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Connecting all the dots: Identifying the "actor level" challenges in establishing effective innovation system in Indonesia

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ABSTRACT

Establishing an effective innovation system is a gigantic effort for Indonesia and surely will face many and diverse challenges. The challenges can be found at all three levels (core, ecosystem, and anatomy) within the innovation system. At the core level, communication and interaction between domestic technology developers and users have to be intensified. At the ecosystem level, it is more complicated for creating a favorable atmosphere for nurturing an effective and productive innovation system which will significantly contribute to economic growth and social welfare improvement. Hard challenges at the ecosystem level are to harmonize all regulations and public policies such that they are more in favor of innovation system development; and to synchronize prioritized programs and activities of all related public and private institutions. Deeper insight into each actor of innovation system and the challenges faced is required for advancing innovation. This analysis uses case methodology to identify these challenges. Scientific collaboration among technology developers is low; therefore, it could cause inefficient use of national R&D budget. In-house R&D activities and technology absorptive capacity of domestic industries are also low. Finally, the role of an intermediation agency is not yet significant.

1. Introduction

One of eight Indonesian development missions as clearly stated in Law Number 17-2007 on Long Term National Development Plan (RPJP) 2005–2025 is improving human resource quality and Science and Technology (S&T) capacity and its application for increasing national competitiveness. This RPJP is divided into four Medium Term National Development Plans (RPJMs). While the first RPJM (2005–2009) did not specify the role of S&T inn reforming Indonesian development aimed at creating a safe, peaceful, just, democratic, and prosperous Indonesia; however, starting from the second RPJM (2010–2014), the needs for increasing the quality of human resources, including efforts to build capacity in S&T and strengthen economic competitiveness are clearly declared. At the third RPJM (2015–2019), Indonesian economic competitiveness will rely on sustainable natural resources management, competent human resources, and improved S&T capacity.

The role of S&T in economic development has also been recognized in Presidential Decree Number 32-2011 on Master Plan for Enhancement and Expansion of Indonesian Economic Development 2010–2025 (known as MP3EI). There are three main pillars for supporting future economic development in Indonesia. Firstly, the establishment of six economic development corridors based mainly on natural resource potentials and geographical characteristics. Secondly, the development of the required infrastructure for strengthening – corridor connectivity across and within

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corridors, especially transportation networks for facilitating workforce mobility, raw materials, and processed products. Thirdly, the improvement of human resource competency and the development of relevant technologies for enhancing economic growth.

In comparison, China formally recognized the important role of S&T in economic development as early as 1978, when Deng Xiaoping declared the guidelines for development of China. His inspiring tagline was 'S&T are the primary productive force' (for economic and social development). In 1995, China launched its national development strategy, focusing on 'Invigorating China through S&T and education' [1,2].

Despite recognizing the important role of S&T for the future development, an actionable, measurable, and well-defined plan for S&T development has yet to be formulated in Indonesia. Based on his long working experiences in many Asian countries, Sharif [3] recommended that it is crucial to define technology in a way that enables managers to pull levers for actions that will produce desirable outcomes in order to integrate technological innovation considerations with development investment decisions.

An actionable and measureable S&T development plan is urgently needed. It is a prerequisite for establishing an effective and productive innovation system. In this regard, Hyung-Sup Choi's view as quoted by Sharif [3] is wise to consider: "Adaptive implementation of a progressively improved simple plan is far better than obsession with grandeur but non-implementable grand plan".

Indonesia should have an applicable and measurable 'simple' plan for establishing an effective innovation system. To be applicable, the plan has to be based on actual current conditions (potentials and limitations). To be measurable, the plan should be clearly defined; current conditions must be comprehensively understood; and the main objective and targets for achieving desirable goals should also be firmly set.

2. The national innovation system and economic development

It has been firmly believed for many decades that only innovative countries will achieve high performance in economic development, except for few small countries with extremely rich oil and gas resources. From the 1960s onwards, differences in economic performance were mainly caused by differences in technological capacity; and two decades later, during the 1980s a lot of studies were published on cross-country differences in the levels of development and growth performance associated with technology. It was commonly concluded in these studies that unsuccessful countries in developing appropriate technological capabilities should be expected to continue to lag behind. Concepts of a "national innovation system" were suggested during the 1990's and, since then, a burgeoning empirical literature has emerged, focusing on these aspects of development [4].

In the first decade of the twenty first century, more studies on innovation systems were conducted. Some large-scale, well-organized, and more comprehensive surveys were initiated by international organizations. For example, INSEAD commenced to publish its annual reports on the global innovation index in 2007; and in 2012, WIPO joined INSEAD in publishing the report. Empirical evidence gathered from this global-scale survey confirmed the strong positive correlation between innovation capacity and economic development [5].

INSEAD and WIPO [5] clustered 141 surveyed countries into three groups, i.e., underperformers, learners, and leaders. The clustering was based on correlation between GDP per capita and Global Innovation Index (GII) score. Underperformers were countries with low GII score and typically also low GDP per capita, for instance Sudan, Angola, Syrian Arab Republic, and Algeria; but some countries included in this category may also have high GDP per capita due to high oil and gas resources, such as Qatar, United Arab Emirate, Brunei Darussalam, and Bahrain. Learners are countries with a higher GII score, but have relatively low GDP per capita. Two new economic super power countries (China and India) are among the learners. Leaders are countries with a high GII score and high GDP per capita, including Scandinavian countries (Swedish, Finland, Denmark, and Norway), Western European countries (Switzerland, Netherland, United Kingdom, French, and Germany), Northern America countries (United States and Canada), East Asian countries (South Korea and Japan), Australia, and Singapore. Some other countries, such as Indonesia, Russia, and Brazil are among countries in transition, positioned better than the underperformers but not yet as good as the learners.

Sound theoretical foundation and solid empirical evidence on the significant role of technological innovation for enhancing economic development compelled many countries to establish or strengthen their national innovation system (NIS). However, efforts in improving human resource competency and R&D capacity were unconnectedly executed. This leads to mismatch between competencies of human resource and required technologies to be developed for supporting economic development caused ineffectiveness and low efficiency in some national systems of innovation.

Based on their study on OECD countries, Guan and Chen [6] identified that overall efficiency of NIS was mainly determined by downstream commercial efficiency; therefore, improving commercial efficiency should be a primary consideration in formulating innovation policy. They also confirmed that public policy exhibited a positive impact on NIS performance and suggested that the policy should be country-specific and process-specific. They also confirmed the significance of technology adoption by industry or other users in establishing effective and productive NIS. Unfortunately, this segment of NIS is frequently overlooked during the early stage of NIS establishment.

NIS is much more complex than just having high quality human resources and high R&D capacity. Most successful countries implement a more comprehensive approach in developing their NIS; tailoring the system for its best fit into socio-cultural norms and values, and continuously adjusting to global economy and political dynamics. In short, it should be more broadly understood that a NIS is a much more complex system and cannot be simplified to just improving the quality of human resources and strengthening R&D capacity.

Fagerberg and Martin [4] identified four different elements of economic capabilities: the development of an innovation system, the quality of governance, the character of the political system, and the degree of economic openness. Among these four elements, they found that innovation systems and governance are of particular importance for economic development. However, since these four elements are strongly interrelated to each other; if an innovation system was developed based on and implemented according to good governance principles; and also be simultaneously adjusted to political dynamics and the degree of economic openness; then, this innovation system could act as main driver for economic development.

Moreover, Castellacci and Natera [7] indicated that the dynamics of a NIS was driven by the coevolution of three innovative capability variables (innovative input, scientific output and technological output) and three absorptive capacity factors (infrastructures, international trade and human capital). In addition, the NIS specific pattern was also characterized by its level of development.

Sun and Liu [8] suggested that observations of the structural transformation of China's NIS since 1999 was useful for understanding the rapid economic growth experienced in China; and for adjusting S&T development strategies of other late-comer or underperformer countries. The structural changes included shifting funding structure from a government to an enterprise-centered model; and a performing structure from a double-centered model (enterprise and research institution) to solely lead by enterprise. However, the central government remained as the leading force in reforming China's NIS. Based on Sun and Liu's explanation, it implies that strategy for technology development should be shifted from a supply-push approach to demand-driven approach. Enterprises and other technology users are the ones that create demand.

Gao et al. [9] found that outputs of S&T in China were growing faster than its economic growth. This finding indicates that, even though China has been classified as learner and its innovation system was categorized as efficient [5], there should still be rooms for optimizing the efficiency of its NIS. Marxt and Brunner [10] also underlined that even a very innovative country, such as Switzerland, still needed to keep its leading position by enlarging and strengthening its NIS in a sustainable way.

Since communication and direct interaction amongst innovation actors are very crucial in improving the performance of the NIS; the role of information and communication technology (ICT) in enhancing a NIS development has been assumed to be positive. Wiseman and Anderson [11] found that ICT-based education had the potential to build capacity in knowledge development, which was a key component in the establishment of NIS. However, the results of their study in the Gulf Cooperation Council (GCC) countries suggested that the ways ICT were used in education did not build capacity in knowledge development in youth. Although evidence showed that GCC countries do have institutional capacity in ICT, it was not (yet) used for knowledge development, in part because of limitations imposed by the cultural contexts for education in the Gulf. This finding implies that it is not just the technology (as hardware) which is advantageous for the development of a NIS, but also more importantly, how the technology is used in intensifying positive communication and productive interaction amongst innovation actors.

Social, cultural, and political factors should not be disregarded in developing NIS. Svarc [12] figured out that Croatia had failed to capitalize on its inherited science base, which could have been used as a starting point in the transition towards a knowledge-based economy (KBE), because it had not made the shift from an obsolete socialist-style science policy to a modern innovation policy (IP). The latter was seen as the new policy paradigm necessary for structural adjustment to the KBE. The country-specific historical heritage prevented recognition of need for structural adjustment to the new technology regime, and have led to belief that the IP was not only irrelevant but also was a relic of the state interventionism inherited from socialism, which was the most serious obstacle to policy reform. Moreover, he concluded that the transition of a Central and East European Countries (CEEC) from a conventional economy to a KBE required a serious redesign of the development policy. The effectiveness of this transition depended on social change, determined by the political recognition and social assimilation of the new technological regime.

A national innovation system is not an isolated or formulaic system. It is affected by technical factors within the system, such as use of ICT [11] and can also be affected by past national policy, such as in the case of Croatia [12], or it could be influenced by economic turbulence at the global level. Filippetti and Archibugi [13] observed that the effects of the economic downturn in terms of firms' innovation investment were not the same across European countries. The competences and quality of the human resources, the specialization in the high technology sector, together with the development of the financial system appeared to be the structural factors which were able to offset the effect of the economic downturn on innovation investments of firms across Europe.

Lessons learned from this brief review include that there are solid empirical evidence and a sound theoretical basis for a strong positive correlation between innovation capacity and economic development. However, it should also be noted that:

1) A national innovation system is a complex system which can perform well if all actors communicate and interact intensively in a mutualistic manner;

2) A national innovation system is country-specific and characterized not only by its developed technologies, but also by social, cultural, and political sphere in which the NIS is established;

3) A national innovation system is not an isolated system, many internal and external factors could influence its characteristics and effectiveness; therefore, these factors should also be comprehensively considered.

3. Methodology, data sources and theoretical development

This study uses a conceptual analysis methodology based on the qualitative and quantitative methodology advanced by Furner [14]. In 2011, the Ministry for Research and Technology (RISTEK), Republic of Indonesia conducted a survey on R&D and innovation activities at public R&D institutions. The total targeted sampling units were 366 R&D centers and 272 centers returned the questionnaires. After verification, data from 250 centers were analyzed, or 68.3 percent of total targeted centers. In 2012, a similar RISTEK's survey was conducted, but it was aimed at public and private universities. Of 75 targeted universities, returned questionnaires from 56 universities (74.7 percent) were analyzed. Results of these two surveys were used as empirical evidence for portraying the current capacity of technology developers and intensity of their communication and interaction with domestic industries and other technology users.

In addition, data was collected which spans the last eight years, combined with data and information obtained from focused group discussions, and survey data to identify the actor level challenges for establishing an effective innovation system in Indonesia. Conceptual analysis was carried out, systematically breaking down the innovation system into the constituent parts in order to gain a better understanding of a particular philosophical issue in which the concept is evolved. Furner [14] explained that the goal in using conceptual analysis as a method of inquiry into a given field of interest was to improve our understanding of the ways in which particular concepts are (or could be) used for communicating ideas about that field.

While the conceptual analysis is the methodology used for this study, the theory is that of a three layered innovation system. It has been well recognized that innovation policy must be complemented by wide range of other policies, including policies on education, mobility of human resources, trade, industry, tax and finance. Collectively, Metcalfe and Ramlogan [15] named these complementary policies as the innovation ecology. Faulkner [16] used the same term. Segura-Bonilla [17] also recognized the importance of explaining national innovation system as a dynamic and evolutionary system that continuously interacts with other sectors. However, he did not identify a specific term for “the other sectors”. Most recently, Archibugi et al. [18] observed that innovation activities at the firm level were affected by the 2008 economic crisis, implying that the innovation system was significantly affected by external factors. All of these studies, however, only focused on two layers, i.e. the innovation system and the innovation ecology [15,16], the other sectors [17], or external factor [18].

Not connecting or bridging these layers when discussing a national innovation system and the innovation ecology leaves a gap in our theoretical understanding. In this study, the innovation system is perceived as a larger and unified system that includes the innovation ecology as a part of this system. Therefore, in this study's theoretical framework, there are structurally three levels of interactive subsystems recognized within innovation systems: the core, the ecosystem, and the anatomy. The ***core*** of an innovation system is represented by direct interaction between technology user and developers, facilitated and regulated by government as the third actor in this subsystem. The ***ecosystem*** consists of all factors (outside the core) which are capable of influencing performance of the core, including human resource capacity, natural resource availability, market demands, and existing regulations and public policies. This layer is equivalent to the term “innovation ecology” used in Metcalfe and Ramlogan's and Faulkner's studies. However, in this analysis, it is treated as a subsystem of the innovation system. The anatomy, an additional subsystem, describes inward observation within a cluster of technology developers or users and characterizes the internal conditions of these primary actors of innovation. This theoretical framework was developed as a mechanism for bridging or connecting the factors identified across major theoretical constructs.

Based on this conceptual analysis we identified ten challenges in total: four challenges at the core level, and three challenges each at the ecosystem and the anatomical levels in the Indonesian context.

The results of this conceptual analysis have been introduced and ‘tested’ using focus groups in stakeholder meetings. The last forum for tapping experts' opinion was the Special Session on Indonesia, at the Asia-Pacific Economic Cooperation (APEC) Research and Technology Workshop in 2013.

4. Challenges at the core level

It is believed that any technology innovation system should have at least three major actors or institutions directly involved: the technology developer, the technology user, and the government as regulator. The technology developers include university, public R&D institution, and any other institutions or individuals that develop technology. Technology users include industry (producing goods or services), government (especially for providing better public services, also for national security and defense), and any other institutions or individuals who require technology for executing or improving quality and/or efficiency of their activities. Besides its regulatory role, government is also expected to proactively facilitate communication and interaction between technology developers and users. In this context, regulation should be formulated with main aim to establish favorable ecosystem for innovation system to blossom (Fig. 1). Tax incentives are common tool used by many governments for directing prioritized technologies to be developed, improving absorptive capacity of the users, and facilitating interaction between developers and users.

It should be noted that this core of innovation system is not isolated. It surely interrelates with its ecosystem. Auerswald and Branscomb [19] described that today the invention-to-growth relationship was more complex and less bounded than ever before. Therefore, emerging policy consensus should focus on three steps. Firstly, generating research ideas suitable for commercial exploitation; secondly, converting basic science inventions into market-ready innovations; and thirdly, providing new firms with financial and managerial resources required for rapid growth. These Auerswald and Branscomb's three steps are

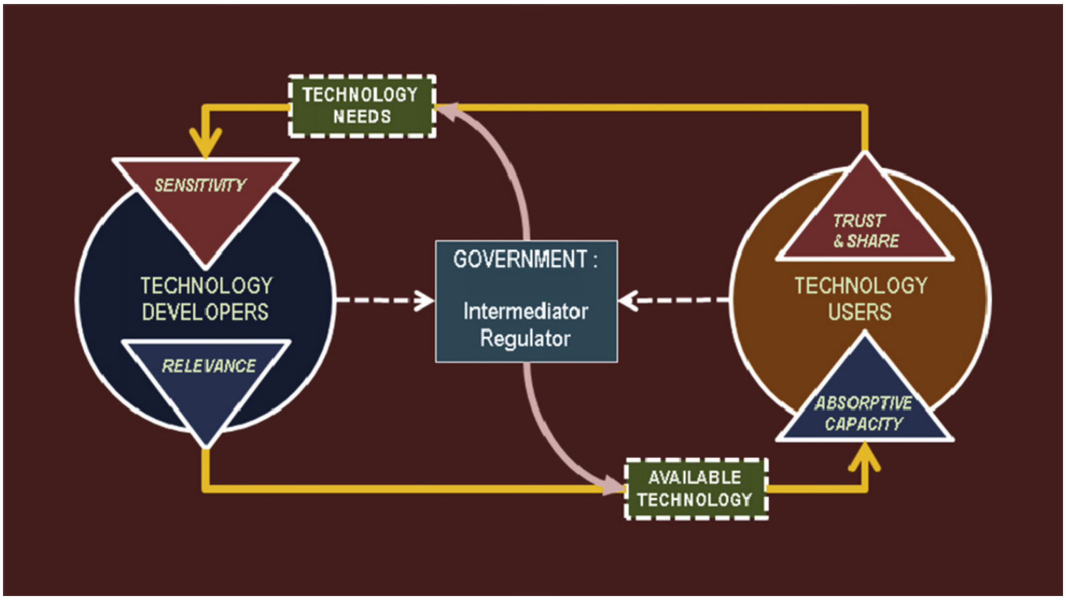

Fig. 1. Core of the innovation system.

entirely accommodated in the core of innovation system as shown in Fig. 1.

Indonesia has shown noteworthy efforts in strengthening the R&D capacity of universities and public R&D institutions. Indonesia has enacted many regulations and public policies aiming to facilitate or create a conducive environment for establishment a national system of innovation. However, these efforts seem to be inadequate. More systemic efforts must be initiated. For this reason, the main issues at all levels need to be comprehensively identified.

At the core level, there are at least four main issues which have been recognized. Firstly, there are few indigenous technologies which have been adopted by domestic industries or other domestic users. Secondly, technological demand of domestic industries is considerably low; thirdly, communication and interaction between technology users and developers has not been intensive; and lastly, the 'Ivory Tower Syndrome' still exists at universities and public R&D institutions.

4.1. Low adoption of indigenous technology

Despite intense efforts at institutional levels, the innovation system is only considered successful if developed technologies are adopted by users in manufacturing goods or providing services. To improve the probability for successful adoption, the developed technology should align with user's needs. Otherwise, it will have a slim chance to be adopted by users. Clearly, the demand-driven approach in developing technology has advantages over the supply-push approach. Unfortunately, the majority of technology development in Indonesia is still using the supply-push approach: ignore the needs, create technology, and then try to market the technology. In addition, technology developers, in most cases, do not have marketing skills and are unable to identify potential users of their technologies. Moreover, most of technology developers do not feel that marketing the technology is part of their responsibility.

Actually, even a technically-relevant technology cannot be guaranteed to be adopted by users, since there may be similar technologies already available which become competitors for the indigenous technology. Under these circumstances, users have options in acquiring technology they need. Therefore, in addition to technically relevant, the indigenous technology must also be economically competitive. At present, more Indonesian enterprises acquire foreign technology to be utilized in their business activities. Wonglimpiyarat [20] found that Malaysia and Thailand were also heavily reliant on foreign multinationals to drive their technology development and innovative activities.

One approach for encouraging indigenous technology development is to have government institutions set the example in adopting the indigenous technology. The '*Aku Cinta Produk Indonesia*' (I Love Indonesian Products) campaign could be enforced after indigenous technology is technically viable and even if it is slightly less competitive economically.

Research culture at universities and public R&D institutions has to be invigorated. Government budget allocation for R&D must be treated as a public investment return on investment coming in the form of beneficial technologies or the advancement of knowledge. Technology developed should create economic or academic value. Basic research at universities should provide strong scientific foundation for development of relevant indigenous technologies. Higher education institutions (both public and private) in Indonesia are expected to perform three missions mandated by the government. These are expected to educate students to become knowledgeable and skillful human resources. They are expected to conduct R&D for the advancement of science and technology. Finally, they are expected to contribute directly to national or local development. In the context of Indonesia's national innovation system, this triple mission (known as *Tridharma*) should include the dissemination of relevant indigenous technologies to potential users.

4.2. Low technological demand of domestic users

Business in Indonesia is dominated by trading. Manufacturing industries are mostly subsidiary companies, focusing on mass production and doing very limited in-house R&D activities. They implement technologies developed by their parent companies. Large capital-intensive multi-national companies rely on technologies created at their own in-house R&D department. Domestic industries are dominated by small and medium enterprises (SMEs). These SMEs generally have low absorptive capacity for advanced technologies; therefore, they opt to adopt less expensive available technologies. All of these circumstances lead to a limited option for marketing indigenous technologies created by domestic universities and public R&D institutions.

Most of domestic industries are associated with commodity handling and early-stage processing to produce intermediary products which require low to medium technologies, except for those in the ICT business. Frontier industries requiring cutting-edge technologies are very limited. The establishment of SMEs that require medium to high technology should be encouraged, in order to increase demand on indigenous technology. It should also be facilitated with suitable government incentives.

Recent government policy to cease activities on exporting raw material is a positive gesture. Facilitating and providing incentives for downstream industries are another appropriate policy. If these policies are consistently and persistently implemented for a long period of time, it will generate and increase the needs for indigenous technologies by domestic industries. National and local technology developers should not miss this opportunity.

There is a large gap in technology capacity between universities and public research institutions (as technology developers) and business enterprises (as technology users) in Indonesia. This gap was similarly observed in China. There is a large gap also in the process of technology transfer and adoption. Subsequently, R&D activities at universities and public research institutes in China do not contribute to technology advancement in Chinese firms with great significance [21]. China has subsequently opened the possibility for human resource transfers from university to industry.

Improving absorptive capacity for SMEs by temporarily mobilizing human resources from public university to industry has also been suggested by the Indonesian National Innovation Committee. Besides increasing absorptive capacity, this policy is expected to create opportunities for SMEs to establish their own in-house R&D units for developing affordable and appropriate technologies. Based on China's experience, however, Mu and Qu [21] affirmed that there were still major barriers to the mobility of human resources in S&T from universities or public research institutes to business enterprises. In Indonesia, current regulation does not permit academics or researchers (who are officially civil servants) to fully work in private businesses.

Even if a change is legally approved, the mobility of human resources from government institutions to business enterprises may not be smooth, due to the differences in working culture between the two institutions. In China, universities and public research institutions tend to devote more attention to publishing in international scientific journals rather than improving market potential for their research. At the same time, enterprises focus more on the potential profits of their activities [20] and do not give much attention to scientific publication. These conditions are similar to those of universities, R&D institutions, and business enterprises in Indonesia.

4.3. Limited of interaction between technology users and developers

In the context of technology innovation, the intensity of interaction between technology developers and users in Indonesia is relatively low. Many Memorandum of Understanding (MoU) between university and/or R&D institution as technology developer with industry or other technology users have been signed. However, in most cases, implementing activities following-up with the MoUs and successfully developing technologies is relatively scarce.

An innovation system will not work unless concerned actors or institutions intensify their communication and interaction, as a precondition for information exchange to occur. Moeliodihardjo et al. [22] argued that university and industry in Indonesia appeared to be still in the state of lacking understanding about each other. Universities and R&D institutions would have a better chance to create relevant technologies if they received precise and sufficient information on technological demands and preferences directly from potential users. Trust and willingness to share information should be fostered between users and developers.

A lack of intensive interaction between university, public R&D institution and industry is also observed in China. Despite China has become one of the largest countries in terms of number of enterprises, universities, and public research institutes, the linkages between these institutions are still relatively weak [20]. In the case of Korea, Eom and Lee [23] prompted that industry–university and industry–public R&D institute cooperation cannot guarantee the success of a firm in technological innovation. Rather, it may have an influence on the selection or direction of the research projects of the firm. In contrast, Lee and Park [24] found that collaborative R&D, especially between downstream firms and universities, would likely improve innovative activities' chance of success.

The national innovation system (NIS) of Korea remained unbalanced or immature with the strong dominance of government and a few big firms called Chaebols, and weaker roles of universities and SMEs. These unbalanced characteristics of the Korea's NIS caused its knowledge industrialization systems to remain underdeveloped compared with those in the advanced countries. It was only during the late 1990s that Korea realized the significance of knowledge industrialization and started to promote it through government initiatives [23].

Compared to the US, Lane [25] believed that success of the US as the world leader in S&T and R&D in the 60 years following World War II was due, in part, to a successful public–private partnership in research and higher education. Public institutions involved in this partnership were university and Public R&D institutions. While private partners were business enterprises.

If it is wisely managed, partnership or collaboration between technology developers and users will create reciprocal benefits such as an increase in R&D capacity of the developer and financial benefits for the user. In the case of Indonesia, it is suspected that both sides (developers and users) contribute to the low interaction. Technology developers are generally not sufficiently pro-active and technology users, on the other hand, do not rely on indigenous technology in doing their businesses. Reciprocal needs between technology developers and users have not yet emerged.

4.4. Ivory Tower Syndrome is still existed at universities and public R&D institutions

Academicians and researchers tend to work on R&D topics associated with their field of expertise and are not focused on actual issues. Only a few academicians or researchers are willing to dedicate their time for familiarizing themselves by direct encounters with real problems. The majority of them feel more comfortable staying within their academic sphere.

It is hard to drag them out of their comfort zone since – for one reason – performance and promotion of academics are evaluated based on their academic achievements within their field of expertise. This regulation needs to be amended. Higher appreciation should be awarded to academicians or researchers who directly contribute in solving local or national problems or for creating appropriate technology for development in any sector at all levels. Be it a very simple or very sophisticated advanced technology, as long as the technology were adopted and proven to increase productivity or the efficiency of user's activity.

The mindset of researchers is mostly stuck in an old paradigm that they should lead and direct the innovation processes. Consequently, the approach used in developing technology is dominantly supply-push. First, create technology and then create demand for the technology. This approach has been practiced for a very long period in Indonesian R&D history. The demand-driven approach has been seriously elevated during last few years. Shifting from supply-push to a demand-driven approach will require a change in mindset for the academician and researcher. Systematically engaging this process of change is a challenging task.

Change is a keyword. Mashelkar [26] explained that over the centuries, India's scientific and technological position among developed and developing countries has shifted. Several centuries ago, India was characterized by scientific thought, capabilities, and techniques more advanced than many countries. However, when the scientific and industrial revolutions took place in the West, India was in a stagnant period. However, during last ten years, Rao [27] noted that significant changes have been made in the Indian government's S&T structure and new institutions for S&T and higher education have been created. India's total investment in R&D is expected to rise to 2 percent in next few years. Indonesia will stay in a stagnant period if it is not making some fundamental changes, including changes in the mindset of technology developers.

Academics and researchers need to be more pro-active in reaching out for partnerships with industry and other business enterprises. Indonesia should learn from developed countries. In the US, the collaborative culture between government, academia, and industry has been fostered and R&D has been closely linked to the marketplace [28].

There are two other options worth pursuing. Firstly, encouraging and facilitating academics to create start-up companies so that they will have first-hand experience in managing business and increase their understanding of consumer's needs. Hopefully, some of the start-up companies will progress further into profitable business enterprises. However, success or fail, at least they already have better understanding on demanded technologies by business enterprises. Secondly, assisting universities to develop entrepreneurship programs for students and non-students to learn and directly involve them in business activities. Direct exposure to business culture would accelerate the process of changing the academic mindset and culture.

5. Challenges at the ecosystem level

The performance of technology developers and involvement of technology users in an innovation system is influenced by many factors, such as availability and quality of human resources, related policy and regulation, comprehensiveness of knowledge on available natural resources, and market demand (Fig. 2). It should not be overlooked that all activities at the core level and their interactions with related elements at the ecosystem level are taking place within the Indonesian cultural-social-political sphere. The national innovation system of Indonesia should be understood based on this comprehensive perspective. Yet, it is not an isolated system. It is open to foreign technologies, be it directly acquired or through spillover of foreign direct investment (FDI).

The availability and quality of human resource are crucial elements in shaping and propelling the innovation system. The role of the university in providing knowledgeable and skillful human resources with relevant expertise is very significant. Sohn and Kenney [29] studied the Korean experience and suggested that the most important contribution of universities to economic development was not through the transfer of research results, but rather it was indirectly through the preparation of high-quality graduates.

Even in a borderless world, the primary playing field of an innovation system is domestic resources. Indira Gandhi (as Indian Prime Minister at the time) announced India's first technology policy statement, whose very first

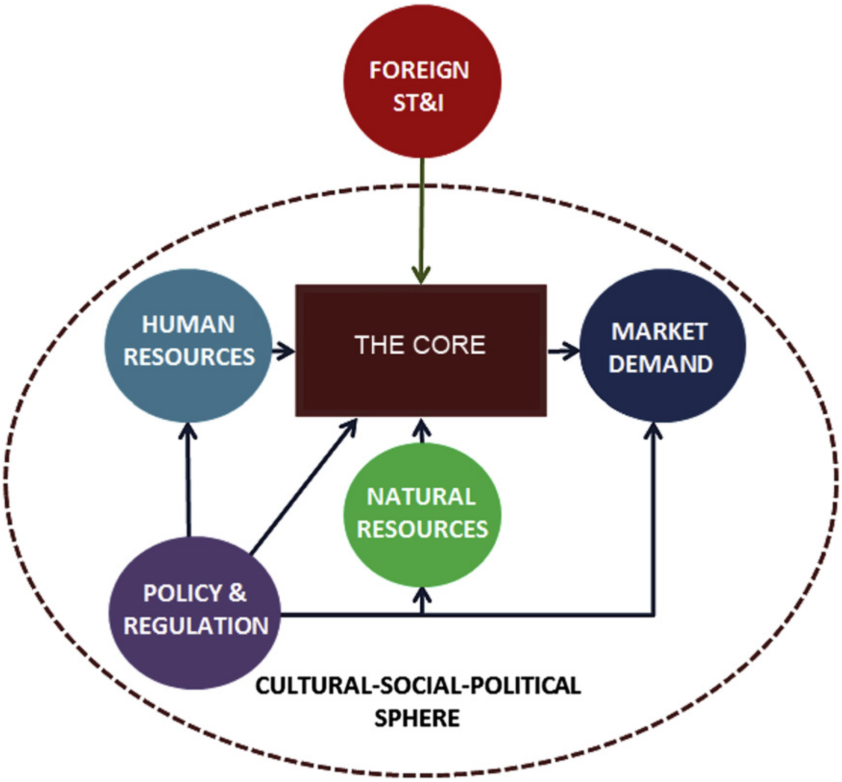

Fig. 2. Ecosystem of innovation: External factors influencing performance of the core.

objective was to attain technological competence and self-reliance for reducing vulnerability, particularly in strategic and critical areas; and making the maximum use of indigenous resources [30]. Natural resource rich nations will not be prosperous unless they are able to couple these rich resources with ability to develop relevant technologies for managing the resources. Otherwise, they will be trapped within the 'resource curse' (The Paradox of Plenty) [31].

Policy and regulation are the most dynamic factors influencing innovation system. They are the main gate for political interest to intervene in an innovation system either positively or negatively. Ratchford and Blanpied [32] argued that in many ways competence in science and engineering was the 'controllable' driving factor. A policy framework, stable governance, and military power were boundary conditions. They were necessary but not sufficient for sustained economic growth. But these boundary conditions could help assure a flourishing economy driven by S&T, if structured correctly. These realities can be seen in the case of Indonesia.

5.1. *Uncoordinated human resource and technology development*

Recommended topics of government-funded research, as clearly mentioned in the National Research Agenda (NRA), does not fully match with the expertise of domestic researchers. Research priorities in the NRA were selected based on domestic natural resources and aimed for fulfilling basic needs of the people, enhancing economic growth, and national security. The priorities include research on food and agriculture, new and renewable energy, transportation, information and communication, health and medicines, new and advanced materials, and security and defense.

At the macro level, there are available human resources for each prioritized research field. However, it might be insufficient in term of quantity, quality, and relevance of their expertise to cope with current challenges. In addition to S&T human resource, there are other constraints for S&T activity in Indonesia, such as lack of laboratory facilities and low R&D budget allocation.

In the case of Indonesia, research topics are predominantly determined by the expertise and preference of researchers. Unfortunately, a large portion of the selected topics are not directly oriented toward solving real problems or satisfying user's needs. Therefore, the results of these researches do not lead to the accumulation of knowledge required for developing relevant technologies.

Higher education and technology development in Indonesia are managed by two different ministries. There are some efforts to intensify coordination between these two ministries, including efforts on synchronizing research priorities. The NRA has been used as reference in setting up research priorities at universities, with some additional fields to accommodate wider spectrum of academic fields.

On idea of merging the Directorate General for Higher Education at Ministry of Education and Culture with current Ministry for Research and Technology into a new single ministry has been brought up in many occasions. Yet, there is no action to follow it up so far. In the meantime, efforts to formulate implementable regulation and policy to align higher education and technology development programs should be pursued.

Even though many Indonesian universities have declared their desire to become reputable research universities; the main activity in almost all Indonesian universities is teaching. Consequently, the contribution of the universities to economic growth is more on delivering educated human resources than relevant technologies for establishing effective and productive innovation system (Fig. 3).

Higher education institutions should also produce a skillful workforce for industry. Consequently, more polytechnics or vocational schools need to be established. A highly skilled workforce will directly strengthen industrial production capacity. Hopefully, it is also positively affecting technological absorptive capacity of the industry. There should also be training programs at the university for incorporating business perspectives to engineer and scientist mindsets.

5.2. *The priority of technology development is not linked with natural resource potential*

Even though Indonesia is an archipelagic country, maritime technologies have not been prioritized, resulting in weak national capacity for managing marine resources as sources of nutritious food, pharmaceutical active substances, renewable energy, and mass transportation mode. Technologies for managing marine biodiversity for ecological purposes are also not well developed. Furthermore, despite being a tropical country situated on 'the ring of fire', the development of technologies for harvesting solar and geothermal energies has not been satisfactorily progressed. These examples are indications of a mismatch between human resource competencies, R&D capacities, and needs for domestic natural resources management.

Efforts in directing R&D activities to focus on indigenous resources have been attempted, for instance by formulating the NRA. However, the NRA's recommendation may only work if there are sufficient academicians and researchers with relevant expertise for developing the needed technologies. Subsequently, there should be more universities offering fields of study on, or related to, management of marine resources and for harvesting available renewable energy sources; so that needs for qualified human resources with relevant expertise could be fulfilled.

Indonesia should strengthen R&D capacity and encourage business activities in managing marine resources and renewable energy sources in the tropics. However, it should always be kept in mind that any effort dealing with national resource must comply with the constitution. The Indonesian constitution clearly states that the objective of natural resources utilization is for improving the prosperity of the people. This mandate has to be adequately and consistently implemented. It should be noted that prosperity is not only an economic issue, but should also include ecological considerations, so that economic growth could be sustained.

It is clear that natural resource management has two sides, i.e., economy and ecology. Obviously, business enterprises are more interested on economic benefits, but government has to play its role for balancing economic and ecological benefits.

5.3. *Ineffective regulations and policies for supporting innovation*

The survey conducted by the Ministry for Research and Technology (RISTEK) in 2011, indicated that most of R&D

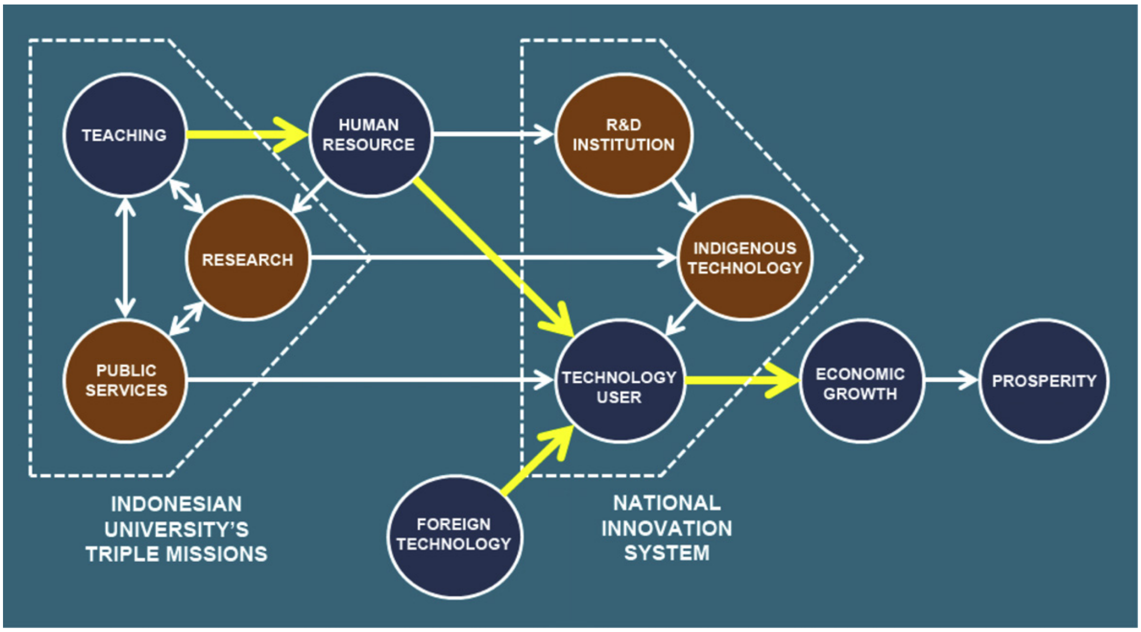

Fig. 3. Current path of university contribution to economic growth.

spending at public R&D institutions was for applied research (63.7 percent). Spending on experimental development was only 18.6 percent and basic research was 17.7 percent. Based on the RISTEK survey in 2012, composition of funding sources for R&D activities in 56 public and private universities in Indonesia were 52.8 percent from government, 33.0 percent from international institutions, and 14.2 percent from domestic industries.

Based on a low R&D budget disbursed by public R&D institutions on experimental development and a low share of industry to the total university R&D expenditure (from the two RISTEK's surveys), it is fair to assume that only a few results from R&D activities at public R&D institutions and universities will be potentially attractive for industries. Moreover, the low budget share from industries for R&D activities at universities may indicate that university is not a main technology source for domestic industries.

In the US, industry devoted about 70% of the total national investment in S&T in 2006. This high share of industry might have been stimulated by the R&D tax credit (now called the research and experimentation tax credit); however, the main driving force for the growth in industry-funded R&D has been the recognition that innovation is the key to competition in future markets. Most of these R&D activities were conducted at industry itself, not in partnership with university, since industrial support on university research was still relatively small, i.e. around 5% of total academic research expenditures in 2003 [25].

The higher percentage of industry-funded R&D at university in Indonesia is due to the low public R&D budget (only 0.08 percent of GDP in 2010, see [33]). Due to the low public R&D budget, industry support for R&D activities at university and public R&D institutions is very important. Therefore, efforts to increase involvement of business enterprises have been intensified. The Indonesian government had enacted two regulations, i.e. Government Regulation Number 35-2007 and 93-2010.

Regulation 35-2007 is designated for granting tax incentives and/or technical assistances to business enterprises in return for their support to R&D activities at university or public R&D institution. Up to now, the tax incentives have not been implementable since the formal technical guidance has not been endorsed by the Ministry of Finance. The technical assistance offered seems to be not appealing, since in-house R&D activity at domestic enterprises is considerably limited.

As an alternative, Regulation 93-2010 encourages business enterprises or individuals to contribute to supporting social and educational programs, including R&D activity. The amount of contribution is limited to up to five percent of net income of last fiscal year. In return, the contributors will be taxed based on their net income after being deducted for the contribution. In other words, the taxable income is deducted, not the tax. This incentive scheme seems to be unattractive for business enterprises.

Inappropriate regulation may be ineffective in boosting innovation and also could restrain innovation process. Technically relevant and financially affordable technology could not always make a significant contribution to economic development, if it is restricted by improper regulation or public policy. For example, locally-developed processing technology for modified cassava flour (known as 'mocaf') has been widely adopted by small-scale rural industries in East Java, Indonesia. This flour could be used for producing cassava-wheat composite flour, acceptable for modern food industries. However, a 20-percent tax for processed products is applied to cassava flour and unreasonable free import tax was granted for wheat flour in 2008. Consequently, locally-produced cassava flour loses its competitive edge.

Putranto et al. [34] also recognized that the integration of business and technology strategies was an attractive approach for industries in developing countries, such as Indonesia. However, to be successful, these strategies could not be implemented according to company's objectives alone, and ignoring involvement of other players. The inclusion of related technologies (developed by partners) should be positioned as part of the strategy if the strategy was expected to perform well and remain sustainable.

Wong [35] highlighted the importance of industrial policy and value-enhancing rents for indigenous technology development and suggested that developing economies should pursue an industrial development strategy that promoted indigenous technologies in order to obtain linkages and technology spillover that were similar to those in many of the newly industrialized economies in Asia. For instance, Singapore recorded significant progress in indigenous technology development. This was largely attributed to an industrial support mechanism that promoted learning in the indigenous production system.

6. Challenges at the anatomical level

An additional constraint in establishing an effective innovation system in Indonesia is not only the lack of interaction and unsynchronized priorities between technology developers and users at the core level, it is also occurring among institutions within R&D clusters. Limited interaction and collaboration among R&D institutions, including among universities, may repetitive R&D activities which in turn will trigger an inefficient use (of already low) R&D budget.

Domestic industries are characterized with low absorptive capacity for newly introduced or state-of-the-art technologies, except for few technology-based industries. Constraints in inspiring Indonesian industries to become actively involved in establishing effective and productive innovation system include: firstly, their low trust of indigenous technology, therefore, they prefer to acquire foreign technology; and secondly, they are mostly focusing on current market demands, therefore, they cannot afford to wait for technology development processes and are not willing to take risks for research failure.

The role of government-affiliated intermediation agencies have not been significant and are overly focused on the 'marketing' of indigenous technologies. There is no significant effort on mining information on technology demand, preference, and absorptive capacity of domestic industries or other potential users.

6.1. Low R&D collaboration among domestic technology developers

Based on co-authorship in scientific publications, collaboration among domestic R&D institutions and among Indonesian universities is noticeably low. On the other hand, Indonesian universities and public R&D institutions showed a strong preference for collaboration with foreign institutions [36]. A hesitancy to collaborate among domestic institutions is associated with limited resources to be shared, unclear shared goals, and also possibly due to institutional pride.

Preference for collaboration with foreign partners is mainly generated by the roles of foreign partners in providing funding, facilities, and knowledge. Numprasertchaia and Igel [37] argued that universities in developing countries that had limited in-house resources and wished to strengthen their research capability should implement strategies that aimed at extending their potential through collaboration with a variety of external partners, especially with universities and R&D institutions in developed countries. Kang and Park [38] also found that international linkages were much stronger than domestic connections in R&D activities of Korean biotechnology SMEs and concluded that networking with foreign universities and research institutions was strategically important.

RISTEK has encouraged R&D collaboration among university, public R&D institutions, and business enterprises through competitive research incentives. The formation of research consortia on specifically assigned topics has also been facilitated. However, outcomes and positive impacts of these efforts have not been satisfactory. Reformulating incentive schemes for encouraging workable and sustainable collaboration among domestic technology developers are needed.

6.2. Low technological absorptive capacity of domestic industry

Some domestic industries do not feel the urgency for establishing R&D units within their business organization, but some of them do assign their staff for conducting experimental development. Typically, in the case of China and many other countries, including Indonesia, the purpose of technology development in enterprises is to meet present market demand instead of developing future markets [21]. If business enterprises have sufficient capital and limited R&D personnel, they prefer to acquire proven technologies than to develop their own technology, for enhancing the commencement of production activities in order to be competitive in early penetration to potential markets. Certainty and quick actions are much more desirable in business activities. Unfortunately, developing new technology will consume an uncertain period of time and has no guarantee for success.

Madanmohan et al. [39] studied Indian and Indonesian manufacturing firms and revealed that R&D investment and availability of technical personnel; the transfer channels; government's involvement; and the firm's learning culture were significant contributors to the technology capability process. In contrast, the acquisition of mature technology just to boost production capacity or improve product quality but contributed very little to the development of technological capability of the firms. In contrary, Blalock and Veloso [40] believed that importing was a source of international technology transfer and linkages. Import-driven technology transfer occurred through vertical supply relationships.

Subsidiary companies are generally not equipped with adequate R&D capacity since they are obligated to apply technologies developed by their parent company. Most of the subsidiary companies in Indonesia focus on manufacturing marketable products and/or providing services. Multi-National Companies have their own R&D department for developing technologies, so they are almost untouchable for domestic R&D institutions. The large domestic market of Indonesia is the primary factor attracting foreign investment besides the abundance of natural resources.

Due to the high capital investment needed and high technology sophistication, i.e. for exploration activities in mining sectors and for managing maritime resources, the required technology of state-own enterprises (SOE) in these sectors is still mainly acquired from foreign sources. However, technologies required by SOE in agricultural sectors are mostly acquired from domestic sources. Domestic R&D institutions in agriculture have been adequately prepared to play their role in developing and delivering technologies for agricultural businesses.

Realistically, since there is only a small window opening for indigenous technology by MNCs, subsidiary companies, and SOEs; technology development in Indonesia should be more concentrated on satisfying the needs of SMEs (Fig. 4). Motohashi [41] found that smaller firms achieved higher productivity through university-industry collaborations than large firms did. In light of the findings, it appeared that these collaborations were likely to play a strong role in reducing the dependence of Japan's system of innovation on in-house R&D conducted at large corporations.

The government of Indonesia has encouraged the use of domestic products. For government institutions, it is an obligation to prioritize the use of domestic products which have highest domestic content (President Instruction 2-2009 on Increasing Use of Domestic Products). R&D expenditure in developing the products is considered part of the domestic components. This regulation is expected to enhance R&D activity at business enterprises.

Aminullah [42] argued that constantly low investment in national R&D was caused by three situations: very low private R&D investment, most of industries were low and medium technology (LMT) industries that did not require R&D, and constantly declining government support to science, technology, and innovation (STI) development. If these situations persisted in the future, in 2025 and beyond, R&D intensity in Indonesia would still be less than 0.5 percent of GDP. To cope with declining R&D intensity, Indonesia needs to apply the concept of 'multiplying absorptive capacity' in STI. Increasing absorptive capacity of domestic industry was a strategy worthwhile to pursue.

6.3. Inadequate contribution of government-affiliated intermediation agencies

Persuading domestic industries and other technology users to adopt indigenous technologies is an intense challenge if the technology itself is irrelevant to needs of the

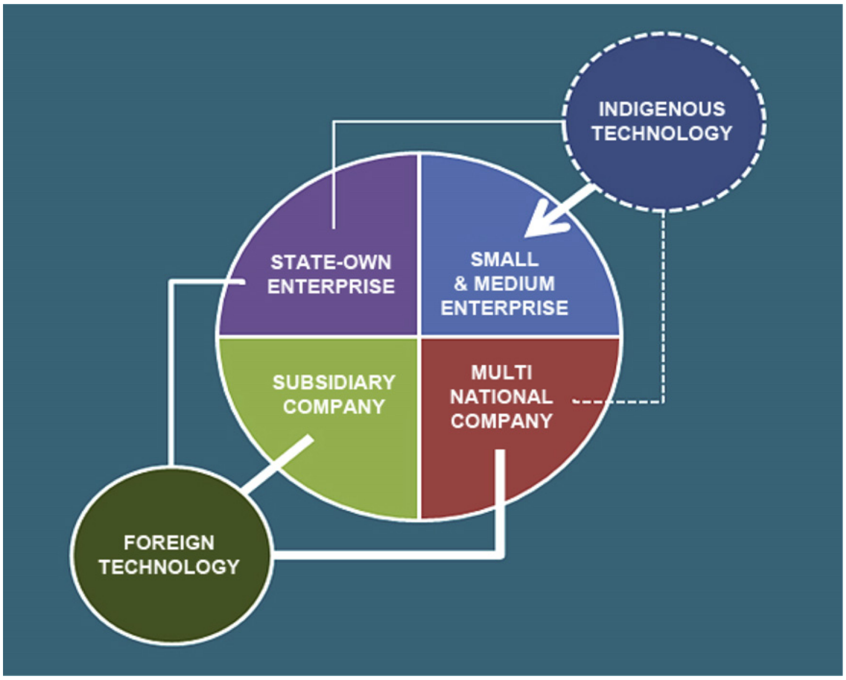

Fig. 4. Indigenous technology should be focused on satisfying SME's demand.

users. The mismatch between developed technology and user's need is a serious issue for establishing a national innovations system in Indonesia, and may also be in several other countries. Intermediation agencies should play a role in both directions, i.e. marketing indigenous technology to potential users and passing along the user's technological needs and preferences to developers. In current conditions, rather than putting all efforts in marketing the unneeded technologies; the intermediation agency should focus more on gathering and analyzing information on technology demands of potential domestic users and delivering the information to appropriate R&D institutions.

At the time when direct communication and interaction between technology developer and user have not been well established, the role of the intermediation agency should be intensified. Authority and resources of the intermediation agency should be strengthened. Then, government could have a facilitating role through this agency. Unfortunately, at present, the existence and role of intermediation agency has not been well recognized by other R&D actors.

Indonesia had established a Business Innovation Center for executing this task; however, government support to this agency has not been significant. Currently, Indonesia also initiated a program to establish an Indonesian Science Technology Park (I-STP) as an innovation cluster for facilitating interaction between technology developers and users, by revitalizing current R&D facilities at Puspiptek Serpong, located on the outskirts of Jakarta.

George and Prabhu [42] indicated that Developmental Financial Institutions (DFIs) can play an intermediation role. If the DFIs are proactive in making technology assessments, it will be an important link between developing a firm's absorptive capacity and building a nation's innovative capacity.

Indonesia should maximize the use of R&D budget as a policy instrument for directing researchers to develop relevant technologies for fulfilling the needs of domestic industries, especially the SMEs. Based on his study on the implementation of a national innovation system in Thailand and Malaysia, Wonglimpiyarat [20] concluded that it was the government of both countries that took leading roles in terms of providing supportive institutional arrangements as well as financing programs to support the process of bringing R&D to commercialization.

7. Concluding remarks

Research and development (R&D) activities in Indonesia are mainly funded by the government and conducted at universities and a few public research institutions. Unfortunately, these R&D activities are mostly academic and rarely focused on solving actual problems or providing relevant technologies for economic development and/or social welfare improvement. Public R&D institutions responsible for developing technologies for supporting national development have drifted into academic mainstream.

At the core level, all of these unfavorable circumstances lead to sequential problems:

1. There is a mismatch between technology developed by universities and those needed for economic development
2. The low availability of relevant indigenous technologies

3. The adoption of indigenous technologies by domestic industries or other users is very limited
4. The contribution of indigenous technologies to economic growth and social welfare improvement has been insignificant. Since only disseminated and adopted technologies can be categorized as innovations [43], therefore, low indigenous technology adoption has been a major obstacle for establishment of an effective NIS.

At the ecosystem level, current R&D policy and its supporting sectors' policies are clearly worth to be reexamining. Technology policy will not be successful if it is not upheld by complimentary policies in other supporting sectors. Trade and industry strategies should be aligned with technology policy. Higher education and technology policies should also be synchronized in human development scenarios. In Indonesia, education and technology are currently administered by two different ministries. This institutionally separated condition does not make it easier for establishing an effective NIS. Unifying the two ministers has been discussed in many occasions and is believed to be a better option for synchronizing human resource and technology development programs.

At present, there are also regulations regarding incentives for business enterprises that financially support R&D activities. However, these incentives do not seem to be alluring from the business perspective.

During the last few years, the demand-driven approach in developing technologies has been encouraged in order to create more relevant and affordable technologies. It is recognized, however, that changing the mindset of the researchers will not be an easy task. Industries and other technology users have been urged to be directly involved in identifying or pinpointing relevant technologies for economic and social development.

Formulating technology policy for establishing an effective national innovation system is not as simple and straight forward as some might envisage. Synchronizing all supporting policies is essential, yet very hard to realize, in order to create an advantageous atmosphere for the innovation system to flourish. It should also be highlighted that establishing an effective national innovation system will take a considerable and consistent period of time. Actionable and measurable policies are needed, and hopefully will also be consistently implemented. Shared goals and a roadmap for achieving the goals should be disseminated to, and understood by, every stakeholder.

Challenges at the anatomical level are even more problematic. The commitment of all actors involved is a necessary precondition. Indonesia has relied heavily on universities and public R&D institutions in developing technology for more than half century. Meanwhile, the 'ivory tower' syndrome at Indonesian universities still exists. Getting commitment from researchers and academicians to focus on developing relevant technologies to user's needs has not been easy. It requires a radical mindset change of these technology developers since they have been for so many years focused on his/her field of academic expertise. There are two other constraints that prevent mindset change. Firstly, the promotion of researchers and academician in Indonesia is heavily based on academic achievement. Secondly, there is inadequate appreciation given to those who have made their contribution to economic or social development. This focus on academic achievement easily leads to development of technologies that do not match with user's needs.

Meanwhile, business leaders in Indonesia prefer to acquire available foreign technologies rather than to collaborate with domestic researchers or academicians for developing their required technologies. There are two main rationales for this preference. Firstly, in a very competitive business world, certainty is preferred and quick action is needed. In contrast, success in developing indigenous technology is relatively uncertain and will take a considerable period of time. Secondly, most of technology developers in Indonesia have not been able to prove their full commitment to develop economically competitive and technically reliable technology. Meanwhile, in-house R&D at domestic industries is relatively inadequate and technology spillover from foreign investments is considerably low.

It is clear that there are challenges at the core, ecosystem, and anatomical levels for establishing an effective innovation system in Indonesia. These identified challenges cannot be undertaken partially in order to make the national innovation system work. Every single challenge has to be tackled systematically and comprehensively as an integrated and essential element of developing a national system of innovation.

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