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CHINA'S NANOTECHNOLOGY IN ACTION

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SMALL SCALE, GREAT AMBITION: CHINA'S NANOTECHNOLOGY IN ACTION

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ABSTRACT

SMALL SCALE, GREAT AMBITION: CHINA'S NANOTECHNOLOGY IN ACTION

By

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China has attracted a good deal of attention for its ambition to become a global leader in nanotechnology. This study explores China's ambitions in this area, through interviews with 21 Chinese experts in nanotechnology fields. Using several theoretical concepts that draw from science and technology studies (STS), results show that any understanding of these ambitions must take into account social and historical contexts, practical support offered by the government nanotechnology R&D, and other factors that effect China's nanotechnology development. Such a focus shows a gap between ambition of being a leading nation in nanotechnology and reality. While noteworthy achievements have been accomplished in China's nanotechnology development largely due to policies of the government, informal regimes shaped by legacies of the past will continue to hinder its efforts to move ahead in this global race.

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Introduction

Nanotechnology has often been expected as the key transformative technology of the 21st century which will affect almost every aspect of people's lives (Michaelson 2006). It has also become a field of intense international competition. In more than 80 countries, governments are investing considerable financial and human resources in nanotechnology as a key to global economic competitiveness. These countries not only include advanced industrial nations, but also nations in the developing world such as China and India (Appelbaum et al. 2006).

In particular, China has attracted a good deal of attention for its ambitions to become a global leader in nanotechnology (Appelbaum et al. 2006). Estimates of the total public spending for nanotechnology in China range from $160 million in 2005 (Bai 2005b) to $250 million in 2006, which put China just behind the U.S and Japan, placing third in nanotechnology funding (Bai 2001). A series of important policy instruments to promote nanotechnology have been adopted by the Chinese government. According to Bai Chunli, the director of the China National Center for Nanoscience and Nanotechnology (NCNN), "it (China) will become a leading contributor (in the field of nanotechnology) in the coming years" (Bai 2005a).

Judging by various studies (Bai 1998; Appelbaum 2007) referring to China's nanotechnology development, China's nanotechnology ambitions appear promising and the future of nanotechnology to remake Chinese society seems infinite. However, most of the research concludes that based on quantitative data on the Chinese government's R&D expenditure on nanotechnology, nanotechnology patents, and publications. Only a few studies (Appelbaum et al. 2006) empirically investigate the gap between ambitions and effort of the Chinese government on nanotechnology development and the reality. Moreover, to date, there have been no studies examining theoretical assumptions under the conclusions: science and technology are independent of the society; and social progress is driven by technological innovation.

In the present paper, I seek to learn the gap between the nanotechnology ambitions of the Chinese government and the reality by engaging in an exploratory research that looks at how the ambitions have been practiced. The research is based on previous literature and interviews conducted in the summer of 2007 with twenty one nanotechnology scientists and managers in nanotechnology-related companies in six Chinese cities. The findings are analyzed based on several key concepts drawn from the science and technology studies (STS) literature, where science's embeddedness in institutions, history, politics, and rhetoric has been widely studied (Ward 1996). Finally, conclusions are made based on the previous discussion. The nanotechnology ambitions are embedded in a complex collection of dynamic, interrelated activities that involve various actors and institutions, thus they will not be achieved alone. There is a gap between China's nanotechnology ambitions and its reality due to various underlying regimes.

Background

Before embarking on a review of the literature, it is necessary to contextualize the study within the history of nanotechnology in China. It can provide a background to the topic as well as provide context to the trends emerging in the analysis.

There was a debate in China concerned the critical relationship between indigenous innovation and technology imports. Some economists argued that China should continue to focus on industrial upgrading through technology transfer from foreign multinationals engaged in manufacturing in China, while members of the scientific community argued that China should develop its own advanced technological base. Ultimately, the scientific community won the argument, and its plan was launched (Cao, Suttmeier, and Simon 2006). In 2006, China initiated a 15-year "Medium-to Long-Term Plan for the Development of Science and Technology" (MLP). It calls for spending 2.5 percent of China's increasing GDP in research and development by 2020, up from 1.34 percent in 2005 (Cao, Suttmeier, and Simon 2006). Through the MLP, an important message is sent that lots of social and economic problems could be solved by science and technology development.

Even among high technology fields in China, nanotechnology has enjoyed particularly rapid development in the past decade (Bai 1998, 2005a). On the institutional side, the Chinese Academy of Sciences (CAS), the National Natural Science Foundation of China (NSFC), and the State Science and Technology Commission (SSTC) began funding nanotechnology-related work and activities as early as the mid-1980's. In 2000, the National Steering Committee for Nanoscience and Nanotechnology (NSCNN) was founded to oversee national policy and planning in these arenas. The committee was set up, among other organizations, by the MOST, the State Development and Planning Commission (SDPC), the Ministry of Education, CAS, the Chinese Academy of Engineering (CAE), and the NSFC. On the funding side, nanotechnology had become one of the central areas for scientific research and development by 2006, as reflected in the MLP (Appelbaum et al. 2006; Feng 2006).

This background sets the stage for the later analysis of embedded science and technology.

Embedded Science

Modern science and technology seemed to have developed in Europe and various social and intellectual constituents induced Chinese civilization to excel in scientific and technological achievement in medieval times (Needham 1954-2004: 154). Therefore, the concepts of scientific knowledge and technology in China are epistemologically different from those that dominate the west (Baark 2007). Baum (1982) suggests that the complexity of the environment for science and technology development in China is precisely the dynamic tension between new and old, between foreign and indigenous, between values and practice. What these scholars suggest can be shortly summarized as: science and technology are historically and socially embedded.

In science and technology studies (STS), there is much literature on embeddedness of scientific research and technological innovation (Ward 1996). In this section, I review several concepts in this field, which are helpful for the following investigation and final conclusions.

Science in Action

For advocates of scientific realism, science, and only science, is capable of revealing secrets of nature and providing accurate representations of reality. Scientific facts are "factually true generalizations about the actual behavior of real physical objects existing in nature" (Rescher 1987:4). In Latour's word, "Nature talks straight, facts are facts. Full stop. There is nothing to add and nothing to subtract" (Latour 1987: 100).

However, to Latour and Woolgar (1979), it is not the case. Using anthropological methods, they illustrate the intricate craftwork used by scientists to construct and fortify claims. Instead, if a scientific object possesses an absolute essence that science unveils, they argue that it is the intricate and sustained microsocial work of the laboratory and their mobilization of resources at their disposal, which can be called "networks", that are responsible for creating and stabilizing the meaning of an object. In other words, "reality was the consequence of the settlement of a dispute rather than its cause" (Latour, and Woolgar 1979:236). In *Science in Action* (1987), Latour seeks to examine the numerous processes and associational linkages involved in building and sustaining knowledge. Latour argues that the scientist, by successfully recruiting allies, appealing to authority, referring to former texts and procedures, compiling data, and utilizing laboratories and equipment, is able to create networks of supporting and extending a truth claim, through which, scientific facts are made.

Therefore, science and technology must be studied "in action" (Latour 1987), which requires opening the blackbox to examine the actors, dynamics and events that perpetuated the packaging of a scientific development rather than ready made science. As Latour (1987: 14-15) writes, "...we will enter facts and machines while they are in making; we will carry with us no preconcepts of what constitutes knowledge...and be careful to distinguish between two contradictory explanations...one uttered when it is finished, the other while it is being attempted."

The literature reviewed above is of particular interest to this paper, as it explores the process in which specific actors in the scientific community are utilizing 'network' techniques to create scientific facts. As nanotechnology is an emerging technology, this approach to investigate it in action enables us to reveal its stories close to the reality.

Scientific Research, Technological Innovation and Institutions

For historical reasons, China has a very unique science innovation system (Liu and White 2001). Baark (2007) notes that the institutional framework for innovation in China can largely be traced on one hand to the interaction of Chinese social epistemology of scientific knowledge and attitudes to technology, and on the other hand to the contemporary influence of policies adopted for science and technology by the Chinese government. The Chinese government's science and technology policies were influenced by the Soviet model after 1949, in which the government acted multiple roles from the core coordinator of idea creation to the final user of new products by issuing National Science and Technology Plans. It swung to a market based mechanism in the 1980's with the economic reform, which encouraged research institutes and universities to engage in pure revenue-generating activities, often in the form of spin-off ventures.

Various frameworks have been applied to studying China's science and technology innovation system, such as the National Innovation System (NIS) analysis (Liu and White 2001), intellectual property data analysis (Fai 2005), and institutional framework (Baark 2007). Baark's quantitative study (2007) provides useful information for this research. He adopts concepts from Douglas North (1990) such as formal and informal institutions to understand the ways in which institutional change provides incentives or constraints for the production and utilization of knowledge and how informal constraints shape the activities of research and innovative activities in China. He concludes that there is a mix of slow-moving institutions largely shaped by legacies of the past and fast moving institutions that are linked to the ambition of leadership during China's reform (Baark 2007).

Inspired by Baark's work, I will draw the same concepts from North's work and apply them in my analysis. North (1990) defines institutions as rules of the game including both formal rules (e.g. law and contracts) and informal rules (e.g. norms and customs). Institutions matter because they constrain human interaction and provide incentives for individuals and organizations to engage in productive and /or destructive political, economic, social and other activities. North believes that formal and informal institutions should be treated as continuities rather than disjoint elements. To understand the sources of informal institutions, we need to examine human interaction in the absence of formal rules.

Scientism, Statism and Marketism

For Busch (1999), Bacon, Hobbes and Smith each proposed to resolve the problem of order by investing moral authority in a "Leviathan"(Hobbes 1991 [1651]) that would guarantee order: science, state and market, respectively. The three themes that emerge from attempts to put their works into practice are named as scientism, statism and marketism, each of which respectively proposes that a single mechanism like science or state or market can solve all the problems of the society. These three approaches are inherited by people today to solve the problem of social order. For instance, the faith in science can be summarized as "If we can just get enough science, all will be right with the world" (Busch 1999). An example is Taylor's (1911) declaration that he had discovered the one most efficient way to do any job and could end the struggle between workers and management by using science. Statism is reflected in, for example, many corporations in the U.S today that employ more police than do the various levels of government. Marketism can be seen in the move to strengthen intellectual property rights (IPR).

In sum, people today are the heirs to centuries of scientism, statism and marketism. Therefore, if nanotechnology innovation, for example, were being done in a society where market is the solution of order, it might start within companies and be used to promote nanotechnology's economic aspects which are based on increasing profits. However, in a society in which state is the solution, it might be used to meet the interests of the state.

Science as Rhetoric

The "rhetoric of inquiry movement" argues that scientific theories should be inspected, like all texts, as pragmatic attempts by the scientific community to make sense of certain types of events and phenomena using established linguistic conventions (Ward 1996). Latour (1987) suggests that rhetoric becomes extremely important when debates are so exacerbated that they become scientific and technical. On the one hand, science is seen as the opposite of rhetoric; on the other hand, science itself is rhetoric powerful enough to allow one man to win over many prestigious authorities. Of course, science is not made purely idiosyncratically or illogically (Prelli 1989). Instead, doing science is a rather localized, rhetorically influenced construction of a claim based on the interactive and interpretative rules of the scientific community.

Although there is no study that specifically applies this notion to the Chinese context, Cao (2004) notes that politics and social responsibilities play an undisputed role in the Chinese scientific community. The introduction of modem science itself in China was driven by the long-standing commitment of Chinese intellectuals to build up a strong country through it (Wang 2002). The Science Society of China, which incorporated both nationalism and professionalism, is considered the first local scientific community in China (Wang 2002). There is a tension within members of the association between the demand for professionalism as scientists and their equally strong desire to strengthen Chinese nationalism.

After the People's Republic of China was founded, a planned development of S&T in state-run research and design institutions was established. One important factor which led to the centralized system was a desire to ensure that scientists who had been trained in pre-revolutionary times were committed to socialist construction and would do serious work on priority projects. After the reform of the S&T system in the 1980's, "political correctness" was gradually supplanted by economic measures as the dominant criteria (Liu and White 2001).

A link between the Chinese scientific community and politics can be traced in the existing literature. This link will help us to understand the science rhetoric in Chinese settings.

Research Questions

The review of the literature proposes that it is necessary to study China's nanotechnology within social settings instead of collecting quantitative data on nanotechnology R&D expenditure, patents, and publication rates. Emerging from the review of embedded science, I developed the following research questions that guided the study.

Research Question 1: Why has the Chinese government set up the nanotechnology ambitions? In other words, for what purposes are the goals made? Are they based on China's practical scientific and technical capacity?

Research Question 2: How has the Chinese government supported the nanotechnology research and development? How have the effort paid off?

Research Question 3: Is there a gap between the nanotechnology ambitions of the Chinese government and the reality? If so, why? What are the barriers?

To answer these questions, I followed the methodology suggested by Latour (1987) by following nanotechnology in action as opposite to looking at ready-made nanotechnology.

Method and Findings

Research Method

The simplest way to study science in action is to follow the scientists in their labs and as they carried out research activities (Latour 1987). Due to limited resources, observing nanotechnology scientists in their labs is practically impossible for me. Instead, I found that the semi-structured on-site interview was the appropriate method by which to study the three open-ended research questions noted above. I began collecting information from those persons associated with various organizations researching nanotechnology in both the public and private sectors in the summer of 2007.

Selected Research Objects

As one part of a larger project, this exploratory research was initially designed to examine nanotechnology specifically in the agrifood field[1] in China. As soon as the research was conducted, I found that it was nearly impossible to keep my interviews only in the agrifood area for two main reasons[2]. Therefore, I extended my research area to both agrifood nanotechnology and general nanotechnology.

In the public sector, I looked at state institutions involved in biotechnological management and national institutions of nanotechnology. Secondary data were used to identify those institutions. Then I called those institutions to set up interviews with persons working on nanotechnology.

On the business side, I searched the websites of companies which have agrifood nanotechnology related products. Then I contacted the companies for interviews.

Moreover, a search for "nami"(Nano) or "Nami Jishu"(nanotechnology) in the Wanfang Data Chinese Journals Fulltext Database[3] and the CQVIP Chinese Scientific Journals Fulltext Database[4] was conducted. Then, I went through the listed articles to find those that focus on nanotechnology agrifood issues. The authors of those articles have

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[1] Since the research and development of agrifood nanotechnology are still at an early stage (Kuzma and VerHage 2006), nanotechnology was interpreted broadly in this research in terms of the entire supply chain from input supply to final consumption. Thus, in addition to work based specifically on food, other related areas such as radio frequency identification (RFID), packaging, nanofilters, and pharmaceuticals were included.

[2] First, nearly no experts are doing research exclusively in the agrifood nanotechnology field. More or less, they are studying more general nanotechnology. Second, it is difficult to understand agrifood nanotechnology by divorcing its connection with other nanotechnology areas. In many cases, agrifood nanotechnology does not rate as a separate line in the government budget for nanotechnology research.

[3] Wanfang Data has been a unit of the Institute of Scientific and Technological Information of China (ISTIC), of the Chinese Ministry of Science and Technology since the 1950s. It focuses on digital resources such as journals, dissertations, conference proceedings, patents, standards, and Chinese companies. As of April 2007, there are 5,844 journal titles in Wanfang's Online Journal database, covering almost 98.5% of the core journals in China (http://www.ilib.cn/).

[4] CQVIP Chinese Scientific Journals Fulltext Database is the largest national comprehensive documentary database, covering 8.3 million documents that were published in more than 8,000 periodicals since 1989 (http://www.cqvip.com/).

their emails or telephone numbers listed on the journals, and these were used to contact them.

No attempt was made to obtain a random sample of interviewees. Interviewees were seen as key informants and the intent of the interviews was to maximize variation in responses to obtain as complete a view of agrifood nanotechnology as possible (Glaser 1967). As suggested by Strauss (1990), in some instances, interviews were transcribed and analyzed specifically in order to permit an understanding of how different meanings and concerns converge on a set of complementary practices.

Basic Findings

Nanotechnology centers and companies are founded mainly in the following cities: Beijing, Shanghai, Shenzhen, Tianjin, Guangzhou, Xi'an. Twenty-one persons from these cities were interviewed, who are experts in agrifood nanotechnology, basic nanotechnology research and development, nanotechnology standards setting and worker safety studies[5]. A large range of areas were covered such as nanofood (nano tea, and health food); nano medicine (drug delivery); nanopesticides; fertilizers; films and plastic bags for storage of fruits and vegetables; animal feed, and cosmetics. Techniques such as microfluidics and RFID were also included. The interviews were conducted in Chinese by me. After each interview, the note was immediately translated into English. A summary of the interviews is provided in Table 2.

Although there are a variety of related products on the market, the research and development of agrifood nanotechnology in China is still in its infancy. Nanotechnology, currently a popular subject in physics, is not familiar to people working in food and

[5] A summary of the information about the 21 interviewees is provided in Table 2 in the appendices.

agriculture areas. According to one of the top Chinese nanotechnology scientists, in certain areas such as nanomaterials, China is in a leading position. In other areas, such nanodevices and nanostructures, China is approximately at the same level as other countries that are doing this type of research. Other areas like nanobiology, nanomedicine and agrifood nanotechnology are far behind.

On the regulatory side, among institutions[6] which are in charge of the nationwide control of biosafety, no organization is in charge of agrifood nanotechnology issues. The government generally considers biotechnology as a more urgent and recent issue, while agrifood nanotechnology is still "too advanced" to be regulated (a phrase used by several experts in those institutions). Meanwhile, the government funds allocated to nanotechnology research in the agrifood arena have been rather meager. Funding for it is always included in other more general projects. For example, in 2006, the MOST funded 211 million RMB (about US$ 28 million) for areas in the modern agriculture theme of the 863 Program[7]. This included animal and plant breeding and varieties, agriculture information technologies (RFID, GSM, IT), food engineering, and crop growing using remote sensing. Compared to the total investment in nanotechnology, this is not a large investment.

Regarding the problems of funding, some attention has already been raised in China about agrifood nanotechnology. From the policy side, the modern agricultural

[6] Zhao and Ho (2005) studied the politics of Genetically Modified Organisms (GMOs) in China. According to them, the Ministry of Science and Technology (MOST) was initially in charge of the nationwide control of biosafety. In the early 1990s, a National GMO Biosafety Committee was established under MOST for the supervision, administration and approval of activities in biotechnology. In addition, there are four other state institutions with overlapping duties in lawmaking, control and supervision of biosafety and GMOs. They are the State Environmental Protection Agency (SEPA), the Ministry of Agriculture (MOA), the Ministry of Public Health (MPH), and the State Administration for Entry-Exit Inspection and Quarantine(SAEEIQ).

[7] Table 1 in appendices provides a brief overview of the main programs controlled by the Chinese Ministry of Science and Technology (MOST). The program title is showed along with its aim.

theme of the 863 Program in 2007 includes 0.4 million RMB (about US$ 50 thousand) for nanotechnology food areas. This amount is not significant, but does represent a change, as agrifood nanotechnology was not mentioned at all in the earlier 863 programs.

Discussion of the Results

In this section, the study results are presented in the order of how the three research questions were posed.

Nanotechnology Goal as Rhetoric

The first research question asks: why has the Chinese government set up the nanotechnology ambitions? In other words, for what purposes are the goals set up? Are they based on China's practical scientific and technical capacity?

From the interviews, it is clear that scientists are divided between those who are enthusiastic about nanotechnology progress and its future economic benefits, those who are concerned about the impact of its safety, and (somewhere in the middle) those who believe that through regulations negative effects will be controlled. The first category and the last category are the mainstream, but even some of them do not know how the nanotechnology goals are set up.

A senior scientist said:

> I am a scientist who does not understand political slogans such as 'raising China's technological standing by developing nanotechnology'...However, I do not literately interpret the goal set by the government. All I know is it [the goal] shows the determination of the government to support our research... It is the result of years of effort of nanotechnology scientists to convince the government that nanotechnology stands for the new directions of technology development in the future. Government's investment in the area and our hard working [as nanotechnology scientists] will make our nation stronger in the future... You can not just tell the deep meanings by reading the governmental reports word by word (Interviewee 5).

Indicated by interviews, years of effort by nanotechnology scientists include many activities besides basic research such as building up "networks" (a word used by nanotechnology scientists themselves). Building up "networks" comprises making ties among experts in the nanotechnology field and integrating experts from other scientific areas into nanotechnology to cooperate and put resources together. In addition, convincing critical officers in the central government is necessary.

A senior nanotechnology scientist indicated that "tactful" strategies are applied when scientists are building networks. For instance, there are three versions of Chinese nanotechnology achievements. Each reveals different "facts" of nanotechnology research. One version is mainly about problems while another is about achievements, and the third one is about "pure facts".

> It is important to tell different audiences about different aspects of our research for various purposes. After all, nanotechnology research is important, and we must use various approaches to get support. Our counterparts in other countries do the same. They claim that China has invested astronomical amounts, using this to get more funding from the public sector. It is all about competition between countries, after all (Interviewee 15).

The central government and scientists working in the national institutions are not the only powers that set up China's nanotechnology goals. Local governments, scientists, and private firms contribute in certain ways. For instance, a nanotechnology medicine company tried to convince the local government that nanotechnology will improve the competitiveness of the city by enhancing its fame. In a proposal by the company for policy support, it remarks:

> We are trying our best to build our company in X city into a leading high-tech company in the world. To achieve that, we invited the vice president of X [a nanotechnology company] to negotiate for cooperation. The new nanotechnology

> provided by their company can help us to achieve the goal and keep X city ahead of others… (Interviewee 3)

Why do the central government and local government buy into the promises of nanotechnology and its scientists? As mentioned earlier, the MLP indicates that science and technology have been identified as a panacea for the great economic, social, and political challenges faced by the nation. Therefore, scientists take the responsibility not only for scientific research and development, but also for social problems.

Most scientists claim that their specialty in nanotechnology will support China economically, both locally and internationally. A good example is a company based on a national 973 nanotechnology research project. The president who founded the company was a famous retired scientist. He used his personal relationships to put together the company, not for profits, but for his belief that the nanotechnology revolution is a golden chance for China to catch up with those developed nations, which has a significant meaning for him (Interviewee 18).

Naughton (1990) has noted that the Chinese government has little experience in designing and predicting the outcome of policies that affect behavior without dictating it. I argue that this notion ignores the rhetorical feature of Chinese policies. In the nanotechnology case, the goal itself is not set up after careful examination and evaluation of China's practical scientific and technical capacity to develop nanotechnology. Instead, it is a result of rhetoric of the Chinese scientific community to persuade both the central and local governments accept nanotechnology promises. They are ambitions rather than goals, which suggests the determination of the Chinese government to follow the belief that there is a close link between science, technology, economic development, and competition capacity. The ambitions are parts of its long path to build a strong nation through science and technology. At the macro-level, it sends a message of technical determinism to solve social as well as economic problems. At a micro-level, it shows the significant influences of the Chinese scientific community on public policy. The scientists try to convince others that not only could nanotechnology help to solve problems at home such as raising living standards, but can also enhance the nation's standing in international competition.

China's nanotechnology ambitions should not be strictly read from the government report and literally understood. Instead, it should be interpreted within its setting background. This conclusion will help to understand further analysis.

Scientism and Statism

The second research question queries the Chinese government nanotechnology policy in action and its gains. This question aims to understand to what extent nanotechnology research and development is being influenced by the Chinese government. The results demonstrate an interesting link between national science's effort in nanotechnology and nanotechnology progresses.

Governmental research institutions are the central research and innovation powers. The scientists working in governmental research institutions, such as the Chinese Academy of Agriculture Sciences (CAAS), play central roles in agrifood nanotechnology, while their colleagues in the National Steering Committee for Nanoscience and Nanotechnology (NSCNN) lead other nanotechnology research and development. They play multiple roles of researchers, public policy makers, consultants to industries and entrepreneurs. Main projects of nanotechnology are initiated by the state and given to leading scientists in related areas from government research institutions and universities.

The commercialization of nanotechnology generally develops products based on previous national projects. Smaller private firms may be started by one or two of the scientists involved in national nanotechnology programs. Some big companies are significantly developed in national research, production, and sales of nanotechnology products, while the scientists in related projects work as their innovation consultants. Joint-stock firms always involve the marrying of a governmental research institution and a private firm in which the research institution is in charge of the innovation while the firm finances its application. Spin-offs are permitted by the government and regarded as a means to exploit nanotechnology and nanoscientific knowledge.

One interviewee who works in both governmental institutions and the spin-off firm revealed:

> The initial idea for starting the nanochemical company came from several of us who shared the same interests in our institute. At that time [in the incubation period], we had the commercial ideas and the familiarity with the technology. However, it was not mature. If we founded a private commercial venture on our own, we would lack the capital, laboratories, infrastructure, and other resources to carry us to the product stage. Our institute [the government research institution] is like a parent unit which offers all kinds of resources. We have access to our labs, offices, and other facilities. Meanwhile, it is easier to be funded under the title of the institute than as individuals. If funded by the government, our research may last for years and involve large numbers of researchers, which is impossible for launching a small private company by ourselves. When the technology used has been completed from the perspective of basic research, we will officially establish the company. By then, it will require only the secondary stages of commercialization in order to develop marketable products. By that point, the basic research will have been almost completed (Interviewee 4).

The target for the nanotechnology market is also the state. For most companies in China, nanotechnology is a selling point to the government rather than ordinary consumers and companies. One type of company is using nanotechnology and advertises it to the government as such. For instance, a private enterprise which develops RFID in the field of agriculture and food safety attributes its business success to following government guidelines. A manager at this company told:

> RFID is a new field. Both individual farms and companies do not know much about it.... We learn from our bad experiences that the potential consumers of agriculture information business in China are the government and collective farms, not individual farmers. We happen to have been born at the historical moment when food safety has gained such attention from the government (Interviewee 21).

There are various preferential government policies for high tech companies. For example, new firms in national technology parks are exempted from corporate income tax for two years. Licenses are waived for the import of materials and parts used in producing goods for export. A firm's revenue from technology transfer is only taxable beyond the first 0.3 million RMB. Intangible assets such as intellectual property can be factored into a company's registered capital (Xue and Wang 1998). In order to qualify as high tech companies, firms are required to have the high and new technology nature of their technology and products certified by a government agency (MOST 2001). To gain a ticket to enter Chinese technology parks and enjoy these preferential tax policies, some companies act as if they are doing something with nanotechnology but, in fact, they have little connection to it.

A manager in a nanotechnology food processing equipment company indicated:

> The advantage of purchasing the nanotechnology based machines for them [the collaborator companies] is to gain the name of a high tech company, enter technology parks and be qualified for policy incentives.
> It is even easier to gain needed support in local technology parks by labeling their products as "nanotechnology," because a large number of technology parks established by various levels of the local government do not usually employ the same stringent criteria that the national parks use to certify the high-technology status of firms in the park. It is difficult for local governments to evaluate nanotechnology (Interviewee 11).

In a word, the main Leviathan in the Chinese society is the state; therefore, the Chinese government plays the main role in the nanotechnology arena. It is making great effort including funding a variety of national programs on nanotechnology and creating preferential. The rapid nanotechnology advances that China is experiencing can largely be attributed to governmental spending on related research, development, and commercialization. This may be quite unique compared with other countries where great nanotechnology progresses are made. It is important to understand the science and technology policy of the Chinese government in order to understand the business opportunities brought by nanotechnology. However, as the study indicates, qualitative gains from governmental support are not always matched with quantitative spending. China's nanotechnology ambitions may not be met as the progress is not as significant as the government expected.

Informal Institutions as Barriers and Checks

To gain a better understanding of the relationships between the nanotechnology ambitions and the practical gains, I have posed the third research question: Is there a gap between the ambitions of the Chinese government and the reality? If so, why? What are the barriers to nanotechnology?

There are many problems that emerge with the development of agrifood nanotechnology and nanotechnology in general. First of all, research projects are always given to certain leading experts in authorized institutions while experts in less prestigious institutions can not get funding. Some doubts about the fairness and impact of these projects while other interviewees argue that the concentration of resources will increase the efficiency of research.

At the same time, the blurring of the boundaries between spin-offs and their parent government institutions are questioned by some experts. According to several scientists interviewed, commercial spin-offs do not cut them off from the security of government employment since the individuals who transfer to a spin-off retain their formal employment with their state work unit, together with the employment benefits, job security, medical insurance, social security, and other benefits and perks associated with a public-sector job. Therefore, being involved in a spin-off offers great benefits—the higher income afforded by the success of a commercial venture, together with the security of state employment.

> The lack of a well-enforced intellectual property rights regime allows individuals in power to take as much advantage as they could from the common property. They are the ones who benefit the most (Interviewee 11)!

Second, some companies use the word nanotechnology in misleading advertisements to gain government support without contributing anything in this field. For instance, some downstream companies do not produce new products after buying nanotechnology processing equipment. Neither have they done any research on possible applications of nanotechnology. Therefore, their upstream companies could not develop new technologies further (Interviewee10).

Moreover, many other existing problems in the educational and academic systems , although they are not new at all, are hindering the newly developing technology. For instance, there are gaps between nanotechnology scientists and agricultural scientists owing to the lack of interdisciplinary education. Few scientists and engineers in agricultural research organizations have training in fields such as electrical engineering and physics while nanotechnology scientists do not know much about agrifood. The most common question raised by those who are in the nanotechnology research institutions is, "How on earth is nanotechnology related to food or agriculture? Is it too costly to apply it to agrifood?" In other words, it is considered to be too early to apply cutting edge nanotechnology to something as down to earth as agricultural research.

There is an information gap among those who study agrifood nanotechnology. Though there are only a small number of scientists in this field in China, they are unfamiliar with each other's research. For instance, a scientist who studies the application of nanotechnology to pesticides noted:

> Nanotechnology application in agriculture is rare in China. I am interested in this area because of my nontraditional multi-disciplinary educational background. However, it is just my interest. I can not put my main focus on it. After all, it is new and few people in academia will pay attention to it. You will not get public approval by studying it. I do not think that the application to agriculture is promising because most people in agriculture have no knowledge of material while people who do research on nano have no interests or knowledge on agriculture. The main and hot area of nanotechnology is on the material side (Interviewee 2).

Another senior scientist from China's most prestigious agricultural research institution, the CAAS said:

> Agrifood nanotechnology is a new area, and it calls for the cooperation of different disciplines. It is a pity. I am getting old and will retire, and there appears to be no chance for me. None of my students is able to do that because they do not have an interdisciplinary background as I do. I could not find the right student with a multidisciplinary education to work with me before my retirement...(Interviewee 6)

Last but not least, it is difficult to apply basic nanotechnology research to practice due to an immature market system and inefficient technology infrastructure. As government-financed research mainly focuses on basic research, the market application side is limited to a few institutions.

> Not many companies in China have the financial capability or the patience to apply expensive nanotechnology to their products, let alone low profit businesses such as agrifood. They would rather wait for technology transformation from other developed countries (Interviewee 1).

There is also a difficulty in applying nanotechnology basic research findings technically. In the interviews, some experts indicated that putting the innovation into practice in this area can be as difficult as.

> We needed certain equipment for processing materials in a novel way. However, we could not purchase the equipment in China. It is too expensive to buy it from other countries. So we decided to design the machine by ourselves. We gave the engineering drawing of the machine to a company. The company could not produce such a machine because the material to make the machine is hard to get in China, and the technology to make the machine is not sophisticated enough. Therefore, we had to give up. In a developed country, it is easier since other areas offer better platforms for the development of nanotechnology (Interviewee 11).

Though nanotechnology is considered as a "platform" technology by the ETC[8], my research demonstrates that it should be built on a platform provided by other technological foundations. Science and technology are not created in a vacuum. Among other factors, scientific institutions, intellectual property rights protection and the education system hinder the advancement of nanotechnology.

North (1990) indicates that institutions are shaped by the legacies of the past and may be undergoing either incremental or sudden change. Therefore, all the existing informal regimes which go against the government plan can be seen as the extension of the past legacy and institutions. As a result, it seems to be impractical to avoid these symptoms overnight, even as the government sets an ambitious goal to do so.

[8] ETC Group (http://www.etcgroup.org/en/) is an international organization dedicated to "the conservation and sustainable advancement of cultural and ecological diversity and human rights". The full legal name is Action Group on Erosion, Technology and Concentration.

On the other hand, such informal institutions with Chinese features may function as checks for China's nanotechnology development. For instance, the fuzzy ownership types and the lack of a well-enforced formal property rights regime may limit the efficiency of firms while it also forms checks and balances because the main actors--scientists--need balance among their different roles. Not only are they scientists who work in governmental institutions as professionals, but they also live with their relative autonomy from the state in companies, and their readiness as intellectuals to fight for their academic opinions. These dynamics hinge on a tension among Chinese scientists' various roles and form a check for issues such as nanotechnology safety.

A good demonstration that shows the multiple roles of scientists can be found from the answer given by a scientist when he was asked about the public engagement in nanotechnology regulation. He said:

> Public? How can you expect the public in our country to engage in issues like this? Farmers who work in the field will not know what "nanotechnology" is even after being told. NGOs? I do not think there are any environmental NGOs in China that have the energy to deal with nano already. They have much else to deal with. Our society is not like those developed societies which have very clear boundaries. However, as there are needs, there are people who will take care of them. In China, we [scientists] will ensure the safety of nanotechnology to protect the public, and make it a productive technology for the society (Interviewee 2).

Another example is that the regulation for nanotechnology products is developed by the same scientific community which supports nanotechnology research and development, which may be viewed as a conflict of interests. National nanotechnology standards were developed by the National Technical Committee on Standardization of Nanotechnology, which is one part of the CAS-affiliated National Center for Nanoscience and Nanotechnology (NCNN). It aims to control the overuse of the term "nanotechnology". One scientist from the center indicates:

> It actually took two years for scientists in this area to come to a final agreement because of the worry that over regulating nanotechnology would hinder its development. However, most of the nanotechnology scientists convinced others with opposing views that only appropriate regulations could guarantee the healthy development of nanotechnology research and application in the long run. We need to be responsible for nanotechnology research and development.

In short, informal regimes are developed while formal regimes are not functioning well and will not change overnight. While the typical "civil society" (the conventional model of civil society is formed by the public) in China is not well developed, various informal institutions feature some forms of civil society that differ from the conventional model and involves an interaction between state and society. Being aware of the informal institutions can help to understand the ongoing dynamics among the national nanotechnology ambitions, the private firms' desires to use nanotechnology to gain profits, and the power to regulate nanotechnology.

Conclusions

The purpose of this paper is to study the gap between the nanotechnology ambitions of the Chinese government and China's nanotechnology in action. Given the results of the research, it is safe to say the gap does exist even though nanotechnology R&D in China is still in the early stage. We can make some general conclusions as following:

First of all, the Chinese government's plan for nanotechnology is one part of its long path to build a strong nation through science and technology. It shows idealistic ambitions rather than clear goals to be accomplished. To understand it, it is important to consider science and technology history in China, especially, the connection between the country's struggle to be strong and S&T development. At a macro-level, the ambitions are constructed by the faith in socially advantageous technology to solve social as well as economic problems. At the micro-level, it shows the significant influences of the Chinese scientific community on public policy.

It also suggests a close link between the state and nanotechnology. The great achievement of nanotechnology in China today is largely due to various policy supports of both the central government and local governments. However, some actors are less motivated by nanotechnology than by direct benefits of nanotechnology preference policies. Thus, they apply the name of nanotechnology instead of the technology itself, which decreases the expected accomplishments of the government.

By applying North's concept of informal institutions, I suggest that informal regimes are developed while formal regimes are not functioning well. The informal regimes have both positive and negative functions. Old problems will continue to hinder China's nanotechnology ambitions since scientific innovation is just one variable among the complex dynamics. Hidden informal structures in the Chinese science and technology system and immature market system form complicated dynamics for the future of nanotechnology research and development. None of them will change overnight even though the Chinese government makes great goals for spending on nanotechnology research and development.

Appendices

Acronym

CAAS: China Academy of Agriculture Science

CAE: China Academy of Engineering

CAS: China Academies of Science

CSREES: Cooperative State Research, Education, and Extension Service

ETC: the Erosion, Technology and Concentration Group

GSM: Global System for Mobile communications

ME: Ministry of Education in China

MLP: Chinese National Medium-to Long-Term Plan for the Development of Science and Technology in the 2006-2020

MOA: China Ministry of Agriculture

MOST: China Ministry of Science and Technology

MOST: Ministry of Science and Technology of China

MPH: Chinese Ministry of Public Health

NCNN: National Center for Nanoscience and Nanotechnology

NSCNN: China National Steering Committee for Nanoscience and Nanotechnology

NSFC: National Science Foundation of China

RFID: Radio Frequency Identification

SDPC: China State Development and Planning Commission

SEPA: China State Environmental Protection Agency

SSTC: China State Science and Technology Commission

STS: Science and Technology Studies

Table 1 **Main Programs Controlled by the MOST**

Program Title	Descriptions
973 program	National Basic Research Program. Aims to improve capacity for innovation.
863 program	National High Technology Research and Development Program. It was launched in 1986. Focuses on the strategic, forefront and foresighted high technology, and fostering new growing points of high-tech industry.
Key Technologies R&D Program	Initiated in 1982. It aims to address major S&T issues in national economic construction and social development. It has made contributions to the technical renovation and upgrading of traditional industries and the formation of new industries.
Torch Program	Launched in August 1988, it is China's most important program for high-tech industries.
Spark Program	Launched in 1986, it aims to revitalize the rural economy through science and technology and to popularize science and technology in rural areas.

Table 2 **Information about the 21 Interviewees**

Institution Type	Number	Location	Research Type
State Research Institution	7	Beijing	Basic research, Development research, Applied products
Local Research Institution	1	Guangzhou	Basic research, Development research, Applied products
University Research Institution	3	Beijing, Shanghai	Basic research, Development research, Applied products
Private Firm	10	Beijing,Shanghai, Shenzhen, Tianjin, Xi'an	Applied products

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