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A Case Study and Explorative Analysis of the Development of Nanotechnology in Malaysia

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Abstract. The theme of this paper – that which prescribes the term nanotechnology is no stranger to the scientific community around the world, even though it remains a mysterious realm of unknown possibilities among the broad-spectrum of scientific faculties and a current oblivion to the common public. It is undoubtedly a subdivision that branches out from various scientific faculties such as physics, biology and chemistry. None of these disciplines can claim its ownership on nanotechnology. However, it has yet to be regarded as a standalone field of technology. It is therefore currently considered as both a multidisciplinary and interdisciplinary field of science. The scientific activity that takes place between 1 – 100 nm has brought about prodigious participation from interested governments in various countries who have tumultuously become absorbed with its soon to be seen visionary benefits. One of these countries is Malaysia. The National Nanotechnology Initiative (NNI) was initiated in Malaysia in 2006 and local developments are still at its infancy. Nonetheless, it can be observed that there has been lot of activities that have been conducted by various universities/institutes/CoEs to coxswain the advancement and sustainability of nanotechnology in our country. Efforts have been boosting but the level of progressive outputs has been slow paced, resulting in the sluggish rate of infiltration of nanotechnology prototypes - products into the commercial arena. Even way before the NNI was initiated; many of these universities/institutes/CoEs have been granted hefty amounts of dough to assist in translating lab prototypes into full-fledged products. Even so, there seems to have been a lack of any visible and massive impact coming from these endowments. In comparison and notwithstanding the fact that many countries' nanotechnology initiatives have suffered major pitfalls in bridging the R&D and commercialization of nanotechnology; yet these countries possess several significant and successful R&D to commercial outputs to their name. This paper provides a case narrative and analysis of the development of nanotechnology in Malaysia via a brief synopsis that identifies the country's principal propellers of science and technology, particularly in nanotechnology, which have been significantly designated as a major thrust area. A further elaboration on the current setting of university based research institutes and non-university based research institutes with relevance to nanotechnology, current outputs of nanotechnology research in Malaysia, Malaysia Plans (5th until the 10th), past and present grants related to R&D in general and nanotechnology; and insight analysis have been discussed in this paper.

Keywords: Commercialization, nanotechnology, prototypes, products, R&D.

Brief Synopsis

The National Nanotechnology Initiative [1](NNI) made its debut in the year 2006. It is the country's nanotechnology plan that has been integrated into the Ninth Malaysian Plan (9MP) (2006-2010). Malaysia's NNI can be viewed upon as an avowal of the government's undertaking to not only protract but to sustain nanotechnology in this country for an elongated period of time alongside other developing countries until the outgrowths of its efforts can be fully embraced and relished for the betterment of our country. The National Nanotechnology Directorate (NND) within the Ministry of Science, Technology and Innovation (MOSTI) is at present been entrusted to forefront the planning and development of the NNI. It is Malaysia's aspiration to be one of the top ten nanotechnology nations that will transform the nation by creating new and innovative sources of economic growth for the hope of future generations. But this is easier said than done. It will take nothing but positively time consuming and relentless efforts for this ambitious aspiration to be converted into reality.

Literature and Data Oriented Analysis

Institutions and Research Centers in Pursuit towards Sustaining Nanotechnology in Malaysia

Nanotechnology research in Malaysia is primarily being carried out by public universities and public research institutes. Except for International Medical University (IMU), there are no other private institutes or private universities who have visibly declared conducting nanotechnology research in Malaysia. Malaysia's investment outlay towards R&D has summed up to RM124.3 million hitherto. However, this aggregate amount has not been specifically stated as being directed towards nanotechnology alone. The common and fundamental key

[1]The establishment of Malaysia's NNI has resulted in the founding of the National Nanotech Center (NNC) which will serve as a central coordinating platform for driving the government's nanotech policy and coordinating national R&D programs and infrastructure as well as liaison with industries to address business and economic issues. Malaysia's NNI aims to ensure that Malaysia will benefit from the advancement of nanotechnology related sciences by clustering and linking the resources and knowledge with Malaysia researchers, industry and government.

goal of Malaysia's National Nanotechnology Initiative (NNI) is the fortification of world class research institutions, expenditure on nanotechnology R&D, competitive business milieu, a robust education and training system, highly skilled and diverse workforce, efficient infrastructure, integrated involvement in nanotechnology activities, international cooperation and global network. These goals have not yet comprehensively been attained but efforts are ongoing. Although, there is a common linkage between basic research and the commercial development of nanotechnologies, Motoyama, Y. and Eisler, M. N. (2011) proclaims that it is difficult to correlate the national efforts made in basic science with national economic productivity.

Outputs from Malaysia's Nanotechnology Research

Amongst the research outputs to date, one of Malaysia's utmost commendable nano products is Malaysian made aerogel; known as Maerogel by UTM. The maerogel is the cost effective, non-toxic and environmentally friendly raw material made from silica in rice husks, which produces high premium quality insulation material that can be applied to medicine and construction, among other areas. It has significantly resulted in 50 – 75 percent cost reduction and resembles that of frozen smoke. Traditional aerogel costs about RM15, 000 per kilogram (has existed approximately since 1931); whereas Malaysia can produce it for only RM5, 000 per kilo (News Straits Times, 28 Feb 2010). Maerogel has been patented in Malaysia and 22 other countries worldwide and is currently being commercialized through UTM's spinoff company known as Gelanggang Kencana Sdn. Bhd. This product was also chosen as the product of the year 2008 by the International Clean Energy Circle, United Kingdom. Another research output from Malaysia's nanotechnology research is nanoherbs by UniMAP. This is an herbal extract which is nanosized and functionalized as Drug Delivery Systems (DDS) that serves as a medical treatment for brain cancer, brain healing, HIV, influenza H1N1, immunization improvement and bone healing. Nevertheless, there has not been any discernible evidence to indicate that this product has been commercialized as yet; and its impact to society is yet to be confirmed. Another research output from Malaysia's nanotechnology research is

the biosensor kits by UniMAP. The function of these biosensor kits is to be able to perform halal product detection, early cancer detection and medical diagnostics. Nonetheless, there has not been a single piece of data to indicate that this product has been commercialized either; and its impact to society is yet to be acknowledged. Apart from MOSTI, research centers and universities, it must be emphasized, that there aren't many papers published in the area of nanotechnology R&D and commercialization in Malaysia. In addition to this, there has been insufficient quantitative and qualitative data available concerning nanotechnology R&D. Even statistical organizations have not begun to capture nanotechnology data in a time series basis. Furthermore, in comparison to the global distribution of nanotechnology literature, which has grown dramatically over the years, it can be said that research literature on nanotechnology contributed by Malaysian scientists remains bleak. There is also a strong deficiency of local expertise in nanotechnology in this country. Nevertheless, from the market driven perspective, few sectors have been given precedence to jumpstart Malaysia's entry into the nanotechnology business. The sectors are: oil and gas, palm oil, electronics, ICT and agricultural food (Star, 1 Nov 2011).

Malaysia Plans and Industrial Master Plans

Since the Seventh Malaysia Plan (7MP), Malaysia has for decades trained scientists capable of contributing to the national development in science and technology (S&T), where some pioneering work in nanotechnology was initiated. Current database (according to an unrevealed source) indicates that there are about 150 local scientists directly involved in diverse areas of nanotechnology research. But, there has neither been any substantiation nor verification to confirm this statistic. The Intensification of Priority Research Areas (IRPA) program of the Eighth Malaysia Plan (2001 -2005) (8MP), which is governed and funded by MOSTI, identified nanotechnology as one of the 14 research priority areas, and is categorized under "Strategic Research" (SR). During IRPA, Strategic Research received an even distribution of 35% or RM 350 million of the total IRPA budget which was RM1 billion. That 35% was divided into fourths

over the 5 year period between 2001-2005, with nanotechnology and precision engineering as one of the four subcategories. Photonics, which could come under the category of nanotechnology and precision engineering or optical technology, saw an approved amount of RM 51.7 million. The SR projects are for a maximum period of 60 months, with potential for enhancing future competitive socio-economic development or new breakthroughs with commercial potential. Additionally, the projects must be multi-disciplinary, and have industrial linkages, with potential for commercialization. In terms of R&D incentives, the Intensification of Research Priority Areas (IRPA) apportioned funding to public research institutions or public and private institutions of higher learning as well as to projects involving collaborations by either of these organizations with industry. The bulk of IRPA funding was apportioned to activities that would lead to commercialization with some funding allocation offered to research activities intended for knowledge encroachment. As of 2006, IRPA grant currently supports three (3) nanotechnology programs and seventeen (17) projects with total funding of about RM 143 million (approximately US$37.6 million). Other than IRPA, the Industry Research and Development Grant Scheme (IGS) funds companies with at least 51% Malaysian ownership in "Critical Technologies" which includes nanotechnology; whereas the Multimedia Super Corridor Research and Development Grant Scheme (MGS) allocates funds for private sector and MSC status companies related to nanotechnology R&D. And finally, the Demonstrator Application Grant Scheme (DAGS) funds for facilitating social economic progress of Malaysians via innovative use of different technology such as ICT and nanotechnology. For the Eighth (8^{th}) Malaysia Plan, the corresponding amounts in US$ are US$224M, US$62M, US$27M, and US$24M respectively. However, there has not been any specific numerical allocation indicated for R&D grants for nanotechnology in the Ninth (9^{th}) and Tenth (10^{th}) Malaysian Plan. At the end of Eighth (8^{th}) Malaysia Plan, MOSTI had awarded about RM160 million to nanotechnology related research projects. The inclusion of nanotechnology as a priority area under IRPA for Eight (8^{th}) and Ninth (9^{th}) MP was timely, and was poised to position the country in the long term to nurture a nanoscience research culture among researchers, and develop world

class nanotechnology laboratories in Malaysia. During the Ninth Malaysian Plan (2006 – 2010), government funded RM 107 Million (US$35.26 Million) for nanotechnology. At present, nanotechnology has been emphasized in the development of the National Key Areas (NKEAs) under the Tenth Malaysian Plan (2011-2015). Under the more recent National Science and Technology Policy II (STPII) that was launched in 2003, nanotechnology was included in the strategy of building competence for specialization in key emerging technologies, and has been identified as a key technology area to support the local industry. Under STPII, the Malaysian government stated that it aims to augment its R&D spending to a minimum of 1.5% of GDP by 2010 and wants to achieve a minimum of 60 RSEs (Researchers, Scientists and Engineers) per 10,000 labor force (0.6%) by the same period. The interim (short – term) strategy of Malaysia is geared en route towards identifying researchers in diverse areas of nanotechnology with specific proficiencies; raising the standards and equipping nanotechnology laboratories with high-tech facilities; and to plan a broad all-inclusive human resource development agenda for generating a large group of nanotechnologists. Nevertheless, this remains a prescribed strategy and not yet an accomplished goal. It must also be pointed out that during the Ninth (9^{th}) Malaysia Plan and the Tenth (10^{th}) Malaysian Plan, IRPA, IGS, MGS and DAGS were discontinued. These grants were replaced with the Science Fund, Techno Fund, Inno Fund and Nano Fund which still exist till today. The per year allocation of these grants have not yet been disclosed to the public because the allocation disbursed was in sum totality and not specifically to a single grant. The allocation amount is subject to a quarterly or annual review of these grants. Nevertheless, only the quantum or the maximum amount approved for each grant has been disclosed. The Industrial Master Plan (IMP3) that spans a 15 year period (2005 – 2020) is reported to recognize nanotechnology as a new emerging field. Malaysia's National budget 2006 unveiled the allocation of RM868 million to be provided by MOSTI for R&D. The focus was to be on biotechnology, nanotechnology, advanced manufacturing, advanced materials, ICT and alternative source of energy including solar, to promote innovation and new product development among local companies.

Nano Fund

According to the data provided by MOSTI at year end of 2012, it is evident that the total amount of nano fund approved for nano devices oriented projects far exceeds the amount approved and dispersed for nano-material and nano-application oriented projects. A total amount of nano fund approximating to RM7 million was given to twenty (20) nanotechnology projects in the year 2011. The 20 nanotechnology projects, which were approved, came from ten (10) institutes and Center of Excellences (CoEs) in Malaysia. The maximum number of projects approved (which were 3 nano projects) went to UPM, UKM and UTM; whereas a total of 1 – 2 nano projects approved went to UniMAP, MIMOS, UiTM, UTP, IMU, MARDI and UM. Most of these projects began in 2011 and 2012 and is expected to complete at the end of 2013 and 2014. The trivial number of nano oriented lab projects that are being funded and conducted indicates that not many researchers and scientists are involved in the field of nanotechnology.

Insight[2] Oriented Analysis

The current development of Malaysia's nanotechnology's environmental setting does not share an identical footing in terms of development as compared to other countries. It can be professed that Malaysia's output worthy developments in the area of nanotechnology is not seen to be as significant and momentous as compared to other developed countries, which are spearheading the global nano race. Nevertheless, it can be said that, Malaysia is not alone in this aspect, as there are other developing countries concomitantly striving to "roll up their sleeves" in the area of nanotechnology development, since productive endeavors cannot be successfully resulted meteorically, and a "decelerated and routine

[2] Ten (11) in - depth qualitative interviews were conducted between the mid of May 2012 and December 2012 (during a seven (7) month period). These ten (11) participants consisted of professors, researchers and directors/heads of departments from universities, research institutes and ministries in Malaysia. Four (4) out of ten (11) participants were chosen for their fine blend of both industry and academia put together; whereas seven (7) out of ten (11) participants were purely from academia.

demeanor" in this area will only obstruct the possibility for our nation towards reaching the eightfold strengths and métier of our nano leading forefronts'.

As a professor states, "*Nano research still remains to be only conducted at the university level. Initially, the development of nano in Malaysia was not directed towards commercialization, but lately, the government began to make an initiative to provide funding for commercialization".*

This finding therefore positively indicates that there is currently a precipice between research in the university and commercialization in our country. This finding indirectly positions itself to connote that in whole, the existence of a precipice between the two disparate platforms have caused it to elude away from the smooth transition of prototypes from the university into marketable products in the commercial arena. This finding solitarily distinguishes that commercialization of nano products is currently being enabled and activated through the assistance provided by the government, even though nano developments, which remains to be wedged within the demesne of basic university research have been neither proactively directed nor fixated towards the government's key mission of steering its way towards nano commercialization.

In support of this finding, a researcher endorses this statement by stating "*…because in the university, most of the research is focused on basic R & D. We have not shifted our focus on to any particular product for a specific target market".*

Another view by a researcher states that, "*Malaysia has actually emulated lot of overseas research. Therefore, Malaysia has the capability in terms of nano. It's just a matter of forging all of it together into a product. That is slightly moving in a slow state. Initiatives carried out to make this all work has not fortified properly".*

These findings signify that the output of current research remains at the prototyping stage. It also provides substantiation that the initiatives carried out have not been concrete in its endeavors. This means that compared to other countries, the outputs have not augmented in parallel with the amount of ventures performed to convert a prototype into a fully-fledged product. Nevertheless, through recent observatory evidence, it can be put forward to state that the trend seems to be gradually migrating from prototype specific to product specific even though not rapidly.

As another researcher denotes that, "*…with the advent of commercialization funding, researchers have switched their approach from focusing on university-based research towards working in the direction of generating products that can be marketed".*

A professor provides a pragmatic viewpoint to say that, "*At the beginning, the gap that would have taken from 5 to 6 years between university research and commercialization, then; has grown lesser now*".

In contrary to these optimistic, affirmative yet pragmatic findings, there have been observations that divulge scenarios, whereby in some cases, many universities who emerge with new prototypes ultimately end up not being commercialized.

A researcher acknowledges this by stating, "*It is a matter of cost actually – the cost of processes. That means the method to make no matter what prototype or material, if the cost is high, then many companies are not willing to pick up the technology until the cost can be brought down".*

Nonetheless, the cost is not the single most cause of why many prototypes have not been transformed into products. There is another relatable reason as to why these transformations are not taking place.

A researcher points out to say that, "*Universities are not being guided by market needs"*. This does not imply that universities are blindly conducting research. As a researcher states that, "*...because universities are moving in the direction where they want to get recognized. To get recognized, they have to do good research. Priorities between industry and academia are different"*.

This is not to state that universities are not making any effort in pursuit towards solving this dilemma. There are several universities who have set up their own divisions to look into the Intellectual Property (IP) and technological related ideas. Still, there seems to be a void that exists between academia and industry.

Furthermore, as a professor points out to say, "*You cannot entirely say that it's the fault of the university because most industries in Malaysia are still not very high tech"*.

This finding paves way to a contrast to other developed countries whereby big industries have excelled in R&D through the convergence between industry and academia. Compared to companies overseas, industries in Malaysia in general are not very strong in nanotechnology R&D. This is because these giant foreign companies have excelled in the research establishment since a very long time.

A professor states to say that, "*Shell Global and all the other giants are very strong in R&D but Shell Malaysia is close to nil in the R&D of nanotechnology"*.

Shell Global is currently looking at alternative energy as one of their green initiatives and nano-materials are said to be embedded into this alternative energy. PETRONAS also is one large company in Malaysia who has penetrated into the field of nanotechnology. Other companies like Exxon Mobil, Talisman, Murphy, Petrofac, Carigali Hess, Newfield and Motorola have not yet ventured into the field of nanotechnology. Nevertheless, companies like Hitachi, Sharp and Philips have infiltrated their way into the field of nanotechnology.

A researcher admits to say, "*Yes, there have been some efforts and initiatives taken by PETRONAS".*

In fact, the company has invested in a center known as COINS situated in University of PETRONAS (UTP). However, compared to these efforts, a professor endorses to say that, "*University of Malaya is in a much stronger position in terms of infra and human capital".*

This finding does not suggest that other universities lack desolately in both these components but professes that University of Malaya has an added edge in terms of advancement. Nevertheless, it must be affirmed that no specific figures have been disclosed to authenticate this finding explicitly. Nevertheless, what is obvious, is that the competition among universities is in the rise in the field of nanotechnology.

In terms of Intellectual Property, a researcher states to say that, "*MIMOS being a research institute, is in the forefront in MEMS and nano. In addition, we want to work closely with universities so that we can tailor it in getting a product that is well suited".* Currently, MIMOS is working with UKM, UM and UiTM.

Nonetheless, whether or not MIMOS wants to work with universities in terms of basic R&D or is prepared to just take the prototype that is ready on the shelf, a professor states that, "*It's more of the latter. They are actually willing to take the prototype that is functioning and what they do is convert it into a technology. That is the Modus of Operandi in MIMOS".*

This directly implies that basic research is not the forte of MIMOS.

As a researcher states, "*We do collaborate. Basic research is done by the universities. Our concentration however is in applied research whereby we have the infrastructure to build up until the device level. But we still need to incorporate the fundamentals into it. As you know, fundamentals need time to*

improve. So, we do have the first generation devices which we test but ultimately it's the second generation devices that we will use".

This research institute is currently looking at mostly sensors containing nano materials that are lightweight and that can serve as a complimentary technology product (combined with other products). The reason for incorporating nano materials into these sensors is to cause it to be more receptive to even the slightest change compared to any other sensor. For instance there are the incremental miniaturized sensors which are low in power consumption and do not always require the power to run. Existing door sensors like the Ingersoll Rand (IR) which is considered to be a security technology is still very high in power consumption. Therefore, these miniaturized sensors have been targeted to replace this technology for even a cheaper price.

In terms of how many of MIMOS's products are out there in the market, a researcher states that, "*There is only one (1) in the market and they are the MPK sensors, which are considered to be more nano related. The others are still undergoing research".*

These sensors are mainly devised for the purposes of the national benefit especially the plantations in Malaysia.

Conclusion

More nano researchers should begin to make the giant leap from basic research into applied research in universities in order to stand in leverage with forefronts that are spearheading the nano revolution. For this phenomenon to take effect, it will require the augmentation in the number of skilled and knowledgeable workforce in nanotechnology especially in basic research, in order to champion the need to shift from basic research to the height and breadth of applied research. Endowing funds to commercialize nano-prototypes, appear to be a "jump the gun" approach to push nanotechnology development and should be regarded as too early at this juncture, considering that many projects in basic

research is nowhere close to commercial realization. Therefore, there should be a certain amount of government focus into investigating why many projects funded for basic research are not mobilizing into the realms of applied research, where true potential of commercial realization closely lies. If initiatives carried out can be driven towards addressing the minor and major pitfalls and anomalies that obstruct the transition of nano prototypes into products within the university and industry arena – qualitatively and quantitatively, there is bound to be result worthy endeavors and implementations coming from university and industry through government assisted programs.

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