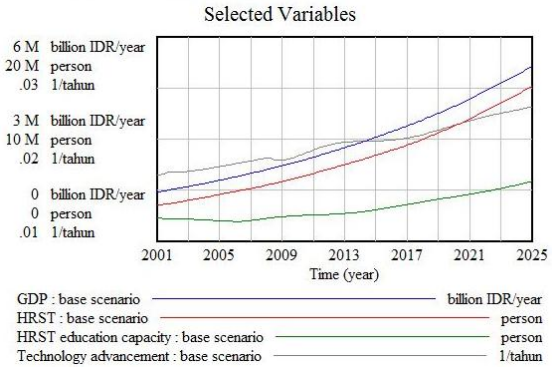

Fig. 9. Comparing main variables.

C. Scenario of Education Capacity Policy

1) Scenario 1: Decreased education capacity

The first scenario is decreased HRST education capacity. This scenario will create preview for HRST education policy causing decrease on HRST education capacity with normal GDP growth and technology elasticity remain 0.3 as we define on base scenario.

The term 'technology elasticity' shows ability to adapt technology in economic activity. Technology elasticity value used 0.3 in accordance with the reference Total Productivity Factor (TPF). In this case used for TPF that shows the influence of technology to drive the economy. Technology advancement improves the economic growth which then provides feedback on improving technology.

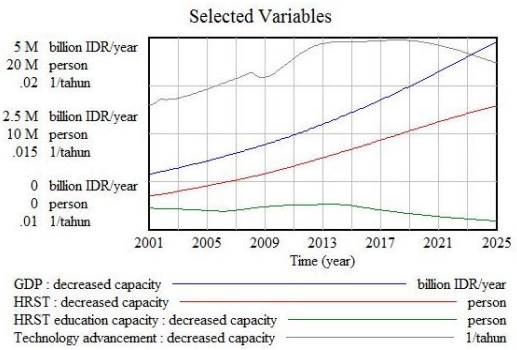

Fig. 10. First scenario result.

Fig. 10 describes the result of the first scenario. Decreased HRST education capacity may result in declined technology advancement. Although HRST and GDP trends are still positive, we should check the trends compared with the base scenario. On Fig. 11 and Fig.12, we found that decreased capacity scenario result is lower than the base scenario result.

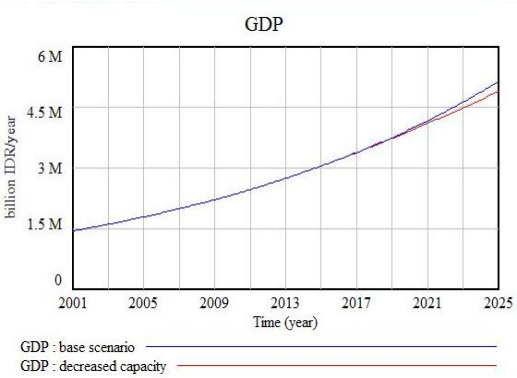

Fig. 11. Scenario result for GDP.

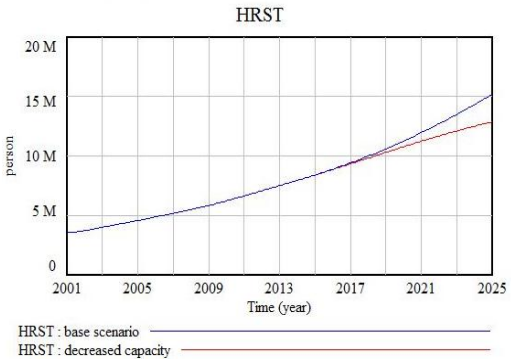

Fig. 12. Scenario result for HRST stock.

Education capacity is determined by the expected HRST education capacity. Education capacity reduction will cause a reduction in education enrollment which then leads to reduced HRST graduates as potential supply. Potential supply is determining the adequacy of HRST stock. This reduction in potential supply leads to reduced HRST stock. Reduced HRST stock means less people working and contributing to economic growth. With the initial assumption that the HRST drives economic growth (GDP), the simulation shows that the reduced HRST stock caused a decline in economic growth. Declining economic growth will reduce the ability to adopt the technology. Lower level of technology does not require high-skilled worker (HRST) because it means that the work can be performed by low-skilled workers, causing a decrease in demand HRST.

We can conclude, although this scenario doesn't significantly sink the trends, the decreased capacity scenario create effect on decreasing HRST stock and GDP.

2) Scenario 2 : Decreased capacity and technology advancement

The second scenario purpose is to define impact of higher technology advancement. The scenario applied decreased capacity and normal GDP growth as the previous scenario. To make differences, we set technology elasticity higher to allow increasing technology advancement as we can see at Fig. 13.

From simulation, compared to the first scenario, there are higher HRST stock but lower GDP (Fig. 14 and Fig. 15). Raise of technology advancement does not significantly influence GDP and HRST stock at certain period of observation.

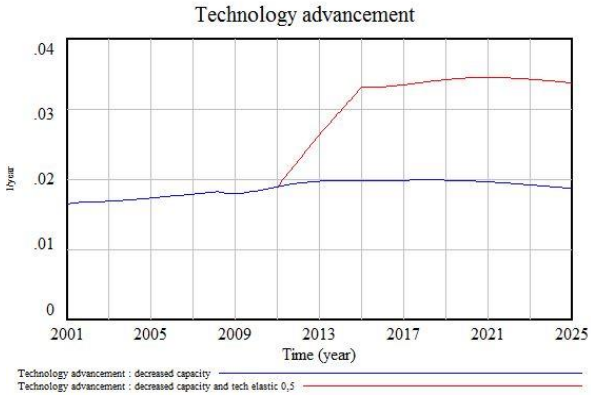

Fig. 13. Technology advancement.

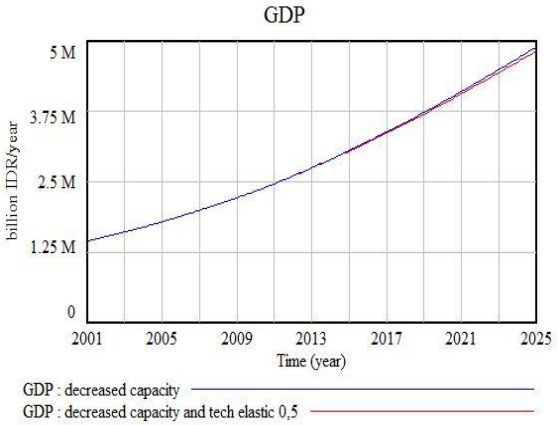

Fig. 14. GDP compared to the first scenario.

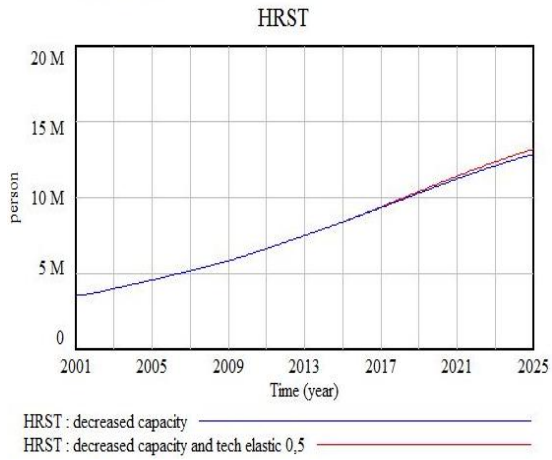

Fig. 15. HRST compared to the first scenario.

V. Conclusion

In this study, we first build a system dynamics model for national Human Resource in Science and Technology (HRST). This model shows supply-demand side of HRST. Supply side of HRST is HRST from tertiary education graduates. Demand side of HRST is HRST in occupation. The model consist of 8 subsystem, i.e. subsystem of HRST, subsystem of HRST demand, subsystem of expected HRST, subsystem of HRST supply, subsystem of HRST education capacity, subsystem of technology, subsystem of economy, and subsystem of wage.

This paper focus on supply side of HRST. The National HRST model can explain the production of national HRST by looking at the relationship between the HRST education capacity, HRST education graduates, potential supply of HRST, and education policy.

Hereinafter we propose scenarios to explain relation between education policy and national HRST performance. The National HRST performance assessed by economic development. The first scenario is decreased capacity of HRST education. Based on simulation, decreased HRST education capacity may impact on lower GDP. We also regard the presence of technology. So, we propose the second scenario to observe impact of technology advancement on decreased capacity as in first scenario. Based on simulation, higher technology advancement does not give significant influence to raise GDP and HRST.

From our study, we conclude that availability of HRST education capacity is important to provide HRST graduates which is create potential supply for HRST stock. Furthermore, HRST fulfillment supported by technology will create productivity and determine performance of HRST to raise GDP and economic development.

References

[1] I. Ozturk, "The role of education in economic development: a theoretical perspective," *Journal of Rural Development and Administration, Volume XXXIII*, No. 1, Winter 2001, pp. 39-47.

[2] *Higher Education in Developing Countries Peril and Promise*. World Bank. [Online]. Available: http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/547664-1099079956815/peril_promise_en.pdf

[3] P. Pillay, *Higher Education and Economic Development: Literature review*. Centre for Higher Education Transformation (CHET), Wynberg, 2011

[4] Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual. [Online]. Available: http://www.oecd-ilibrary.org/science-and-technology/measurement-of-scientific-and-technological-activities_9789264065581-en

[5] L. Auriol and J. Sexton, *Human Resources In Science And Technology Measurement Issues And International Mobility*, 2001.

[6] E. A. Hanushek and L. Wößmann, *The Role of School Improvement in Economic Development*, World Bank Policy Research Working Paper, 2007.

[7] *World Bank and Education in Indonesia*. (2014). [Online]. Available: http://www.worldbank.org/en/country/indonesia/brief/world-bank-and-education-in-indonesia

[8] M. Kennedy. (2011). A review of system dynamics models of educational policy. [Online]. Available: http://www.systemdynamics.org/conferences/2011/proceed/papers/P1117.pdf

[9] Y. Barlas. (1994). Defining system dynamics education. [Online]. Available: http://www.systemdynamics.org/conferences/1994/proceed/papers_vol_1/barla001.pdf

[10] O. V. Pavlov, J. K. Doyle, K. Saeed, J. M. Lyneis, and M. J. Radzicki. (2014). The Design of Educational Programs in System Dynamics at Worcester Polytechnic Institute (WPI). [Online]. Available: http://cpe.wpi.edu/images/CPE-New/Systems_WPI_SD_programs.pdf?_ga=1.131705679.1143689682.1459903881

[11] J. S. Groff. (2013). Dynamic Systems Modeling in Educational System Design & Policy. *NAER New Approaches in Educational Research.* [Online]. Available: http://www.jengroff.net/pubs_files/DynamicSystemsModelingInEducationalSystemDesign%26Policy_GROFF-2013.pdf

[12] L. M. Strauss. (2010). Analyzing the Brazilian Higher Education System using System Dynamics. [Online]. Available: https://secure.orsnz.org.nz/conf45/program/Papers/ORSNZ2010_Borenstein.pdf

[13] I. J. Asmara, E. Achelia, M. Akbar, R. Rahmaida, and M. Arifin, "Indonesia's national HRST scenario 2025," Research Report, Center of Science and Technology Development Studies, Indonesian Institute of Sciences, 2015.

[14] J. W. Forrester, *Industrial Dynamic*, 1st ed. Massachusetts Institute of Technology Press, 1961.

Elmi Achelia was born on Jakarta in 1984. Bachelor in Computer Science from Institut Pertanian Bogor (IPB) in 2005 and Magister in Information Technology from University of Indonesia in 2012.

Elmi is a researcher in research center for Development of Science and Technology, Indonesia Institute of Science (LIPI). Joined with LIPI since 2006. Currently focus in science and technology policy research, specifically in forecasting science and technology resources using System Dynamics method. Also interested in research at field of computer science and information technology, as well as previous research field in data mining and big data visualization.

Indri J Asmara was born in Medan Indonesia, January 4th 1981. of regular papers. Bachelor in Computer Science from University of Indonesia in 2004 and Magister in Information Technology from University of Indonesia in 2012.

Indri is a researcher in Research Center for Development of Science and Technology at Indonesian Institute of Sciences (LIPI). The field of study is S&T management and S&T Policy. The past two years has research about Human Resource that devoted on S&T in Indonesia.

Maulana Akbar was born in Bandung, March 17th, 1989. He has been working as junior researcher at Indonesian Institute of Science since 2015. His focus research at Science and Technology Policy, especially in Human Resource in Science and Technology (HRST).

Muhammad Tasrif was born on Pangkal Pinang in 1952. Bachelor in Electrical Engineering from Institut Teknologi Bandung (ITB) in 1976; Magister of Engineering from Asian Institute of Technology, Bangkok-Thailand in 1985; and Doctor from Institut Teknologi Bandung (ITB) in 2001.

He is a lecturer in ITB since 1977. Currently officiate as associate professor in School of Architecture, Planning, and Policy Development, ITB. He also involved in saveral government projects as an expert on System Dynamics.