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FROM MY PERSPECTIVE

Divergent trajectories of sectoral evolution: The case of Traditional Chinese Medicine in China (1949–2015)

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ABSTRACT

This article explores the divergent evolution trajectories within sectoral innovation system. A sectoral system is composed of three elements, i.e. knowledge and technology, actors and networks, and institutions. Since each of the three components could reveal multiple dynamics, different trajectories co-existing in the sector are able to be integrated shaped by the particular dynamics of the three components. Through investigating the evolution of two sub-sectors embedded in the Traditional Chinese Medicine industry in China, we find that sectoral development does not always follow single pattern but is able to be jointly pushed by the uneven development of different sub-sectors. The strategic policy supports towards a particular sector under such circumstance should therefore fully consider the heterogeneity within the sectoral system and foster the balanced development across different sub-sectors in the long term.

1. Introduction

Divergent evolution trajectories embedded in sectoral innovation system have been initially observed by some existing literature. A sectoral system following the definition of Malerba (2002) is composed of three elements, i.e. knowledge and technology, actors and networks, and institutions. Bergek and Onufrey (2014) demonstrate that multiple technological paths can co-exist in the same industry and are characterized by simultaneous long-term persistence. Leiponen and Drejer (2007) describe the heterogeneity of firms as the main actors within the sector, while Malerba and Nelson (2011) analyze how institutions shape the sectoral innovation system uniquely in different countries. Indeed each of the three components of a sectoral system could possess multiple dynamics which co-exist in the sector at the same time. Nevertheless, until now since different literature only discusses the divergence within the sectoral system from a particular aspect, how the multiple dynamics of the three components integrated shape the different trajectories of sectoral evolution remains unknown.

This article synthetically explores the divergent evolution trajectories within sectoral innovation system. We assume different patterns of development which are characterized by the contrasting dynamics of the three components could exist simultaneously in the same sector. Since each of the three components of the sector could reveal multiple dynamics, different trajectories which are integrated shaped by the particular dynamics of three components will also display unique patterns of development which are distinctive from other pattern co-existing in the sector. A single trajectory which is the composition of the particular dynamics of the three components of the sectoral system in this article is defined as a 'sub-sectoral innovation system'. We assume plural sub-sectors with each own unique evolution pattern are able to be simultaneously embedded in the same sectoral system. We not only emphasize the specific characters shown by the co-existing patterns of evolution, but also the influence of institutions on the plural dynamics embedded in the overall sector. As long as national institutions as widely acknowledged by the existing literature play essential roles in the development of a sectoral system, in this article we pay special attention to the roles of national institutions on the divergent dynamics of sectoral evolution. As government's research, technology, development and innovation (RTDI) policies as specific forms of national institutions especially serve the national industrial concerns, we concentrate our discussion of national institutions on RTDI policies.

We choose the sector of Traditional Chinese Medicine (TCM) in China as the empirical case. The sector has emerged for a long time, yet only recently gains a few academic discussions (Feng et al., 2015). The evolution of the sector however is not fully explored by the present academic community. In fact there are two main sub-sectors embedded simultaneously in the overall TCM sector: the sub-sector of Patent Medicine (PM, *Zhong Cheng Yao*) and the sub-sector of Herbal Piece (HP, *Zhong YaoYin Pian*). PMs are the ready-made prescription medicines which are made up of multiple herbal compounds derived from

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HPs (as shown in Fig. 1), and HPs are the 'processed herbs' which are manufactured through proceeding fresh herbs. A graphical instance of *Compound Danshen Dripping Pill* (*Fufang Danshen Diwan*) is displayed in Supplementary Fig. 1. The production and delivery system of PMs and HPs is shown in Fig. 1.

In practice, the two sub-sectors use the same sources of herbs, and their end products target the same groups of patients who demand TCMs. Nevertheless, the evolution trajectories of the two sub-sectors are distinctive from each other. Both sub-sectors adopt the theory of TCM accumulated in traditional Chinese pharmacopoeias and modern biotechnology developed after the 1970s[1] as their knowledge bases. However, the sub-sector of PM introduced modern biotechnology to reinterpret the TCM theory since the late 1990s to innovate new PMs, while the sub-sector of HP only introduced the knowledge base of modern biotechnology in the 2000s to improve the processing techniques of HPs. Besides, dominant PM firms were the large state-own enterprises (state-controlled companies after the 1990s) which built up networks with universities as early as the mid-1990s; but the main HP firms were the large private pharmaceutical companies which only cooperated with universities in the early 2000s. Moreover, the Chinese government launched different sets of policies towards the two sub-sectors. Only PM was considered as key fundamental industry after 1978 and supported by huge public resources, but even after the mid-2000s the government merely concerned the safety of HPs. In short, the two sub-sectors revealed distinctive dynamics in terms of the three components of the TCM sector. The contrasting trajectories possessed by the two sub-sectors thus provide an interesting example for the analysis of different trajectories embedded in a sectoral system.

To deepen the understanding towards the sub-sectoral innovation systems, we structure the article as the following. Section 2 establishes the conceptual framework based on the existing literature. Section 3 presents the methodology used. Section 4 analyzes the evolution of the two sub-sectors of PM and HP. Section 5 discusses and reflects on the existing literature on the basis of our empirical findings.

2. Literature review and the conceptual framework

The conceptual framework is established upon the literature which analyzes the diversity among the sector. Such literature gradually extends the common wisdom which has assumed the unified evolution trajectory within the sectoral system. In the following paragraphs, we will first review the literature contributing to the divergence of sectoral evolution and afterwards build up our conceptual framework.

Various paths of knowledge and technology innovation could co-exist among the sector. Path in this article is conceptualized as a persistent pattern in the development of a technology (Cowan and Gunby, 1996; Rycroft and Kash, 2002; Sydow et al., 2009).[2] The traditional path dependency theory has perceived that even if the early stages of path dependency allowed some degrees of variety, in the later stage there will be only one path left and alternative technological choices decrease (Arthur, 1989; David, 1985; Foray, 1997). Eventually companies or entire industries become locked-in to one technological option. However, such traditional view of path dependency is insufficient to explain the multi-technology industries which are characterized by long-term co-existence of alternative technologies. Rao et al. (2004) observe that the firms of information and communication technology (ICT) industry in fact possessed high degrees of technological diversity over decades as the response to the structural changes of the sector. Moreover, through the patent analysis of three leading companies in lighting industry (General Electric, Siemens and Philips), Bergek and Onufrey (2014) extend the theory of path dependency that in the multi-technology industries several alternative technologies co-exist and interact with each other over long periods of time. Onufrey and Bergek (2015) further point out that it is the self-reinforcing mechanisms which sustain the technological variety of multi-technology industries.

Heterogeneity of actors especially firms is also recognized by existing literature. Pavitt (1984) sets up the notion of the 'taxonomy' of firms' innovation behaviors. Since all firms of the same sector search for knowledge in the same scope, they will follow homogeneous strategy of innovation. The selection environment of the sector will leave very little variation for these firms. Nevertheless, later research gradually shows the disagreements with the notion of taxonomy. Leiponen and Drejer (2007) investigate the service and manufacturing industries in Denmark and Finland and claim that in most industries, the innovation behaviors of firms could be classified into different strategic groups which execute heterogeneous strategies towards technology innovation. The firms' heterogeneous strategies are attributed to intra-industry differentiation, such as initial strength and weakness of firms, time of entry into market, and historical accidents. De Jong and Marsili (2006) and Jensen et al. (2007) share the similar opinion that the selection environment of the sector does not extinguish the heterogeneity of firms' innovation strategies. Srholec and Verspagen (2012) also conclude the consequence of Community Innovation Survey (CIS) in 13 European countries that different strategic clusters exist simultaneously in the sector due to the process of strategic formation at the firm level. As a result, heterogeneous firms with various innovation behaviors not only remain in the selection environment of the sector but even bring on the dynamics of sectoral development.

Institution as one of the components of the sectoral system could deeply formulate the diversity within the sector. Giesecke (2000) compares the contrasting roles of the governments of the United States and Germany in the development of biotechnology. From her perspective, the government of the United States had more positive supports to the development of biotechnology than the German government, because the United States' government established the favorable 'economic ecology' and overcome the blockages for the development of biotechnology. Niosi (2017) also argues that it is the institutions of the United States which shape the development of biotechnology of the country more competitive than others. Besides, Guennif and Ramani (2012) compare the development of pharmaceutical sector in India and Brazil and find that India has been much more successful than Brazil. It is indeed the design of state policy and the endogenous responses of the innovation system which pushed the two countries along distinctive developmental pathways. Yet, the existing analysis of national institutions only focuses on the influence of the different national institutions which shape the divergent evolution of the sector in different countries. The influence of the national institutions of a particular country which formulates the divergence of the sector within the country remains unclear.

We establish the conceptual framework on the basis of the literature above. The conceptual framework is shown in Fig. 2. A nation is fixed to a geographical border, and a sector and different technologies are developed on a global scale.[3] A sectoral system as examined by Malerba (2002) is 'a set of products and the set of agents carrying out market

[1] In this article, we adopt the definition of McKelvey et al. (2004) that modern biotechnology refers to the biotechnology which is developed in the post-genetic engineering era in the 1970s. Modern biotechnology according to McKelvey et al. (2004) comprised a broad range of knowledge field, including DNA (the coding), proteins and molecules, cell and tissue culture and engineering, process biotechnology and sub-cellular organisms.

[2] In order not to confused the terms used, in this article, a 'path' is defined as a development pattern of a specific technology, and a 'trajectory' is examined as the particular composition of the three components of the sectoral system. In the case of the TCM sector, each of the two knowledge bases of the sector, TCM theory and modern biotechnology, possesses a specific technological path. The two knowledge bases formulate different trajectories in the two sub-sectors of PM and HP.

[3] TCM theory is indigenous in China. However, the knowledge base is also widely shared by the adjacent countries, such as Japan and Korea. Therefore, we consider TCM theory as the knowledge base which is developed on a global scale.