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Current Status of Nanotechnology based Academic Entrepreneurship in Indonesia

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ABSTRACT: The discourse on academic entrepreneurship has been spurring in Indonesia for the last couple of years. However, the study on its evaluation, challenges, and opportunities, especially in the specific field on nanotechnology has yet to be investigated thoroughly. This study aims to evaluate current status on nanotechnology based academic entrepreneurship in Indonesia, while also to provide analysis on factors contributing commercialization success. Study was done by conducting survey to 77 nanotechnology researchers spread across >30 universities and research institutes in Indonesia. Researchers were evaluated on their current commercialization stage, and factors hindering to proceed to further stages. Results showed that 62.3% have proceeded to stage 2, from which 58.3% proceeded to stage 3, 28.6% from stage 3 that could advance to stage 4 (commercialization stage), and finally 25% from stage 4 to 5 (growth stage). While it does make sense that staging from patent to commercialization is the most difficult part, the percentage shows that the productivity of nanotechnology researchers in Indonesia can be considered high in terms of academic entrepreneurship result. Lastly, it was determined by ordinal regression analysis that entrepreneurial experience, interaction with industrial partners, and participation in incubator were three most important factors in the success of nanotechnology academic entrepreneurship. This study could become a preliminary study to formulate a policy recommendation to support academic entrepreneurship in Indonesia especially in nanotechnology field.

Keywords: nanotechnology; academic entrepreneurship; patent; startup; commercialization.

I. INTRODUCTION

Academic entrepreneurship is defined as entrepreneurial activities with the aim of selling or commercializing products developed from research results [1, 2]. In general, academic entrepreneurship occurs in the scope of universities (universities) and research institutions [2, 3]. Academic entrepreneurship has become a new demand for universities or research institutions, bringing the 3rd mission beyond learning and research, as shown in the illustration in Fig. 1 [4]. Academic entrepreneurship is proven to provide a multiplier effect with at least 2 main objectives: (1) to bring forth new innovations that can increase competitiveness in business competition; (2) providing concrete solutions to problems in society with appropriate technologies [5, 6].

Academic entrepreneurship with various schemes in many countries has shown very significant outcomes. In developed countries like the United States; For example, at Stanford University, a University in Silicon Valley in California, in the 2014-2015 period, it received a gross income of 95 million USD, or about 1.3 trillion Rupiah from the commercialization of research results through a licensing scheme. In developing countries such as China, the academic entrepreneurship contributes nearly 278 million RMB to their economies through a licensing scheme [7]. Another country, Malaysia, during the period of 2007-2013 have generated royalties resulting from the commercialization of research results of 1.25 billion MYR [8].

In Indonesia, academic entrepreneurial activities have developed quite well, especially since the popularization of business incubators in universities and research institutes throughout the nation, in the period after 2010. Although it has become a massive activity carried out in various universities and research institutions, studies or studies on entrepreneurship academic or commercialization of research in Indonesia is still quite limited.

This research was conducted within the framework of academic entrepreneurship development and commercialization of research in Indonesia, with area of focus on nanotechnology. Nanotechnology is chosen because it is a field of science that is currently getting special attention, both in academic and business community. Nanotechnology is predicted to be one of the most important disruptive innovations that will shift conventional technology.

The objective of this research is to get a comprehensive picture of the conditions of academic entrepreneurship and the commercialization of research results, especially in the field of nanotechnology in Indonesia. Factors or determinants that influence success of nanotechnology research commercialization will be analysed. From the policy-maker point of view, this study could be used as an academic paper to decide on what strategy to be used to grow academic entrepreneurship, also nanotechnology in Indonesia, thus providing positive implications for Indonesian economic growth based on science and technology.

II. LITERATURE REVIEW

Researchers generally categorize academic entrepreneurial activities or research commercialization

into 3 schemes: licensing, startup company, and contract research; But there are also opinions that do not include contract research into the research commercialization scheme [1, 3]. The most common research commercialization scheme, including in Indonesia, is the contract research scheme; universities or research institutions collaborate with companies to develop joint research products. Licensing schemes can be defined as granting the right to use technology (in the form of patents) to existing companies. Meanwhile, another alternative is that the patent owner founded a start-up company with entrepreneurs.

Research on commercialization of academic research or entrepreneurship has been widely studied by researchers around the world, especially in the framework of management of innovation and technology. One of the most discussed topics is the factors or determinants that influence the success of the commercialization of research in the viewpoint of researchers as entrepreneurs of entrepreneurial activities. Researchers generally divide into internal and external factors, as shown in Table 1.

Table 1: Factors or determinants of the success of commercialization of research from the perspective of entrepreneurial academics.

Factors/Determinants	
Internal factors	age/scientific experience [9]; gender [10]; academic status [11]; time after graduate study [12]; entrepreneurial intention [13]; prior entrepreneurial experience [13]; extrovert personality [14]; scientists' quality/quality of institution [15]
External factors	University entrepreneurial tradition and environment [14]; entrepreneurial peers [12, 16]; incubator/technology transfer offices (TTO) influence[17]; R&D expenditure [18]; business development capability of university [18, 19; Industry funded [20]; The nature of research [21]

Factors that were analysed in this study are entrepreneurial experience, participation in incubation process, and interaction with industrial partners. We are interested in entrepreneurial experience and intensity of interaction with industrial partners, as both have been mentioned elsewhere to considerably affect commercialization success rate [22, 23]. Lastly, participation in incubator was also analysed. Incubator or Technology Transfer Office (TTO) is the most important organization that is supposed to bridge scientists, from their research-oriented nature, to product or market-oriented mindset.

On the other hand, the main theme in this research, nanotechnology is a field of science that studies phenomena or engineered matters in nanometres size (1×10^{-9} m). Materials that are engineered at nano size show unique or superior performance or properties, which are not found in bulk size. This phenomenon occurs because of several physics principles, where for example, material engineered in nanoscale has a significantly increased surface-to-volume ratio. Some of the superior properties arising from nanotechnology, including: increasing mechanical strength, increasing conductivity, improving magnetic properties, increasing resistance to UV rays, etc. [24-29]. Some applications of nanotechnology that have been widely applied on a commercial scale include self-healing paints, superhydrophobic coatings, tennis racquets with carbon nanotubes, air conditioning with nano silver which have anti-bacterial properties, nano calcium toothpaste, and many more.

Research in the field of nanotechnology in Indonesia has actually been running quite massively. Until now, there are at least 300 scientists (250 of whom hold doctoral degrees) who carry out research in the field of nanotechnology which is gathered in a professional organization called the Indonesia Society for Nano (MNI). Some innovations have been in the upper stage in commercialization, i.e. patenting, establishment of startup companies, even licensing to existing companies, but in limited numbers. Some nanotechnology-based companies include PT Nanotech Herbal Indonesia, which produces nano chitosan and nano propolis, utilizing licenses from researcher at Agency for Assessment and Application of Technology (BPPT), then PT Nanotech Natura Indonesia which produces cosmetics made from nanomangosteen skin using research results from Indonesian Institute of Science (LIPI) researcher. The rest, products from the results of nanotechnology research are still limited to the level of patents, or advanced research, but are still constrained for commercialization.

There is a strong demand from policy-makers to design a strategy that can support and accelerate the commercialization of nanotechnology in Indonesia. Commercialization in the field of nanotechnology in Indonesia in various fields has been reviewed by Rochman *et al.,* since 2011, with the finding that nanotechnology-based businesses have a huge potential of market penetration in Indonesia; hence making it lucrative for further analysis [30-32].

Some of the previous studies that have become state of the art in this study are as follows:

No.	Publication	Research Result	Research gap
1	Identifying Effective Factors on Technological Entrepreneurship in Iranian Nanotechnology SMEs [33]	In this study, a questionnaire was conducted to 67 SMEs selling nanotechnology products in Iran. It was concluded that there were 4 factors that influenced the success of the commercialization of nanotechnology by the SMEs, namely: (1) internal processes; (2) individual factors; (3) institutions; (4) network to external parties.	This research focuses on conditions in Iran, and this research do not focus on academic entrepreneurship from Universities
2	Factors influencing nanotechnology commercialization: an empirical analysic of nanotechnology firms in	In this study, questionnaires and interviews were conducted with 206 companies selling nanotechnology products in Korea. It was concluded that there were 3 things that made several companies show better financial	This research focuses on conditions in Korea and large companies (not spinoffs from universities)

	South Korea [34]	performance, including: (1) conducting consistent R&D exploration; (2) get funding from the government; (3) has nano equipment for applications in the field of energy / environment that is adequate. Meanwhile, it is also proven that companies that use products that have the potential to have toxic traces will be difficult to develop, even though the product is not in the toxic category.	
3	An empirical analysis of the valley of death: Large-scale R&D project performance in a Japanese diversified company [35]	In this study, an analysis of 17 large-scale R&D projects in 17 companies in Japan. This R&D project develops a research to become a commercial product. The analysis is done by observing the cumulative profit and loss variable from the beginning of the research to the commercialization stage. This research illustrates that at one point, if the project did not get funding to stay afloat, then the project would "fail" - the so-called valley of death. Some important things to consider in dealing with valley of death include: (1) the duration of the project that depends on the type of product being developed; (2) the cause of failure is usually caused by 2 factors, namely the aspects of technology development or marketing	This study reveals the phenomenon of valley of death, but in the case of large companies in Japan, and not specifically address nanotechnology
4	Challenges in commercialization of nanotechnology in agriculture sector of Iran [36]	In this study, interviews were conducted with experts at the Iranian Ministry of Agriculture to find out the challenges in implementing nanotechnology in the agricultural sector in Iran. It was found that there are 6 factors that cause the implementation of nanotechnology in agriculture in Iran is still slow, namely: (1) infrastructure; (2) knowledge; (3) structural; (4) economy; (5) policy; (6) environment. The biggest factor is found in the aspect of infrastructure, where things like lack of investment or adequate equipment make the diffusion of nanotechnology in the agricultural sector slow	This study only specifically addresses the agricultural sector in Iran
6	Scientist-Entrepreneurs as the Catalysts of NanoTechnology Commercialization [37]	In this study, there were 4 suggestions for how researchers who are also subject to academic entrepreneurs can increase the commercialization of nanotechnology-based research results, namely: (1) researchers are required to understand the principles and practices related to entrepreneurship; (2) patenting products widely, so that they can penetrate into emerging markets; (3) looking for strategic partners to help commercialize; (4) start by commercializing a low risk product, for example substitution of a particular application; (5) choosing a hybrid structure in the organizational structure	This study discusses more on the strategies so that researchers can also become entrepreneurs who can sell their products

III. METHODOLOGY

The purpose of this study is to explore conditions pertaining to nanotechnology based academic entrepreneurship (AE) in Indonesia. Also, factors or determinants that influence the success/failure of AE in nanotechnology in Indonesia were analyzed with ordinal regression method.

The analysis used data obtained from questionnaires distributed to 70 nanotechnology researchers in Indonesia (database was taken from Indonesia Society for Nano) through purposive sampling method. Questionnaires to explore the current condition of nanotechnology-based AE were constructed in accordance to AE questionnaires and models that has been proposed in several papers [38, 39] following several modifications as shown in Fig. 1. Respondents were asked for their accomplishments in each commercialization stages (1-5). Qualitative questions investigating the reason for bottleneck to proceed to next stages were also delivered.

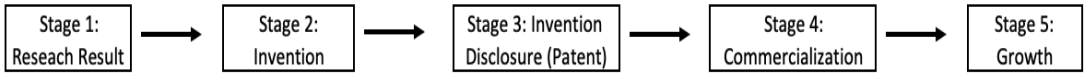

Fig. 1. Academic entrepreneurship stages framework used in this study.

Meanwhile, questionnaires that are intended to analyze the determinants of success/failure of nanotechnology-based AE were constructed referring to related papers mentioned in section II [22, 23, 40]. The main constructs/variables that were investigated in this paper are entrepreneurial intention, entrepreneurial experience, Complete list of questions in the questionnaires are provided in the appendix section.

Respondents were chosen based on main requirement that He/She has published at least 1 international journal article related to nanotechnology within the last 5 years. To ensure the breadth of the respondents'

background, questionnaires were spread to different institutions, covering both universities and research institutes, institutes within Java island and non-Java island, male-female, from renowned institutes in Indonesia, e.g. LIPI, BPPT, University of Indonesia, Institut Teknologi Bandung, Universitas Gajah Mada, and others. Surveys were conducted from January to March 2019.

Ordinal regression analysis was used to help determine which variables are capable of predicting the level of academic entrepreneurial success. Not only that, with ordinalregression analysis, we compared the magnitude of the influence of each factor which determines the success of academic entrepreneurship. Greater regression coefficients, show a greater influence of a determinant on academic entrepreneurial success, compared with other determinants.

IV. RESULTS AND DISCUSSIONS

The information about the respondents in this survey is presented in Table 2. Our respondents seem to represent the normal academic population, as shown in male and doctoral degree domination among respondents. It is also well understood that most of respondents reside in Java island, which is the most populous island in Indonesia (with more than 40% of Indonesia's population). We have tried to reach respondents from outside Java island, however we found only few scientists there that have traceable publication record on nanotechnology topics. This is arguably a persistent problem as highlighted elsewhere, that inequality in access to good facilities between Java and non-Java scientists does exist. Another problem was that some scientists outside Java island have limited visibility to be accessed through email or phone number or even social media. Another important demographical data observed was the institution where the scientist currently tenures in is dominated by university with 81.8%, compared to research institute with 18.2%.

Table 2: Information about respondents in this survey.

Item	%
Gender	
Male	61.0
Female	39.0
Institution	
University	81.8
Research institution	18.2
Place of residence	
Java	89.6
Non-Java	10.4
Last education (by degree status)	
Master	13.2
Doctoral	86.8

Fig. 2 shows the percentage of commercialization accomplishment at each stage. 62.3% of respondents have gone through the stage 2, which is the invention stage, proved by existence of invention prototype. This number shows that majority of respondents found that bringing a new invention do not seem to be a complicated process. Nevertheless, not all inventors could proceed to the next stage, which is patenting stage. 58.3% of the inventors (those who succeeded at stage 2) have patented their inventions. According to follow up questions in the survey, all respondents had no difficulties whatsoever in patenting process. 47% answered that the patenting process is ongoing, or soon will be processed, while 40% think that their inventions are not patentable, or have no significant patentability (Fig. 3). We suppose that the latter might be mixed up with respondents' limited knowledge on patent itself, as well as patenting process, that might be due to the absence of technology transfer offices (TTO) -or in Indonesia mostly referred as incubator, in this stage. In most commercialization model, incubator normally plays a role, not only in the "downstream", which is related to the venture formation or investment pitching, but also in the "upstream", i.e. invention disclosure stage (Rogers, 2000; Siegel, 2004). Invention disclosure stage includes the step of patent drafting, patent registration, and subsequent process needed until the intellectual property can safely be assumed to be protected.

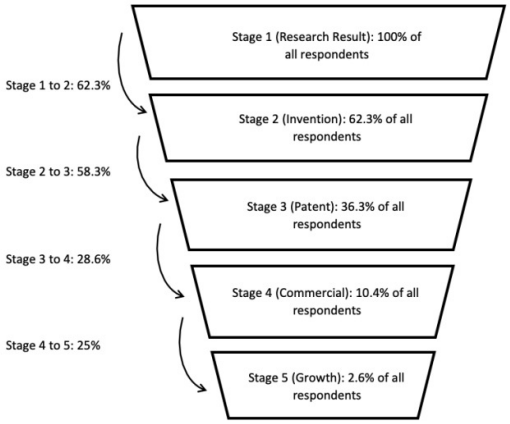

Fig. 2. Accomplishment at each stage of nanotechnology academic entrepreneurship.

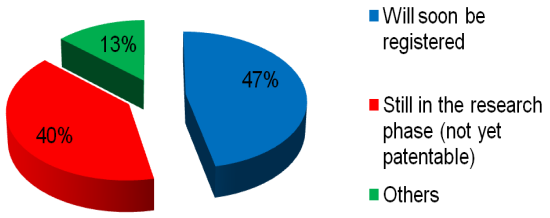

Fig. 3. Reasons for bottleneck to proceed from stage 2 (invention) to stage 3.

While most respondents found that the first 3 stages were not too complex to accomplish (36.3% of all respondents could proceed up to stage 3), the most intriguing part seems to be proceeding towards stage 4, which is the commercialization stage. According to data, only 10.4% of all respondents could proceed up to stage 4 (28.6% of all patent holders). Most dominant reasons mentioned by those who could not proceed to stage 4 are unreadiness to release to market (57%), followed by inability to attract potential partners/investors (35%) (Fig. 4). In this commercialization stage, inventors were to decide whether to license the intellectual property to an existing company, or to form a new startup company. Of 8 that could survive until last stage (commercialized), all went through startup company forming, while no respondents sold the license to existing companies.

It has already been vastly investigated that throughout the commercialization stages, the last step, which is to finally commercialize (license or form startup) is the most difficult part where most scientists fail to proceed through [9. 13]. Two reasons that raised during the survey: market unreadiness and inability to attract

investors are few of most common challenges faced by academic entrepreneurs [41]. We deduce that those reasons persist due to scientists' limited knowledge of step-by-step procedures needed to commercialize their products; in which, TTO, e.g. incubator should play more role in this regard. Also, startup forming is an easier way to commercialize, compared to licensing to existing companies. Licensing to big companies usually needs substantial effort and time until the deal is sealed, even though it is preferred by some academic entrepreneurs because of potentially big capital gain that can be achieved instantly. On the other hand, "the startup way", though easier to create, it usually needs quite long time until real capital gain can be secured; not to mention also that failure rate of startup company is more than 90% [42].

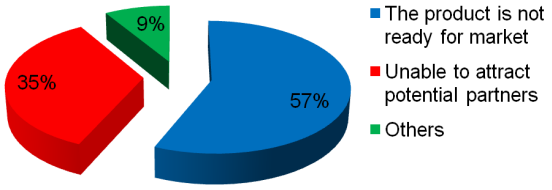

Fig. 4. Reasons for bottleneck to proceed from stage 3 (patent) to stage 4.

Table 3 shows the relationship between variables in the success of the commercialization of research carried out in this study. In this study, we have decided to analyse several variables that are believed to be dependent with the success of the commercialization of research, which are entrepreneurial experience, participation in incubation process, and interaction with industrial partners. According to statistical analysis all variables showed significant influence towards the success of nanotechnology academic entrepreneurship (at significance level of $p<0.05$).

Participation in incubator is commonly known as an important determinant of commercialization success [17]. In most commercialization framework, incubator plays an important role from invention disclosure to commercialization step. It is well understood that scientists have a fundamental gap, where they normally do not understand the step-by-step procedure from bringing research results to intellectual property to commercialization. While scientists are normally demanded to focus on the research side, incubator should be present more intensely at commercialization side. One interesting finding to note is that the correlation number for incubator's participation variable in this survey is lower than entrepreneurial intention; at the same time, it has a very low number. This might be due to the fact that incubator in Indonesia has just started to grow in recent years. The Ministry of Research, Technology and Higher Education's policy to set up a new directorate of innovation in 2014 is believed to be one factor that supports that, that was followed by virally established incubators in more than 100 universities around the archipelago [43]. It can be implied that, the quality of incubators in Indonesia is still arguably low, hence their presence might still not be considered beneficial to the academic community.

Table 3: Ordinal regression analysis result to show which variables have significant influence towards nanotechnology based academic entrepreneurship success.

Variable	β	Wald	Odds ratio	p
Number of industrial partners	-1.297	4.551	0.273	0.033
Number of industrial partners that have high meeting intensity	0.567	6.067	1.763	0.014
Entrepreneurial Experience (0)	-1.343	4.39	0.261	0.036
Entrepreneurial Experience (1)	0a			
Incubator Participation (0)	-3.285	5.226	0.037	0.022
Incubator Participation (1)	0a			
Gender (0)	-0.48	0.751		0.386
Gender (1)	0a			
Institution (0)	0.012	0		0.986
Institution (1)	0a			
Place of Residence (0)	-0.45	0.274		0.6
Place of Residence(1)	0a			
Last Education (0)	0.941	1.47		0.225
Last Education (1)	0a			
Willingness to commercialize	-0.43	1.605		0.205
H-Indeks	-0.006	0.011		0.915
Number of year of researcher	-0.34	0.784		0.376

V. CONCLUSIONS

This study has showed current status on nanotechnology based academic entrepreneurship in Indonesia. It was shown that only 10.4% of all respondents could proceed to the commercialization step, which was to license to an existing company, or to form a startup company. Most that successfully commercialized chose the latter as their mean of technology transfer, denoting higher barrier to proceed for licensing scheme. It was also determined by ordinal regression analysis that entrepreneurial experience, collaboration intensity with industrial partner, and participation in incubator were three most important factors in the success of nanotechnology academic entrepreneurship. We believe that the latter might be the enabler factor that can be introduced as an intervention program as a policy that could enhance success probability of nanotechnology based academic entrepreneurship in Indonesia. As such, we would like to give a policy recommendation that is mainly on strengthening the quality and quantity of incubators'

services to academic entrepreneurs in their respective institutions. The future scope of this research will be more on the evaluation of the operation and financial performance of nanotechnology research based companies in Indonesia. That follow up research will give a more detailed illustration on the level of success of nanotechnology based academic entrepreneurs in Indonesia.

Conflict of Interest. No conflict of interest.

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