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Responsibility in Commercializing Emerging Technologies in China: Early Evidence from Synthetic Biology

Xiao Liang
University of Manchester
Alliance Manchester Business School
xiao.liang@postgrad.mbs.ac.uk

Abstract

Abstract Responsibility in Commercializing Emerging Technologies in China: Early Evidence from Synthetic Biology Xiao Liang Alliance Manchester Business School, University of Manchester, UK PhD in Business and Management, 2014-2018 xiao.liang@postgrad.mbs.ac.uk This paper explores the development of business responsibility in emerging technology innovation eco-systems in China by examining early evidence from the growth of the Chinese synthetic biology sector. The role of government has been addressed in promoting responsibility in emerging technology innovation eco-systems, with existing research mainly discussing top-down policy perspectives in developed countries. This paper, however, sheds new insights on responsibility by integrating bottom-up perspectives of companies with indigenous Chinese emerging technology innovation eco-systems. This is achieved by investigating company perceptions and implementations when government advocates a less direct interference approach. Primary data collection was conducted through elite in-depth interviews and in-depth seminar observations. Secondary data was mainly obtained from government reports and industrial databases. A total of twenty-six interviews were conducted, with the majority of which were from nine companies and eight other stakeholders. Findings indicate that company value is one of the main driving factors in shaping perceptions of responsibility and its practices. In addition, less direct policy approach leads to more uncertainty and instability for companies, it however, incubates diverse ranges of interpretations of responsibility. Policy implications based on the findings include that formalizing responsibility baseline standardization for the industry; that cultivating bottom-up responsibility research and innovation culture in the eco-system and that facilitating responsibility implementations by promoting industrial examples.

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Key Words: Responsibility, Commercialization, Emerging Technology, Synthetic Biology, Governance, Chinese innovation eco-system

1. INTRODUCTION

This paper discusses the early evidence of responsibility practices in Synthetic Biology sector in China.

The rapid development of synthetic biology arises societal concerns globally, in particular among those countries who are global players in synthetic biology industry -the U.K., US and China. With technology assessment and societal aspects research well established in western countries, how does Chinese emerging technology industry perceive responsibility practices still remains mysterious. Given the context of widespread public resistance of GM and adequate concerns of nanotechnology, it is necessary to investigate how does Chinese emerging technology industry practice responsibility in the given context, if to advance the development of synthetic biology.

The first section of this paper discusses the different approaches that businesses and research institutions use for practicing responsibility the past and the current, which followed by that section of why synthetic biology is chosen as the case for this paper. The following section then looks at the Chinese invasion eco-system for synthetic biology sector and deliberates how companies perceive and practise responsibility with one sample case study. Last but not least, the paper ends with a discussion and potential implications.

This article intends to answer the questions of how do Chinese companies in synthetic biology sector perceive reasonability; how do Chinese companies in synthetic biology sector practise responsibility and how does Chinese innovation system influence these practices. Please note this paper is part of my PhD thesis, which is a comparison study of responsible innovation practices and commercialization of synthetic biology sector in both the U.K. and P.R. China.

This paper contributes to the literature by investigating how companies in emerging technology sector practice responsibilities in the context of the historical failures-GM and the new appear of technology assessing approach-RRI; it also contributes to the practical aspects by drawing portfolio profiles of Chinese industrial responsibility practices.

2. LITERATURE

Practising responsibility in science and innovation has long been addressed in the literature. One aspect of which is engaging science and innovation with the public and other actors in the society in the decision making, process, therefore, shape innovation and plan future innovation towards the future-proven direction aiming at solving grand challenges, serving human well-being (RRI Tool, 2013). Underlying this principle, some new social science concepts have been brought up in debates as to fulfill this purpose, including responsible innovation and research (RRI) (European Commission, 2008b; European Commission, 2008a; Commission, 2004; Owen et al., 2012; Owen & Goldberg, 2010). However, practising responsibility in emerging technology sector is not as straightforward as it may seem-the complex frameworks of societal responsibility complicate the situation. This section intends to clear out the frameworks of societal responsibility and introduce the new trendy RRI.

The conversational technology assessing approaches all root in stakeholder theory (identifying stakeholders), role allocation (planning and engaging individuals as well as management board), multiple perspectives in the decision-making process to ensure the openness and multidiscipline in the final solution. They differ, however, in many ways. Future-oriented analysis (FTA) (Cagnin and Keenan, 2012), prioritises solving grand challenges, covering a mixed conception of technology prediction, technology assessment as well as scenario theory. Its principle of multiplicity participation, multidisciplinary and future-orientation (future can be reoriented by the decisions taken today) enables creating new capabilities of understanding public; e.g. improves decision by meeting societal exceptions rather than simply assuming characterises of public (Cagnin et al, 2012). The role of FTA can be seen as informing, structuring and capacity building in technology diffusion (Barre and Keenan, 2008). Technology assessment-the long-existing concept (Ely et al., 2011) - is similar to FTA. It forecasts and assesses the impact of technology design, development and implication, to, therefore, minimizes the costs of mistakes of adopting new technologies (Schot & Rip; Brooks, 1976). It as argued can solve the technological "Collingridge control dilemma" - "Attempting to control a technology is different, and not rarely impossible, because during its early stages, when it can be controlled, not enough can be known about its harmful social consequences and warrant controlling its development; buy by the time these consequences are apparent, control has become costly and slow" (Collingridge, 1980, p19). If TA is implementing effectively, then there should not be any dilemmas (Schot & Rip, 1997) (Grin & Hoppe, 1995; Reuzel, Van der Wilt, Ten Have, & De Vries Robbe, 199). Though both of these conventional approaches have their emphasis on technological implications, with lack of detailed narratives and

guidances, these conventional technology-assessing approaches have not been seen very much discussed in industrial context. RRI, however, is slightly different from the conventional approaches with its reflective aspect. In this research, we adopt the definition with the boarder vision to fit in the innovation eco-system discussion, which is as following: *“Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present. (Stilgoe et al., 2013)”* Under this definition, the principles are Anticipation, Reflexivity, Inclusion and Responsiveness. (Stilgoe et al., 2013). The principles can be used in industrial and researching context, for instance, it has been used in European and International “code of good conduct” agreement on Nanotechnology development (European Commission 2008, 2009), American 21st Century research and development act on Nano (2003), industrial projects (stage-gate guidelines) (Stilgoe et al., 2013, p.3) (Hamarat and Pruyt, 2014).

The Reflexivity of RRI enables companies or research institutions to reflect on their projects and take actions to implement or reject the projects before any actual actions happen, which can be found in my of my Chinese cases. Traces of other societal frameworks can also be found in my Chinese case studies, such as CSR (Corporate social responsibility)¹ and Triple Bottom Line Theory². One of the interesting factor to pay attention to is the way companies communicate their responsibilities with customers. In CSR literature, customers’ behaviours are responding to CSR in various ways. Customers seem have shown hesitation when purchasing products from companies who conduct CSR. Doubt lies in the concerns that companies are conducting their CSR activities mainly based on the participants of achieving higher financial performance (Mohr and Harris, 2001). Consequently, how to communicate with customers is complicated. In addition to that, communicating with customers is vague as technology especially emerging technology such as Nano and biology, could provoke “phobia” towards technology depending on their understanding of technology, which is shaped by media, experts as well as their personal life experience (Simpon and Gillis, 2006). A balancing approach enables companies communicate their technologies, responsible innovation and CSR with their customers is needed. Thus, this is investigated in my Chinese case studies.

¹ The origin of corporate social responsibility concept was very blurry and broadly associated with social responsibilities, business ethics, stakeholder structure theory and corporate citizenships (Harrison & Freeman, 1999; Waddock et al., 2002; Whysall, 2004; Matten & Crane, 2005; Shinkle & Spencer, 2012) as early as 1940s (Bowen, 1953), when Fortune magazine interviewed enterprises about their perceptions in terms of their social responsibilities (Garriga & Mele, 2004) (Mohr, 1996; Carroll, 1991) (Kotler, 1991; Perkus, 1992; Woodruff, 1992).

² The triple bottom line theory addresses on the notion that companies keep sustainable balance in three realms: economical, societal and environmental. Sustainability in this concept refers as long-term maintenance of balance. The biggest difference between triple bottom line and CSR is that triple bottom line is more European rather than American. Another theory: Stakeholder theory is developed by Edward Freeman, it investigates and describes the individuals or groups who interacts with cooperates, wherein the five cardinal stakeholders are company’s shareholders, workers, customers, suppliers, and community (including human community as well as environmental community) (Brusseau, 2012).

As will be discussed in this section, current responsibilities embedding approaches are mainly explored in research environment rather than industrial environment, where commercialization is usually prioritized given the fact that industrial organizations are profit-drive. Little has known in relation to the responsibility practices in industrial environment, especially in the balance between commercialization and societal concerns. More evidence is needed to engage responsible innovation in both R&D activity level as well as corporate strategic level. Thus, to explore the embedment of responsible innovation and research at industrial management level, in particular in the balance with societal concerns. This study intends to draw a profile of approaches used by companies to practise responsibility in emerging technology sector.

Additionally, the role of government has been advocated as important in promoting responsibility emerging technology innovation eco-systems. The Chinese government, however, advocates a less direct interference approach. This study also investigates the impact of Chinese government on industrial responsibility practices.

3. CHINESE INNOVATION SYSTEM FOR SYNTHETIC BIOLOGY

Overview

Researchers and the Chinese government have realized the importance of developing synthetic biology and are facilitating its development through various activities such as funding researches, and incorporating into government plans.

The earliest literature of synthetic biology in Chinese is at 2005 by Lin Qishui and followed by other literature discussing the emergence and potential of synthetic biology (Lin Miao; Duan Haiqing; Shen Huipeng; Zhao Xue; Wang Qinzhao). The first national formal synthetic biology seminar was later on held at Tianjin University at 2008, where the concept of synthetic biology was introduced by MIT Prof. Drew Endy and Caltech Prof. Smolke. At the same year Chinese undergraduate students started to involve in iGEM competition, as there were three iGEM teams separately from Tianjin University, Peking University and Tsinghua University participating. With the arise of awareness around world, especially after the UK government published its Synthetic Biology Roadmap, Chinese government identified Synthetic Biology as one of the six strategic technologies to focus on for long-term technology development. Many conferences were conducted in the past few years in China, discussing how synthetic biology should be further explored. In February 2008, the Xiangshan Conference on synthetic biology was held and it was the first of its kind in China. In July 2009, the Key Laboratory of Synthetic Biology of Chinese Academy of Science (CAS) organized a forum on the design of drug and energy products based on synthetic biology techniques (Zhang, Chang, & Wang, 2011). More forums were held in the following years, where experts and scholars were invited to discuss the current status and development strategies of synthetic biology, with the aim of promoting its further prosperity in China. Societal aspects have been considered and paid attentions to during technology and science leadership seminars, in line with European and USA societal impact discussion agendas. However, there is no evidence indicates that Chinese government has established a innovation system or designed explicit policies for Synthetic Biology, in particular for research funding, technology transfer policy as well as responsibilities.

From policy guidance perspective, there is no specific evidence indicates Chinese synthetic biology road map will be published in the future. Additionally, there is no funding institution or departments established especially for synthetic biology. Companies cannot apply for any specific funding in the name of synthetic biology nor can they receive any specific policy benefits. Therefore, though synthetic

biology is one of the six strategic technologies identified by Chinese government, a well-established supporting mechanism is urgently needed for the development of synthetic biology. On the other hand, universities are working closely with industries, but activities are very limited within the R&D domain. Judging from the big picture of landscape, China has not yet established an efficient eco-system for supporting synthetic biology development.

Synbio Map and iGEM Participation

There are mainly four universities who are training students with synthetic biology course and having labs for synthetic biology in particular. These universities are Tianjin University who is the first university in China to build up iGEM team; Peking University; Tsinghua University and University of Science and Technology of China. In addition, there are 5 research centers have been established by Chinese Academy of Science and one state lab (State Key Laboratory of Microbial Technology at ShanDong), in total there are currently there are more than 15 institutes that have projects focused in this field. The list below shows the CAS labs with financial support from Chinese Government.

Institute of Plant Physiology & Ecology, SIBS, CAS (Shanghai)

Shenzhen Institutes of Advanced Technology, CAS (Shenzhen)

Guangzhou Institutes of Advanced Technology, CAS (Guangzhou)

National Centre for Gene Research, CAS (Beijing)

Tianjin Institute of Industrial Biotechnology, CAS (Tianjin)--National Engineering Laboratory of Industrial Enzymes

Other research labs are mainly located at the universities where iGEM teams exist. Detailed information please refers to the map below.

iGEM Team Name		University/Location
1	SCUT	South China University of Technology , Guangzhou, Guangdong, China
2	SJTU-BioX-Shanghai	Shanghai Jiao Tong University , Shanghai, China
3	SCAU-China	South China Agricultural University , Wushan Road, Tianhe District, Guangzhou City, Guangdong Province, China
4	XMU-China	Xiamen University Xiamen, Fujian province, China
5	Nanjing-China	Nanjing University , Nanjing, China
6	NJU-China	Nanjing University , Nanjing, China
7	SUSTech_Shenzhen	Southern University of Science and Technology , Guangdong, China

8	Jilin_China	Jilin University , Changchun, Jilin, China
9	SYSU-CHINA	Sun Yat-sen University Guangzhou,Guangdong,China
10	Fudan-YuFeng	Fudan University , Shanghai, China
11	Tongji_Shanghai	Tongji University Shanghai,China
12	Tsinghua	Tsinghua University , Haidian District, Beijing, Chin
13	SCU-China	Sichuan University Chengdu, Sichuan, China
14	TJUSLS_China	Tianjin University Tianjin,China
15	Fudan	Fudan University Shanghai, China
16	Tsinghua-A	Tsinghua University Beijing, China
17	JSNU_CHINA	Jiangsu Normal University , Xuzhou, China
18	XJTLU-CHINA	Xi'an Jiaotong-Liverpool University Suzhou, China
19	BNU-China	Beijing Normal University Beijing,China
20	SYSU-MED	Zhongshan School of Medicine , Sun Yat-sen University
21	TMMU_China	Third Military Medical University , Chongqing, China
22	ZJU-China	Zhejiang University Hangzhou, Zhejiang, Chin
23	SYSU-Software	Sun Yat-sen University , Guangzhou, China
24	SZU-China	ShenZhen University ShenZhen CHINA

Biotechnology Industry Funding

There is no funding institution or departments established especially for synthetic biology. Companies cannot apply for any specific funding in the name of synthetic biology nor can they receive any specific policy benefits. Therefore, though synthetic biology is one of the six strategic technologies identified by Chinese government, a well-established supporting mechanism is urgently needed for the development of synthetic biology. Additionally, comparing to UK, more universities should pay attention to cultivating synthetic biology talents for future purpose. However, companies can apply through high-tech project funding, green goods funding, returnee starting-up funding and on if eligible.

Regulations

Though there is no specific regulation on synthetic biology, Chinese government (Ministry of Agriculture) published “Regulations on Administration of Agricultural Genetically Modified Organisms Safety” regarding assessment over exporting and importing GMO at 2001 (MoA, 2001). Synthetic Biology Project therefore predict that further regulations or policies could be issued over synthetic biology given the fact that synthesized organisms are included in GMO category.

The most updated dialogs on synthetic biology regulations, especially on social aspects are seen at Xiangshan Conference and within conferences within Ministry of Technology, yet no agreement has been reached nor any decisions have been made over synthetic biology. The most recent official documents that we could refer to as a regulation guides are the published notes from Ministry of Technology internal conferences, which have also be cited by social scientists such as the another of “Discourses on Synthetic Biology in Europe, India and China” (Xiangshan Conference, 2015).

Chinese Roadmap

The roadmap has not been published yet and has not yet been confirmed of its publication in the future. The first draft was initially announced by the President of Department of Basic Research of Ministry of Science and Technology, at the synthetic biology workshop of US, UK and China, 2012.

Drafting roadmap was initiated together by government and scientists, originating from the idea of promoting synthetic biology and positioning its strategic status in a 5-year plan. Scientists from 973 project and 863 project, as well as people from industry (by invitation) are involved in drafting roadmap. The entire drafting process was carried out through several seminars. By now the roadmap has been updated and re-fined for 3 years and yet not been published. Thus, a popular question among Chinese synthetic biology scientists is about its publication date. Yet, there is no evidence of publication intention from the government, although the draft has been delivered to Ministry of Science and Technology. Our interviewee believes that the roadmap publication delay is due to the slow examination process and publication itself is full of uncertainty: “it may end up like Chinese nanotechnology roadmap, which has never been published out eventually.” Although Chinese synthetic biology roadmap may never been published, many researchers in synthetic biology domain have already been circulated with the drafts.

Although the main author of roadmap indicated that roadmap draft has already been circulated and communicated among the researches and industry, yet the direct evidence demonstrated the opposite:

only 2 of the interviewees have seen or heard of the China synthetic biology roadmap including the author himself. Though we cannot deny the possibility of coincidence, more evidence is preferably needed to understand the popularization of roadmap.

Perception

It is quite noticeable that China has facing with intensively emerging debates about GMOs and Nano Technology. China, one of the countries with the most non-religious population is facing with the challenges of popularizing GMO products, which elevates the debates up to the politics level. In 2012, a Chinese study of GM food accused American research team of feeding Chinese children GM grain and test the effects without acknowledging their parents, which raised intense debates about whether American government is using China as its GMO food test field grand (Charles, 2013). Although the incident solved with legal punishment in terms of ethical rules breaking, the public concerns remain and a new concern relating to authority reliability has risen. Nonprofit organizations such as Greenpeace (2004) generated a report indicated that Chinese customs are very resistant towards GM food while some recent papers criticized this report, arguing that their research result showed that although Chinese customs are requiring more information of the technology, their resistance is believed to be limited. Moreover, there are reports criticizing both research results by concluding that customers attitude towards GM food is inconsistent with their purchasing behaviors.

According to our interviewees, ethic research in China has not been as addressed as much as in EU or US. China has not yet specially gathered social scientists to discuss over synthetic biology ethical issues, nor established a state ethical committee to regulate. Some of the outstanding ethical research is the result of cooperation with EU (e.g. Austria) and there is recent evidence that Chinese government intended to apply ethical regulation of traditional biology on synthetic biology, as Synbio itself is not stepping beyond the traditional biology ethical issue domains.

Though without extra attention to Synbio, Chinese government has indeed paid attention to ethical issues, for example, synthetic biology programs in China 973 project and 863 project are associated with requirements for researchers to conduct public education and communication while researching. Thus, communicating basic technology knowledge as well as most updated research with public, therefore easing their phobia has been the responsibility of researchers and researching institutions. Though, the biggest issues of public communication are still quite deep-seated as the main barrier roots in the public mistrust towards Chinese authority.

Among the most concerns, environmental safety is always one of the most popular topics in synthetic biology domain in China and the world. Comparing to traditional biology engineering, Synthetic biology reforms organisms in a more thorough way. Therefore, researchers have been optimizing the methods preventing artificially reformed organisms escaping to outer environment. A few papers have been published in Science on maintaining artificially reformed organisms activated in labs only as well as depriving their functions when escaping from laboratorial environment. There are some Chinese labs are also researching the same for example Tianjin Microorganism Lab. In industry, similar research has also been conducted (e.g. By Hongxu Suzhou), yet most companies are not willing to risk the chance of activated organisms escaping to outer environment due to the IP.

The author of “Discourses on Synthetic Biology in Europe, India and China” Prof Wenxia Zhang has been interviewed, who is the social scientist of CASS and most recently researching on “researchers’ perspective over societal concerns of GMOs and Nanotechnology”. She addressed on the issue that Chinese government is not paying sufficient attention over societal concerns of synthetic biology at this stage. She believes that Chinese government would consider synthetic biology not been fully commercialized yet, therefore much less attention has been paid comparing to Nano or GMOs. Another issue she addressed on is the publication of ethical issue report. Chinese government rarely published the ethical issue report of any emerging technology because, from her perspectives, it would probably stimulate unnecessary public panic about the technology itself. She mentioned that in some of the emerging technology seminars, nature scientists sometimes expressed the worries of the misleading role of media and environmentalists, which she thought was not quite the case in reality.

One of another main concerns of the accessory risks of commercialization is that the products, components or materials associated with the process may become biohazards once released to the environment. Uncontrolled release may simply have environmental contamination impacts; these non-naturally existing genes may pollute the genome pool through interactions with natural organisms, which may very likely form adventitious presence. Industry and researching institutions are not very worried as ‘releasing activated organisms into outer environment can jeopardize their R&D achievement’. On the other hand, social scientists expressed more concerns, however, there is no Chinese ethic research formalized yet. One outstanding research over Chinese synbio ethic issues is authorized by Wenxia Zhang who referred to ethic reports issued by Chinese Ministry of Technology, based on notes and summaries of MoT internal seminars. Thus, China has long way to go on ethic research.

4. METHODOLOGY

As this research aims at gaining deep understating of commercialization challenges and responsibility practices approaches in synthetic biology industry qualitative methodology will be employed throughout, mainly including in-depth interviews, alongside with secondary data.

Data will be collected from Synbio companies locating across P.R. China. China is chosen not only for an interesting facts of its jurisdictions, innovation systems and public mental set, but also for its leading position in synthetic biology sector. Companies are chose under the synthetic biology definition³ criteria. An online text analysis of their business ranges will be conducted based on their business ranges, wherein companies whose business ranges are within or overlapped with our synthetic biology working definition will be on the interview shortlist. Some additional information such as geographical information, company size, products domain (design, build, test or mixed), IP will also be employed for sampling. The ideal sample set would be feasible, comparative and representative.

The research will be presented in case studies, as this method provides depth insight of comparative investigations (Abercrombie, Hill, & Turner, 1984) and allows extra detailed information for research database (R.K. Yin, 2003). A case study database will be established for more available information for further analysis and future studies. Several analytic softwares will assist the research including Nvivo, which will be adopted for qualitative coding and qualitative data management. Companies will be coded based on their size and business ranges (design; build; test; mixed type 1; mixed type 2; mixed type 3; others).

More specifically, primary and secondary studies will be conducted, wherein secondary study mainly investigates into literature and online text sources to identify the definition of synthetic biology, main commercialization challenges in synthetic biology as well as supplement secondary data for case studies later on in research. Then primary study will be conducted through face-to-face in-depth interviews. The interviews for companies will be semi-structured wherein detailed questions will be adjusted in course depending on the business ranges of companies.

³ In this paper, we define synthetic biology as “systematic engineering way of performing biology through genetic parts to meet the targeted biology functions or organisms”.

5. CHINESE CASE STUDY-SAMPLE

Company A

Company Background

Established at 2013, the key members from the team had rich experience in Biotechnology. With the breakthroughs in synthetic biology and system biology, *de novo* synthesized DNA and RNA molecules or variant libraries are widely used in pharmaceutical, agriculture, bio-fuel and biological/chemical production. As their understanding of DNA sequences (Genotype) and biological functions (Phenotype) increases, the ability to design and synthesize (Synotype) genes, genomes, pathways, and organisms by using synthetic biology techniques is also improving quickly. Company A has created the comprehensive Synotype platforms for biological researchers that dedicate to integrating the cutting edge synthetic biology techniques and bio-informatic tools into an advanced biological innovation platform.

Company A's Synotype platform was conceived, designed and implemented with synthetic biology technology to produce:

1. A novel approach to deepen their knowledge on genotyping (reading by writing);
2. A simple approach to characterize phenotyping (understanding by writing);
3. A quick approach to study the correlations of genotyping and phenotyping (linking by writing);
4. A cost effective approach to design and produce the novel sequence and subsequent function traits (creating by writing).

In addition, Company A is building up the first integrated GPS (Genotype, Phenotype and Synotype) system aimed to a quick and easy translation or reverse translation between "Genotype" and "Phenotype" by using their proprietary "Synotype" platform.

The company's scientific capabilities encompass areas such as DNA engineering, DNA synthesis, genome synthesis, pathway synthesis, synthetic biology, pharmacogenomics, microbiology, translational biology and the applications of synthetic biology. Company A's team has a proven track record regarding translating scientific breakthroughs into cost effective biological solution.

Company Development

The CEO believes that their company tries to achieve a very simple thing, which is using their rich experience in DNA synthesis to do synthetic biology application. DNA synthesis is actually are high professional and commercialized. The concept of synthetic biology only emerged within recent years

and the difference if how to do DNA synthesis in a low-cost and high efficient way. Their CEO is the first one to promote the concept of synthetic biology in industry in China. They were initially funded by American investors and now also gained investment from BGI, which is largest genomic organization in the world headquartered at Shenzhen.

Their understanding of synthetic biology mainly roots at several areas: gene synthesis, basic editing and pathway optimization. They are currently involving in all of the areas. They are also working with Prof Xie Zheng and Prof George Chen to work on yeast 2.0 project. They are currently doing DNA synthesis service and they are promoting new product lines in next a few months. The best business model for synthetic biology from CEO'S point of view should be involving in all stages from design, to build to test and then get back to re-design. They will design in the future, focusing on yeast, coliform, and so on. They believed that this industry is a broad area and the best approach is to give the service covering from the beginning scratch to the very end. Although at the current stage, it is challenging to find the high quality supply so the best solution for industry is to have strong-strong alliance.

They recently announced a new partnership with ALSTEM, LLC, a US biotech company, with the aim of developing various human CRISPR-sgRNA libraries. These libraries will provide novel approaches for characterizing target and drug resistance genes of therapeutic significance. Related applications also promise to accelerate new drug development and advance the understanding of essential genes related to cancer. Applied to sgRNA primer chip synthesis technology, these libraries hold significant value of understanding the activity of pluripotent stem cell. These two companies will cooperate in product development for high throughput oligonucleotide synthesis and virus library applications, both with wide ranging potential for life science research.

Insights in Synthetic Biology, Synthetic Biology Industry and responsibility.

The landscape of Chinese synthetic biology is separated geographically. At Beijing, Prof George Chen, Prof Xie Zhen and Prof Dai Zhengjiao at Tsinghua University are all working on Synthetic biology projects. We have Prof Ou Yangqi at University of Peking. At Shanghai, Prof Zhao Guopin is an expert and managing a synthetic biology center subordinated by CAS, who also held the Synthetic biology conference of US, UK and China at 2011.

CTO believed that they have had this census regarding IP as one of the biggest challenge in this industry. Though open innovation was discussed in the industry and has yet reached an agreement. The openness

of IP in “parts” should be considered, according to CTO. Thus, will certainly contribute to the commercial development of whole industry as well as scientific development, whereas the application or specific products from these parts should be protected for benefit. The CTO stated that from technical perspective, the very challenging part for synthetic biology industry is to find the useable functional bricks as frequently the functional bricks companies have eventually found are already protected by current IP system, which is the underlying reason for the debate of whether “parts” should be protected or not. IP supporters argued that the discovery of parts requires investments of both time and money and it should be IP protected; whereas the objectors argued that IP openness would bring in the freedom of using parts therefore open up the development in the industry. Another problem associated with parts IP openness is that companies are spending plenty time and investment on the parts that are actually already been purified and optimized somewhere in the world without been acknowledged. It is partially because of lack of communication among databases, partially because some companies are not willing to public their findings of the useful parts.

In associated with the problem above, they are planning on the development of coding technology to add to the DNAs where others can detect the origin. Their challenge regarding IP is embedded in iGEM, in terms of the approaches and limitations of how to use the parts that they have developed and tested, especially in China, as there is no clear specific rule to regulate associated actions. Some organizations provides database for academic purpose, however, some academia are not limited in academic research but also involved with industrial research. Therefore, how to define the boundaries between academic research and their industrial research is a debatable question.

Additionally, there are also no regulations on IP during producing procedure in China. Example has designing the paid DNA parts from clients or sharing with clients. Technically the ownership should be belonging to clients yet there is no explicit legislation to clarify the rules or the boundaries.

The CTO also stated that although Chinese government is emphasizing this industry, the role of Chinese government is also very vague as there has no explicit policy regarding synthetic biology issues yet. Government funding is more of general funding in ration to returnees, green goods, or any other relevant broader categories. More importantly without certain number patents or amount of turnover, government funding is not achievable.

They consider themselves lucky to have initial funding from American Investors, which has also close relationship with the CEO’s previous American academe experience. They then gained considerate

funding from a genomic giant, BGI, which is largest genomic organization in the world focusing on genomic reading and testing. The CTO believes that this is the unique phenomena in this particular industry as it is impossible for any individual company to cover every aspect of genomic technology.

From the basic perspective, China does not have a roadmap for these 6 strategic technologies, in terms of funding there are too many restrictions for example you are required to have overall income or specific number of patents to apply for government funding. There is also no specific funding for synthetic biology. The only investment especially for synthetic biology is for government 973 projects, which is not aiming at industry at all. Therefore, that is the reasons why they had funding from American VC. The CTO thinks the biggest issue is still bio safety. He believes the best way is to control the bacterial strain not to escape to the environment, and they are considering adding small molecular to the bacterial strain, and make it their growth subject to this small molecular. Bio terrorism is another big problem, as from the perspective of current technology and technique; it is not impossible to produce bio weapons. Given the context that Chinese public expresses wide spread resistance to GM, the CEO believes it might be the role of policies to direct the public's perception. Additionally, they are supporting the local iGEM teams, offering them labs and the reagents that they need, in addition to project writing and backup plan.

5. DISCUSSION and Conclusion

The Challenges and the Responsibilities

From the pilot work we have noticed that some synthetic biology companies are conducting gene synthesis for big pharmacies to keep their cash flow pumping, which is also the financial support for their synthetic biology research. In terms of commercializing their research, the biggest challenge under current IP system is to find the useable parts. According to several interviewees, Synbio parts are manually altered DNA sequences that are originally extracted from nature organisms. During the process, DNA extraction is not the difficult part rather altering DNA to a useable sequence with specific functions. Therefore, although with the assistance of big data analysis software, computer aid system, robotic equipment, the design and engineering process is accelerating, however, the process itself is still time and labor consuming. This discussion contributes to the debates whether biology should be allowed to be patented or not, from industrial development point of view.

Interestingly to see most of these companies perceive social responsibilities as part of what they should do to (especially companies started up by younger generation). One of the interviewee stated that they believe “only if when we take good care of their employees as well as external environment, can we survive in this free market”, another company believes that this is part of their culture to serve back to the society (this is the company that’s currently developing bio leak prevents). This relates to the research question that whether the explicit responsible innovation policies will affect the company’s responsibility perspectives or activities.

Eco-system

From policy guidance perspective, there is no specific evidence indicates Chinese synthetic biology road map will be published in the future. Additionally, there is no funding institution or departments established especially for synthetic biology. Companies cannot apply for any specific funding in the name of synthetic biology nor can they receive any specific policy benefits. Therefore, though synthetic biology is one of the six strategic technologies identified by Chinese government, a well-established supporting mechanism is urgently needed for the development of synthetic biology. On the other hand, universities are working closely with industries, but activities are very limited within the R&D domain. Judging from the big picture of landscape, China has not yet established an efficient eco-system for supporting synthetic biology development.

The observation indicates that entrepreneurial environment is fairly activated and fostered after the Premier Li's Public Entrepreneurship Plan has been implemented 2014, especially among universities as well as research institutions, which undoubtedly is fostering the technology transfer in China.

Information Unbalance

Although the main authors of roadmap indicated that roadmap draft has already been circulated and communicated among the researches and industry, yet the direct evidence demonstrated the opposite: only 2 of the interviewees have seen or heard of the China synthetic biology roadmap including the author himself. Though we cannot deny the possibility of coincidence, more evidence is preferably needed to understand the popularization of roadmap.

Societal Concerns for Synthetic Biology

One of the main concerns of the accessory risks of commercialization is that the products, components or materials associated with the process may become biohazards once released to the environment. Uncontrolled release may simply have environmental contamination impacts; these non-naturally existing genes may pollute the genome pool through interactions with natural organisms, which may very likely form adventitious presence. Industry and researching institutions are not very worried as 'releasing activated organisms into outer environment can jeopardize their R&D achievement'. On the other hand, social scientists expressed more concerns, however, there is no Chinese ethic research formalized yet. One outstanding research over Chinese Synbio ethic issues is authorized by Wenxia Zhang who referred to ethic reports issued by Chinese Ministry of Technology, based on notes and summaries of MoT internal seminars. Thus, China has long way to go on ethic research.

Recommendations

Since Chinese government advocates a less direct interference approach in its innovation eco-system, it can be seen that the industry interpreted responsibility differently. It is, however, can be concluded that company value is one of the main driving factors in shaping perceptions of responsibility and its practices. In addition, less direct policy approach leads to more uncertainty and instability for companies, it however, incubates diverse ranges of interpretations of responsibility. Policy implications based on the findings include that formalizing responsibility baseline standardization for the industry. Furthermore, cultivating bottom-up responsibility research and innovation culture in the eco-system and that facilitating responsibility implementations by promoting industrial examples.

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