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The limits of academic entrepreneurship: Conflicting expectations about commercialization and innovation in China's nascent sector for advanced bio-energy technologies

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ABSTRACT

Despite many years of substantial government research funding, advanced bio-energy technologies in China have seen limited commercial application. Chinese policy makers are increasingly critical of academic organizations for neglecting their role in the transfer of scientific results into industrial applications. We interviewed a selection of Chinese research groups working on bio-energy technologies, and asked them to describe their efforts at commercialization. We found that they focus their research on technological pathways with commercial potential, they patent and attempt to license their technologies, they are highly involved in large scale demonstration plants, and have created a number of new firms. Industry and government may have unrealistic expectations on the maturity and scale of technologies that academia can develop, however. These findings contrast with many earlier analyses of early commercialization stages of novel technologies, which have commonly identified lacking academic entrepreneurship as a root cause in stalling development.

1. Introduction

Decades of rapid economic development have increased Chinese carbon dioxide to the point where these are now the world's largest [1]. Power generation, heavy industry and transport also contribute to severe levels of local air pollution in China's urban centres [2]. Concurrently, the industries that have previously buoyed economic development (export oriented, labour intensive manufacturing and heavy industries) are losing traction as a successful and desirable mode of economic growth.

Chinese policy makers are pushing for two interrelated transformations to deal with these issues. First, China has ambitious plans for renewable energy, aiming for 15 per cent by 2020 [3]. Second, policy makers are pushing for economic restructuring, moving away from energy and resource intensive industries, and towards innovation driven growth [4]. Particular attention is given to seven 'strategic emerging industries', which include environmental protection, clean transportation, and renewable energy [5]. The R&I policy targets include, amongst others, (1) a substantial increase in R&D intensity (from 1,75% of GDP in 2010 to 2,5% by 2020), (2) improving indigenous innovative strength, and the absorptive capacity for foreign technology, and (3) improved levels of technology transfer, i.e., the application of scientific results from universities and research institutes in commercial, industrial applications, in particular in high-tech industries [4].

The first two goals should help in creating 'world-class research institutions' [6], whilst the latter goal targets what has been called the universities' 'third mission' [7]. This third mission 'encompasses all activities related to the generation, transfer, use, and exploitation of knowledge and other capabilities developed inside universities where the ultimate application is in non-academic environments' [8; p208], whereas the first and second missions refer to educational and research tasks [8,9].

With regard to renewable energy sectors, there have been an increasing number of reports that have highlighted Chinese accomplishments in recent years. Despite marginal developments until circa 2005,

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Chinese investments and installations of renewable power have been the largest globally in recent years [10,11]. Furthermore, Chinese firms are increasingly dominant in equipment manufacturing [12,13], as well as in RD & D output for renewable energies [14,15]. Chinese achievements, however, are particularly apparent in wind and PV sectors [10,11,14,15]. China's bio-energy sector has remained behind in development, compared with global averages, compared with successes in its wind and PV sectors, and even compared with the relatively modest Chinese development targets for bio-energy [16–19]. This is in spite of an abundance of biomass resources, and substantial research efforts into a wide variety of bio-energy pathways [20–25].

As has been the case in other countries [26], Chinese policy makers have voiced criticism on the 'return on investment' generated from science spending, in particular in terms of commercialization results [27,28]. The issue has been a focal point in recent discussions on reform of the Chinese Academy of Sciences, China's biggest science organization [28]. This raises the question whether or not the stalling development of China's bio-energy sector is due to lacking academic entrepreneurship, i.e., whether or not academics are doing too little to have their R & D products developed into industrial applications.

This paper presents a case-study of academic entrepreneurship in China's emergent innovation system for modern bio-energy technologies. Academia are understood to personnel at universities as well as research institutes throughout this paper. We analyse (1) what efforts Chinese academia pursue in commercializing the products of their R & D on bio-energy technologies; (2) whether or not this has been a key barrier in the development of the sector; and (3) what other innovation system weaknesses are limiting the transfer and development of academic R & D products into subsequent economic activity.

2. Theory and method

Policy makers across the globe have at occasions voiced criticism at the, in their eyes, limited societally useful returns from substantial research funding. Some have called for the addition of a 'third mission' to university strategy, for integrated attention to commercial development, or otherwise societally useful application of university research. This 'third mission' is in addition to the existing missions of education and basic research [29]. This policy agenda was inspired by earlier successful examples of university-industry collaboration at e.g., Stanford and MIT in the 1930s, but expanded throughout Northern Americas and Europe in the 1980s and 1990s [29]. A number of universities has reported significant revenues from business start-ups and licensing of patents [30].

In spite of successful examples, however, there is a rather voluminous body of literature that is more critical of academic entrepreneurship and its role in emergent technological fields. The criticism remains that academia have a too myopic focus on fundamental research. They have less regard for development phases beyond scientific or technical breakthroughs, nor are their research agendas strongly driven by industry needs [31].

Some have pointed out that this is in fact partially due to government administered research funds, which are usually mandated only to fund more fundamental forms of research [31,32]. This is out of concern that governments are not particularly good at 'picking winning technologies', and that such choices would create unequal, sub-optimal, market competition between technological alternatives [33,34]. Further, academic rewards, including future career opportunities, are also skewed towards the more fundamental phases of knowledge development [32,35].

There are also institutional or cultural frictions surrounding this third mission. Studies by Kirby [35] and Williams [36] found that university management and staff opposed placing an emphasis on entrepreneurialism, out of fear it would erode core academic values, "such as intellectual integrity, critical inquiry and commitment to learning and understanding" [36; p19]. Courses in entrepreneurship in higher education curricula have generally been limited to business administration programs, prompting organizations including the US' National Academy of Sciences and the European Commission to call for their expansion into technical and scientific programs [30]. Other analysts have commented that university faculty not only lack the motivation and inclination, but also the talent to develop more entrepreneurial activities [35,37].

As our empirical focus is on emergent innovation systems in China, we should consider the specifics of an emerging economy environment on academia's third mission. Policy makers in China and other emerging economies in Asia have pushed for a more direct involvement of universities in industrial innovation. Domestic universities are considered as critical agents in developing indigenous innovative capacity, and as a conduit for understanding and utilizing advanced foreign technology in domestic industries [8,38,39].

So far, there is mixed evidence on the success of this policy push. Some analysts argue that weak R & D capacity in domestic industry has meant that Chinese firms have actively sought collaboration with domestic universities [8,40], whilst others contend that Chinese firms consider domestic universities as having weak innovative capacity, and have therefore chosen to develop in-house R & D efforts [39,41]. Although China has a number of particularly successful examples of university-affiliated enterprises (e.g., Lenovo, Founder), a number of analysts contend that the development of such firms has declined since the mid-2000s [8,39,42]. Lastly, whilst some point to rapidly increased university based patenting in China as indicative of a greater role in the commercialization of technologies, others point out that the share of patents licensed or sold has declined at equally remarkable rates, from 36% of patents granted in 2000 to 8.7% by 2007 [8,43,44].

In the research presented here, we define academic entrepreneurship by building on the framework of 'Technological Innovation Systems' (TIS). This framework suggests a list of activities required to develop or sustain a well-functioning innovation system [45,46] (see Table 1). The framework further stresses that a wide variety of actors is involved in the process, including universities and research institutes, (manufacturing) industry, and government agencies, but also financiers, consultants, certification bodies, maintenance industries, societal pressure groups, consumers etc. [47–49]. This matters because the activities deployed by academics, and the resulting success in furthering the development of the technological field, can never be understood in isolation. The involvement of other actors, and their activities, can create an environment that either limits or propels the results from academic activities into a next phase of technological development. As such, we investigate the extent to which Chinese academia are involved, unilaterally or in cooperation with industry actors, in activities listed under 'entrepreneurial experimentation' in Table 1. That is;

- Creation of new products, processes and services;
- Patenting and licensing of novel technologies;
- Performing of pilot and (commercial) demonstration activities;
- Establishing new firms and production facilities.

This is comparable with items considered in earlier definitions of academic entrepreneurship, but with more explicit attention to piloting and demonstration activities [50–52].

2.1. Method and data collection

We performed a case-study of entrepreneurial activities of academia in China's bio-energy sector. Data collection occurred through a literature review, a round of interviews and a series of workshops. The literature review provided a general overview of the development of China's bio-energy sector and innovation policies. The review also helped identify central actors in academia, industry and policy circles.

A total of 30 specialists were interviewed. Most interviewees were involved in either fundamental or engineering research, and were