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Sustaining University-Industry Collaborations in Nanotechnology Research: The Malaysian Case

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Abstract: *University-Industry (U-I) collaborations during the course of technology development – commercialization cycle needs to be "symbiotically mutual" to both academia and industry. Based on this principle, this paper aims to determine the obstacles in sustaining U-I collaborations. By referring to the qualitative case study of nanotechnology research in Malaysia, it is evident that the two-way opposite directional priorities are what disables the mere fortification of U-I collaborations. Results from ten in-depth interview sessions have highlighted five main barriers to U-I collaborations, namely the issues of distinct logics and priorities, patent and commercialization, time factor, product safety, and product functionality and capabilities. The findings also suggest that the expected yield derived from U-I collaborations are to be the product of continuous re-engineering performed iteratively rather than "fast track" results.*

Keywords: R&D management, technology transfer, emerging technology, research policy

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1. Introduction

University-Industry (U-I) interactions are one of the most important policy instruments to foster the dissemination of university's research and development (R&D) outputs (Scandura 2016; Bychkova 2016). In this respect, the "capitalization of knowledge" is taking place from an entrepreneurial university perspective in which R&D results are scanned for their commercial as well as their intellectual potential (Etzkowitz 1998). This is performed through a variety of channels ranging from joint research projects, patents, spin-off creation, consultancy and specialized training, and other types of informal engagements (Fernández-Esquinas et al. 2015). Preferably, U-I engagement which is "symbiotically mutual", secure financial assistances from the private sector, reduce R&D market failures, enhance problem-solving capabilities, and increase the employment opportunities of students; whereas industries maximize benefits from higher education for skills and development through access to university research infrastructure and expertise (Scandura 2016; Fernández-Esquinas et al. 2015; Balconi and Laboranti 2006). Nevertheless, efforts to foster a close interaction between academia and industry remind as great challenges to policymakers. This is mainly because the conduit that links these two entities (i.e. academia and industry) acts as a piping canal that enables transfer of knowledge via a bilateral process; guaranteed that both ends of the pipe canal is not gridlocked. In order for this to mechanize, a strategic alliance need to be forged between academia and industry in order to further nurture the future sustainability of the U-I based collaborations.

Base on the in-depth case study of nanotechnology research in Malaysia, this paper aims to determine the obstacles in sustaining U-I collaboration from three perspectives, i.e. logics and priorities, patent and commercialization, and time factor. In order to achieve this objective, the study addresses the following primary research questions: (a) To what extent have strategic partnerships ensured the long-term sustainability in the field of nanotechnology? (b) Does publishing and patenting move away in two separate directions and hinder the R&D and commercialization of nanotechnology? and (c) How does time factor serve as an impediment towards the development of nanotechnology products and innovations? As an emerging technology, the selection of nanotechnology as the case study provides ample evidence to this research topic. Nanotechnology is burgeoning into the likes of the global economy in the form of multi-sectorial and technologically innovative products. Indeed, the past three decades has witnessed the revolutionary burst of nano embedded materials and components along with the incremental nano amplifications made to existing products; resulting in the continuous evolvement of benefits that would assist individuals and companies for a better quality of life and service.

This paper responses to the calls for research in seeking specific characteristics of different sectoral research and country cases, as well as the various logics that lead to the different result in sectoral innovation (Balconi and Laboranti 2006; Eun, Lee, and Wu 2006). Despite the importance of understanding the perceived barriers of U-I collaboration, there is little information available on those firms' involvement in these collaborations. Moreover, the state of knowledge remains relatively fragmented. Thus, study on the barriers of U-I collaborations inform policymakers to set in place policies that will alleviate the problems (Bruneel, d'Este, and Salter 2010; Perkmann et al. 2013). This paper is organized into five parts. In the next section, this paper provides the theoretical background of the paper. The third part describes the research methods used in this paper. The fourth part presents the main findings and discussions drawn from the case study. The final part of this paper provides the conclusion as well as the key policy implications.

2. Theoretical Background

2.1 Perceived Obstacles to U-I collaborations

Generally, U-I collaborations take different forms that include, among others, collaborative research, contract research and consulting, etc. (Perkmann et al. 2013). Good U-I relations require a balance between academic objectives and industrial priorities. Studies of U-I related cultural issues have highlighted problems associated with differences in the perspectives of priorities and values of academic and industrial collaborators (Barnes, Pashby, and Gibbons 2002), and the barriers U-I collaborations can be summarized in four perspectives, e.g. cultural differences, institutional differences, regulatory barriers and geographical distance (Villani, Rasmussen, and Grimaldi 2017). Universities and industry are considered as two diverse logics that underpinned by different goals, cultures and structures – academic logic seeks for fundamental knowledge, research freedom and peer recognition; whereas commercial logics practices bureaucratic controls, restrictions on disclosure and the private appropriation of financial returns (Villani, Rasmussen, and Grimaldi 2017). For instance, due to institutional mission, universities normally pursue fundamental research and do not supply industry with ready-made new product technologies (Motohashi 2005).

Fernández-Esquinas et al. (2015) postulate that the most frequent U-I relationships are those related to the training and exchange of human resources, as well as consultancy work. On the contrary, the exploitation of patents and the development of R&D projects are considered less common, and this is probably due to the lack of absorptive capacity of the small and medium-sized enterprises (Fernández-Esquinas et al. 2015). For Bruneel et al. (2010), although the university's long-term orientation remains substantial as a hampering factor in U-I collaboration, other factors especially those related to intellectual property (IP) and administrative procedures are indeed important factors in constraining collaboration. In fact, IP related barriers have seen as dominant obstacles in most U-I interactions due to policies designed to encourage universities to increase the commercialization of research outputs, as well as strategies over the negotiations toward IP have been carried more aggressively by the universities (Bruneel, d'Este, and Salter 2010). In regard to time factor, academic research that often emphasizes on in-depth investigation to ensure correct and substantiated conclusions are drawn has perceived by industry as slow moving and indifferent to the imposition of timescales (Barnes, Pashby, and Gibbons 2002). In addition, the issues related to exacerbate IP related barriers due to multiple collaborators also escalate both the time and costs demands to establish new U-I collaborations (Bruneel, d'Este, and Salter 2010).

In terms of the technology development – commercialization cycle, engineers, designers, R&D specialists and technopreneurs whom stem out from a broad array of scientific disciplines are encountered by unnerving bottlenecks within their strive to translate nano prototypes into fully fledged nano products that is ready for market penetration. In the field of nanotechnology, the role of academia and research is indispensable; and the role of industry is complementary to that of academia in pursuit towards realizing the ultimate goal of nanotechnology R&D and commercialization which is: bringing out marketable, successful and profitable nanotechnology innovations. Through academic entrepreneurship (which specializes on commercialization of science and that which comes in as third after teaching and research in the university in many countries around the world) – the protagonist role of a university can soon be connoted to that of a self-sufficient entity that will comprise their very own exclusive university spin off firms to run the commercialization process for the university. Although this is being attempted in many countries, there has not been any concrete evidence to suggest whether these university spin offs have in fact conquered the possibilities of what a separate yet established large industry has to offer. Till this phenomenon prevails, the U-I collaborations during the course of the technology development – commercialization cycle will need to cultivate a relationship of "symbiotic mutualism".

2.2 Revisiting the Foundation of U-I Collaboration and Its Sustainability

According to Balconi and Laboranti (2006), academia needs direction from industry for reasons because the proficiency of science is associated with intense collaboration with industry and which facilitates knowledge exchanges while simultaneously recruiting highly productive researchers from industry in the case of microelectronics. The authors' standpoint has perceptibly emphasized the prominence of industry compared to academia. However, the authors' comprehensive denotation of the argument tailspins to consider the fact that those highly productive researchers from industry were primarily an initial product and personification of a solid engineering specialization and foundation of academia. In the case of microelectronics, without a specialization in physics, chemistry and electrical engineering in a Masters or Doctorate programme, it is extremely unlikely to produce highly productive researchers in industry merely from training alone. The study also did not specify on how researchers from industry became highly productive without the prior intercepting years of academia. Kato and Odagiri (2012)'s findings disclosed that in the fields of life sciences and biotechnology in particular, the presence of educational institutions in related fields are a pre-requisite for U-I collaborations.

Lee (1996) professes a statement that "*lesser the fear of intrusion, the greater support of transfer; and the greater fear of intrusion, the lesser support of transfer"*. The statement made by the author "*lesser the fear of intrusion*" does not infer a "keep your distance" kind of collaboration but emphasizes a collaboration that infuses closeness whereby industry respects the core values of what academia has to offer which is: education, research and integrity. Nevertheless, the author's expression towards the need for "less intrusion yet close proximal and value respecting collaboration" indirectly suggests that "a certain level of interactive balance" need to be fortified between industry and academia. Yet, how this balance could be realized was not spelt out by the author. Four years later, Lee (2000) concludes from a study conducted based on US soil - that despite the differences that exist between them in terms of technology and knowledge transfer, the overall level of experiences derived from both sides is positive resulting in the continuous collaboration between two parties; but however refers the collaboration to that of "*street level interaction*". The "*street level kind of interaction*" declared by the author unbolts opportunity for further argument as to whether or not the author connotes the collaboration to that of a non-bureaucratic or bureaucratic relationship. Non-bureaucratic interaction personifies flexibility and bureaucratic interaction personifies inflexibility. In the same time, Boardman and Ponomariov (2009) show that there is a positive relationship between behaviours expected of university scientists - such as conducting government-funded research and supporting graduate students - and interactions with the private sector but not in an entrepreneurial capacity. The positive relationship between the two parties as emphasized by Boardman and Ponomariov (2009) is validated by the show of little evidence of conflict between the two parties. In terms of lack of entrepreneurial capacity as pointed out by the authors - even though university research centres are enthused on applied and commercial research, the predisposition to absorb the risks and costs associated to that of a business venture with the private sector is not discernible.

In line with this affirmation, Giuliani and Arza (2009) stress that while knowledge from university is essential in the direct and indirect dissemination within industry, there is opportunity costs involved in researchers forming linkages with industry. The author also emphasizes the need to focus on the factors that drive valuable linkages rather than the U- I linkages per se. In light of the foregoing, the analysis of Perkmann et al.(2013) conducted through a series of literature review on academic engagement and commercialization concludes succinctly that (a) there is a deficiency of understanding about the costs of academic engagement within these collaborations, (b) research on U-I interaction has strongly focused on the role of TTO's and due to this have made policy makers to resort to technological transfer operations at universities, (c) firms be well – equipped in collaboration apart from the fact that there has been a higher volume of emphasis on engagement activities rather than patenting and entrepreneurship and finally (d) the general perception that academic science is a discrete institutional order that differs from industry in the basis of academic norms, values and conventions. However, the analysis made by Perkmann et al.(2013) does not pin point specifically to any particular field of technology or sectors of the economy per se but sheds light on the many studies conducted in pursuit towards attaining a selective and extractive yet discretionary analysis that assist in developing future academic research agendas in terms of academic engagement and commercialization.

3. Methodology

Ten in-depth qualitative interviews were conducted. Four of the participants were chosen for their fine blend of both industry and academia put together; whereas six of the participants were purely from academia. Each participant was contacted via email explaining to them the purpose of the nanotechnology study. Each participant was interviewed one to one separately at their own premises. The time taken for each interview averaged between 70 and 90 minutes. Depending on the area under discussion, economic sector, organization and area of expertise of the interviewees, technical and non-technical form of questions were meticulously planned and outlined prior the interview. Interview data were recorded with the permission granted by each participant prior to the interview and each recording was transcribed into computer files. Each of these participants had expertise from various fields of sciences such as nano materials, nano advanced materials, micro engineering, nano electronics, catalysis, nanotechnology and combinatorial chemistry, mechanical engineering and nano structured materials.

Each participant was asked an average of between 20 and 25 interview questions depending on the length of their responses and time available. Interviews were conducted using an "open ended" approach whereby the questions were not worded in exactly the same way with each participant. The participants were open to respond in their own words; that which paved way to a more complex and multifarious form of responses that went beyond than a mere "yes" or "no" (fixed responses). As a researcher, I had the opportunity to respond and probe immediately to what the participants had to say by crafting subsequent questions to information the participants had provided. Listed below are the selected key interview questions:

- How can strategic partnerships ensure long-term sustainability in the field of nanotechnology? How will the universities' management know if the strategic partnership is in fact actually working?
- What are the several engineering challenges that slow the progress or lengthen the time factor between R&D and commercialization of nanotechnology? What are the possible engineering solutions performed to solve the dilemma and any risks and uncertainties that need to be addressed in pursuit of these solutions?
- To what extent are strategic partnerships doable and how long will it last? Does the publishing and patenting activities hinder the commercialization process? Do you think there should be a separation between these two?

4. Findings and Discussion

4.1 Distinct Logics and Priorities

The U-I collaboration which personifies the dual performing roles of both university and industry is individualistic in their endeavours and priorities. Being an emerging technology, nanotechnology is a field that is heavily research based and therefore, places the research driven entity as a major heavyweight in this partnership. In most developing countries, the core research driven entity lies within the realms of academia where basic research on nanotechnology is still warming up itself; and in some developed countries, in which most part of it is predominantly confined within the realm of industry where applied and commercial research have reached its peak. As one researcher puts it, "*When academics do research on nanotechnology, it is not that they will come out with commercial product immediately. This is not logical or possible.*"

Indeed, U-I partnerships will be futile if ever the priorities of both academia and industry move towards two separate directions. It is a known reality for many years that academia's focus was towards teaching and research, where universities are recognized and the industry's forte was geared towards commercialization. The role of university is personified to that of another form of industry, involved in the production of research publications, which, in part, if not entirely have contributed to the commercialization process. This remains to be given a substantial amount of priority by academia and have been used as one of the performance indicators in the university ranking system to boost the academic's profile. However, the cruciality of its offerings does not halt in the form of paper alone; a matter of fact the state of its findings has also been converted into commercial reality. Nevertheless, this remains an area of less importance to that of the industry, which prioritizes more on commercial output, rather than the act of collaborating to assist researchers to disclose pertinent findings in the form of publications prior to patenting and commercializing the product. Such data revelations are disastrous to the mission of the industry; resulting in the industry and academia unwilling to see eye to eye in their own individualistic, but yet egotistical priorities. These two-way opposite directional priorities are what disables the mere fortification of U-I collaborations and, that which "dichotomizes" the notion of actual nanotechnology sustainability. This phenomenon interferes with the possibility of transition of nanotechnology prototypes into the realm of commercial production and eventually causes the transfiguration to lag behind and prototypes to sit in the shelves.

The rudiments that arise in the form of market needs, places the industry at its "mercy" and thus leaves the industry with no alternative, but to incessantly trigger the role of academia in pursuit towards supplementing for the market opportunity that exist for that particular pre-prototypal invention; to the extent of assuaging the current consumer market environment. In the event of this ongoing perspective, the collaboration that spells out explicitly the requirements through prior arbitration and negotiation propels academia to not only nurture experimental and cognitive researchers, but to boost the recruitment of highly productive researchers from university to stretch and augment their capacity through sufficient scientific and engineering practice from the industry. If a partnership is to be existent, both entities should be able to subsidize each other with their forte contributions, whether in scientific or technology management, in order to sustain the field of nanotechnology.

4.2 Patents and Commercialization

The distinct focuses and priorities of academia and industry are clearly witnessed in the patents and its' commercialization. A researcher comments, "*Let's say if there are 100 IPs, only 5-10% gets into commercial production'*. In the same viewpoint, another researcher remarked that, "*The patenting issue also enters the debate. Patents are a sign that innovation has taken place. If there are many patents in the country, then some of them will become commercialized".* For this to result, it is not merely or solely dependent on the strength and the knowledge of the research academician or the industry partnership itself; it is also contingent upon the market and the cost of converting the prototype into a product. A positive or negative deviation that either progresses or retrogresses the market dynamics, which revolves around the nanotechnology products consumer market is a result of fluctuating consumer requirements that arises from a resilient product competitive advantage that contemporaneously co-exists in the field of nanotechnology. Unless inventions have been prototyped in advance in conjunction with the needs of customer requirements, viable industry production costs and conceivable production mutability, patents are futile to the acuity of industry's commercialization of science but are seen as an affirmative augmentation to the researchers' academic performance index and university ranking system. These patents is a positive indicator that innovation has taken place, but does not prove as a positive indicator that, that particular innovation will be 100% absorbed for the purpose of commercial development.

Industry intervention that exists right from the beginning of the conception of its invention will enable mutual and shared patenting rights between industry and academia; that which will eliminate any incongruences pertaining to the "protective disclosure" of germane engineering and production information. Thus, "technopreneurial" knowledge of the nanotechnology consumer market and the industry production costs, prior to any development of a nano prototype, can stir patents (after reaching the post development stage) into the direction of commercial production. The "technopreneurial" knowledge that descends from the fastidious consolidation of science, technology and management disciplines embedded within the U- I collaborative network will be able to ensure the sustainability of nanotechnology.

One professor remarked, "One should not forget that the university is also another type of industry – an industry that is not only for the purpose of disseminating knowledge but also for boosting up the number of publications." They can do both patent and publications. However, the universities need to give prominence to patenting. Universities should be able to come out with a weighted equation that measurably communicates the ratio of importance of both publications and patenting, in order to incentivize academics to place auxiliary importance towards patenting, as compared to publishing or at equal footing. However, it will be challenging to incentivize, let alone impetus the industry to demonstrate their flexibility towards academics to publish their findings prior to patenting or commercialization of their products. Nevertheless, there can reach a consensus to provide academics the immunity to publish their findings evanescently phase by phase via "stretching" the publication process until a definite sign of commercial output can be realized. Another researcher puts it that, "Patent are normally into the application, design, composition and methodology; whereas scientific publications are more towards understanding". However, publications have been in some scenarios treated as an input for commercialization. Therefore, partnerships need to recognize the two.

4.3 Time Factor

Every U-I research collaboration is subjected to a time frame, whereby if the necessary deliverables are not achieved within the stipulated period, then the partnership is said to have failed in its mission and perforated its core purpose of its establishment. Nonetheless, if it is the other way around, whereby the necessary outputs are achieved within the definite period, then the partnership is said to have met the needs of its mission statement and is esteemed as a euphorically acclaimed success, considering the amount of defiance faced to get to that juncture. The multidisciplinary field of nanotechnology represents itself as a field that cannot be pigeonholed with other technologies, due to its atypical characteristics and complex technicalities. The knowledge of comprehending the amalgamation of scientific procedures involved in nanotechnology, that ranges from the knowledge of diverse scientific disciplines will sufficiently be equipped in predicting the length of time required for the execution of these processes. As one professor puts it, "*It varies from field to field. For medical, it would take around 10 -15 years because they have to go through the health and clinical testing and acceptance. In contrast, let's say for biotech, oil and gas, it would take around 7 years. Even though, venture capitalist would want it to be 2 – 3 years, there should be all kind of help to make it to 3 years to reach the market. But 5 years is reasonable for most products".*

The challenges that contribute to this time factor mainly reside in the area of pre-commercialization or specifically pre-production. The emerging cordons that evolve from continuous nanotechnology research interrupt the planned timeline, whereby bottlenecks that arise are given higher priority of fulfilment by scientists and researchers rather than fulfilling the opposite entities proposed and expected finish timeline, which involves satisfying venture capitalist and investors. These emerging cordons are inexorable and are bound to take place but are soluble; however, the duration of time required to resolving these impediments can't often be prophesied due to the inability to predict the intensity of these predicaments prior to the beginning of R&D. The level of intensity and magnitude of these predicaments is what contributes to the time factor. Furthermore, each process within the multi phased R&D are closely linked and are inter-dependent; meaning which the unresolved bottlenecks that arise within each process will inevitably cause the consecutive processes to become unstable resulting in the entire project to crash prematurely.

4.4 Product Safety

A researcher provides a point that, "The public perception is nano safe. Sometimes the product may be ready for the market, but the market acceptance may not be there because of the fear of the unknown. It takes another group of people to work on the awareness, safety and health issues of nano products". The threshold of any prominent product offering is to embark towards the preliminaries of innocuous product utilization for the wellbeing of the potential consumer; resulting in market readiness being subjected to the absolute orthodoxy of safety regulations placed on a newly declared product prior commercial release. The public knowledge of nanotechnology is not to be overly estimated or taken for granted since the principal responsibility lies in the hands of the "product releaser" who declares the product as nano safe. Nonetheless, it also hinges on at what percentage of nano component is embedded within the product itself, which correlates to what kind of level of exposure and level of detriment it interposes itself to the utilizer. The processes that are required to conform to awareness, safety and health related issues of nanotechnology are multidisciplinary; in the sense that the impacts that unfold from different facets of its sub disciplines are different in nature and subject to various scientific interpretations; that which conclusively defines the level of hazardousness or non-hazardousness of nanotechnology products for consumer utilization.

The predominant aura of these processes makes nanotechnology to be treated with added caution compared to other technologies due to the added thrust of negative ambiguities placed upon it; and thereby resulting in the augmented need in the level of awareness and extra stress placed on safety and health issues. The pertinence of these processes in the course of nano product development becomes the epitome and "central crust" of any U-I collaborative debate related to nanotechnology and thus requires its fullest consideration and responsiveness for the sake of its sustainability. As one researcher puts it, "*It also has to do with the robustness of the technology".* There are also the engineering challenges that can hinder the sustainability of nanotechnology. As one researcher puts it, "*For example, in nano electronics, the difficulties endured when it comes to the nanoscale is getting the reproducibility in characteristics in the electronic device. To make one transistor to repeat with another transistor – in the sense to make it uniform, that is a technological barrier. This is because the physics at that size - is hard to get it very regular".* It also depends on the workability of the technology.

4.5 Product Functionality and Capabilities

The element of product functionality lies within the cortex of its engineering ingenuity, which underlines the originality and uniqueness of each product identity. In the case of nanotechnology products, it is the nano embedded material or component, which authenticates a product from its non-nano product adversaries. Therefore, any nano prototype which becomes the experimental output of scientific fields or sub disciplines of biology, chemistry or physics is subject to undertake a series of engineering mechanisms. This series of engineering mechanisms are piloted during the development of the prototype and also performed during the industrial production manufacturing, which is post R&D. During the development of the prototype, the engineering mechanisms are basically focused on only a single prototype per se. On the other hand, during the phase of industrial production manufacturing, these engineering mechanisms focus on mass production that eventually result in the reproducibility of a single prototype into many numbers. Therefore, the tangible challenge lies in the mutability of a single prototype that needs to adhere to the exact uniformity of the original prototype which eventually burdens the stage of "product regularity conformance" due to the miniaturization of its nano scale.

For instance, as one professor puts it, "When you develop the technology, normally you come out with 2 – 3 prototypes, but when you go commercial, it has to be 1 million – 20 million. You need to have that volume. Production of large volumes is a challenge especially at reasonable cost and high quality". To add support to this point, a researcher comments to say, "It is easier to make them at small scale but to make at a large scale would be difficult in terms of the reproducibility". In a similar tone, a professor explained, "When you do a small number, you can control the parameter. You can make sure the performance is at a certain temperature; whereby you can "twig" (optimize) your recipe so that it will meet the requirements. But if you do 1 million, you don't have all the time in the world to make sure that every single device is "twigged" (optimized). While reflecting on this finding, one researcher provided a more open view point stating that, "It is the procedure that makes nanotechnology complex".

There is a lot more physics that goes into it whereby researchers even experience certain processes happening outside the ordinary. Therefore, the researchers' knowledge, skill and experience are greatly needed to circumvent errors and to intelligently incorporate certain problem-solving methodologies. The problem-solving engineering methodologies related to nanotechnology are very much a "staple part" of knowledge within the R&D ménage to the extent of which when experientially gotten to grips with - can determine the smooth transition of the R&D endeavour and rapidly cope with obtrusive protectorates that can plausibly cause the entire project to fall victim to. Therefore, the selection of an impeccable medley of trouble shooting engineers by key stakeholders of the U-I collaboration can precipitate the process of continual re-engineering of nanotechnology products and thus contribute towards the long-term sustainability of this technology.

Industries are in a constant look out for parties that can offer ground breaking ideas that can help them take their business to greater heights. However, as another interviewee puts it, "*……there should be continual activity together*". This should be mandatory in any kind of U-I partnership. Continual activity merely means constant communication and productivity. Another common problem in U-I partnerships between industry and university is, as one interviewee puts it, *"The university professor puts everything on the table. But the industry does not have the expertise to translate those findings into products because normally what you get from these professors are loads of data, graphs………..But how do you translate those data, graphs, information into something more tangible…. into something that you can sell".*

Therefore, what the industry needs is competency. One is hard work to make the U-I partnership continuously and productively working and the other one is the knowledge encapsulated within each stakeholder of the partnership in order to benefit from each other's contribution. Furthermore, each output from the individual parties need to be periodically monitored. Once all this is properly entwined, that would be the right thermometer to measure whether these partnerships are actually outputting. It is more effective to have market penetration when there is a pull rather than a push because as one researcher puts it, "*By viewing the industry as the off-taker, you can work in a push concept or a pull concept. If the industry identifies where exactly their need is, then the universities should work in support of these needs. That would be better".* Rather than universities saying, "*Look, I have a nice prototype. Do you want it?"* On the contrary, the industry should approach to say, "*Can you work on this prototype that has this particular property in it?"* Based on these findings, the pull concept is much preferred than the push concept. In terms of its longevity, as one researcher puts it, "*Once the product has been developed to a certain level and once the product has been taken up by a firm, then generally it's all dependent on the firm to drive it*".

5. Conclusion and Policy Implications

The true genesis of a U-I collaborative partnership originates from the exhaustive need to partake in the knowledge and technology transfer of pertinent assets available from each side of the treaty and that when is profusely channelled asynchronously will ultimately accomplish the core purpose of the treaty establishment. Nevertheless, the final product that eventually surfaces from the cross inclination of both parties towards the projected outcome is often imminent but far reaching due to the highly prioritized ambitions of individual entities. Nonetheless, the fulfilment of these priorities is the central sphere towards the sustainability of nanotechnology because they define the two opposite extremes, which are hard core R&D and technopreneurship that ubiquitously determine the fate of this technology. The repercussions that follow from the under settling intentions between university and academia can cement the possibility of any successful nano prototypes from envisioning. Hence, deep-down deliberations associated to the transitional blue print of prototypes into products and their corresponding spin off effects need to be capitulated by both entities in advance prior to the commencement of any R&D endeavours.

From the findings, it is evident that the expected yield is to be the product of continuous re-engineering performed iteratively rather than "fast track" results achieved within a short period of time and which do not ensure innovation quality resulting in the planning of a realistic and representative time factor between research and commercialization by university and academia. Graduate student exchange coming from the academic platform into industry is not merely shaped to provide for the needs of the industry alone but also to be at the receiving end to "exploit the intangible profits" that arise from the use of highly equipped infrastructure and application personnel - the phenomenal relationship that can only occur with a high technology firm which parallels to that of a graduate student exchange in terms of production engineers, designers and state of the art nanotechnology equipment. The misapprehension that need to be set aside concerning all patents on the other hand is that it's not necessarily 100% commercialized due to the non-existence and non-participatory role of the industry prior and during the conceptualization and development of the prototype that results in the domino effect of unfeasible specifications and high ceiling cost that are not viable in the real time production world. Many prototypes are found sitting in the shelves as a result of this and patents are not readily absorbed and taken over by the industry.

However, this augury is reversible once the prototype is initially developed in accordance to the industrial market prerequisites, which thwarts the domino effect of unfeasible specifications and unreasonably high ceiling production cost. This augury is also reversible once the protagonist roles of a university become that of a self-sufficient entity that can consist of their very own exclusive university spin off firm to run the commercialization process for the university. Time factor is pervasively making its mark as an impelling part of the R&D and commercialization landscape to the extent of offering a measurement of the level of rapidity or non-rapidness of processes that need to fulfil the expected timeline regardless of the level of attainment of desired outputs. However, the tendency of the time factor to "withdraw itself from the expected timeline" is a result of the "out of the blue" intensity in the level of impasses that arise from the execution of these processes within the R&D and commercialization milieu. This presage can be deleterious if there is a deficiency of core knowledge and skills of problem-solving nano related impediments that can be utilized to circumvent the possible externalities and internalities that surround these unpredictable deadlocks. The concept of nano safe is a form of a "branding" that comes with the territorial standards of assurance, which certifies whether a product is anodyne for consumer consumption. Considering that the term nano still remains just as a buzz word for now, the publics' "parboiled" knowledge of nanotechnology is derisory to be capable of discretely weighing the negative likelihood that might ascend from the consumption of nano embedded products and how it will impact their daily lives; resulting in ambiguous information being misconstrued. Nevertheless, whether the public is sentient or not, this still leaves the product safety regulators fully liable for any anomalies that arise from its product usage and to consequently address safety and awareness issues pertaining nanotechnology through a more serious approach.

Therefore, with the aim of strengthening nanotechnology safety preventive measures, U-I collaborations will need to impose its fullest obligation in response to the percentage of nano components and materials embedded in a product deemed as a nanotechnology product and to the level of exposure it interposes itself to the consumer as an outreach towards attaining nanotechnology sustainability. This frequencies in trajectory with the selection of an impeccable medley of trouble shooting engineers by key stakeholders of the U-I collaboration who will be able to precipitate the process of continual re-engineering of nanotechnology products and thus contribute towards the long-term sustainability of this technology. The scenario in which heaves both entities into the non-communal and contradictory directions that navigates towards the expanse of patenting and the other into the expanse of publishing can be incentivized to demonstrate the flexibility in each other's priorities. Apart from these nuances, what can be ascertained is that the extent of which can propel academia towards the solvation of confounded hitches within the industry's quandary can also complement the extent of which can propel the industry to unearth the capabilities of academia; resulting in academia to shift from the safer inner boundaries of mere academic pursuit into the outer boundaries of untested yet prolific nanotechnology emerging postulations. The extent of these thrusts when being submerged within the U-I collaborative partnership can ensure the sustainability of nanotechnology. The deficiency of shrewd business acumen within the academic capacity does not entirely stagger its position within the collaborative partnership that moves in pursuit towards the commercialization of a nano embedded product. In fact, academia which is deeply entrenched within the realm of basic research is indispensable in the forefront towards maximizing the potential of an emerging nano product because the unpredictable yet dilemmatic intensity of predicaments that arise at the stage of application research is bound for "continuous backward re-engineering" in order to "smoothen up the rough ends".

Entwining the ideals sheathed within the protectorates of academia and industry reinforces the principles needed to attain the diversified form of hybrid required for the sustainability of nanotechnology. This means apart from the educational spinoff effect that emanates in the form of knowledge and technology transfer, that in which moves asynchronously back and forth from academia to industry and vice versa, is the training of low to high skilled production and manufacturing workforce based on training modules that can be conjointly formulated by both knowledge based and industrial based frontiers in order to mutually educate an assortment of nanotechnology workers from both sides of the end streams. Henceforth, the essence unfolded through this research paper is to justify that U-I collaborative partnerships can ensure the sustainability of nanotechnology if only the channels through which both entities transport their individual capacities are executed through approaches discussed in this paper.

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