Linkages among Science, Technology, and Industry

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Abstract

Compared to the linkages between science and technology, the linkages among science, technology, and industry are largely under-studied. Therefore, this paper proposes a main path analysis based framework to discover the linkages among science, technology, and industry, in which scientific publications, patents and products are viewed as respective proxies of scientific research, technological advance and industrial development. To validate the feasibility and effectiveness of our framework, the DrugBank database in pharmaceutical industry is taken as our dataset. From empirical analysis on this dataset, the following conclusions can be drawn: (1) The discovered developmental trajectories indeed encode the interactions among science, technology, and industry; (2) The developments in pharmaceutical industry are mainly pushed by only science, only technology, and science and technology simultaneously; (3) The drugs can help enhance knowledge exchanges between science and technology.

Keywords

Science-technology and industry, Linkage, Main path analysis, Pharmaceutical industry

1. Introduction

As the innovation cycle shortens, the interactions between science and technology are becoming stronger and stronger [1]. Ever since the work by Narin and his co-workers [2], extensive studies on the linkages between science and technology are being conducted in recent years [1,3,4]. The cross-citations between scientific publications and patents provide a window for studying science-technology interplay, which regards scientific linkage and technological linkage as two symmetrical dimensions of the linkages between science and technology [5]. The following perspectives have been exploited in the literature: to identify the contribution of scientific research to technological advance [6-8], to identify the contribution of technological advance to scientific research [9], and both [5].

It is evident that there is already a rich body of studies on the linkages between science and technology. However, in the context of economic globalization, the development of science and technology is not isolated, but rather is accompanied by the development of industries. In the meanwhile, industry development largely relies on the advances of science and technology. Despite this, the linkages among science, technology, and industry are largely under-studied. Therefore, this paper devotes to discovering the linkages among science, technology, and industry.

Our main contributions are summarized as follows:

- A research framework has been proposed to study the linkages among science, technology, and industry.
- Three developmental modes of pharmaceutical industry are revealed.

2. Data and Methods

Similar to many previous studies [1,9,10], this study takes scientific publications and patents as respective proxies of scientific research and technical development. In addition, products are viewed as proxy of industry in this work. Due to more prominent science-technology interactions in pharmaceutical industry [11, 12], the DrugBank database from this industry is utilized as our dataset in this study.

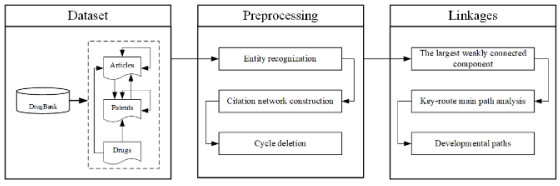

Figure 1: Framework of the linkages among science, technology, and industry.

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The framework of this paper is shown in Figure 1. Our previous works [8, 9] constructed the citations between scholarly articles, between patents, from articles to patents, from patents to articles, from drugs to articles, and from drugs to patents. To discover the linkages among science, technology, and industry, the citations from articles to drugs and from patents to drugs are built after recognizing drug mentions from scientific publications and patent documents. In this way, a heterogeneous citation network among articles, patents, and drugs can be formed. The network reveals the flow of knowledge among scientific publications, patents, and drug products. It is noteworthy that 28 cycles in this network are removed according to several curated rules. Then, the largest weakly connected component is extracted for further main path analysis.

This component involves 16,147 nodes and 41,200 edges, including 8,421 article nodes (52.15%), 5,590 patent nodes (34.62%), and 2,136 drug nodes (13.23%). Finally, key-route main path analysis [13,14] is employed to explore the linkages among science, technology, and industry, where Search Path Link Count (SPLC) [13] is utilized to measure the importance of each edge.

3. Experimental Results and Analysis

To highlight the linkages among science, technology, and industry, the following ten edges are fixed to our key routes: (1) top two edges with the largest weight from patents to articles and those from articles to patents, and (2) top one edge with the largest weight for the citations with the other types. The developmental trajectories in pharmaceutical industry consist of four main paths, as shown in Figure 2.

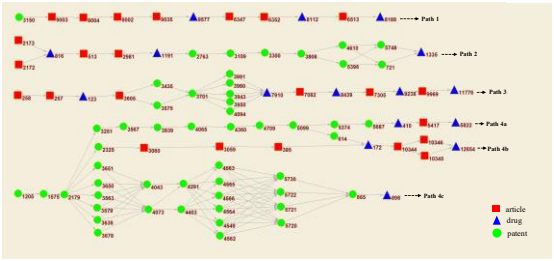

Figure 2: Four main developmental trajectories in pharmaceutical industry.

On closer examination on Figure 2, three developmental modes can be found as follows:

(1) The mode pushed simultaneously by science and technology, such as Path 2 and Path 4b. The early stage of Path 2 mainly focused on scientific research on Cefaclor and Clarithromycin. In the later phase, the emphasis shifts to related technology by combining Colchicine and macrolide antibiotics. The early stage of Path 4b was supported by the anti-abuse Amphetamine compound. The middle and later stages mainly focused on lisdexamfetamine inhibiting human liver microsomal cytochrome p450 and treating children with ADHD.

(2) The mode pushed by science, such as Path 1 and Path 3. Path 1 starts the technology of macrocyclic quinolines for the treatment or prevention of hepatitis C virus (HCV) infection. Based on this technology, the scientific research work is carried out around protease inhibitors and complex inhibitors. The early stage of Path 3 mainly emphasized on scientific research of Omega-3 fatty acids, and in the middle stage, technology played an important pivotal role and proposed the treatment of hypertriglyceridemia. In the later stage, the scientific research focused on Icosapent ethyl, Omega-3 acid ethyl, Omega-3 fatty acids and Gamolenic acid.

(3) The mode pushed by technology, such as Path 4a and Path 4c. Technologies of Path 4a mainly focused on modified release preparations, methamphetamine sustained-release powders, water-based suspension products and methylphenidate sustained-release chewable tablets. The technical route of Path 4c is relatively complex and has multiple branches. Technologies mainly focused on the compositions and methods for the treatment of central nervous system-related diseases.

4. Conclusions

Normally, based on the citation relationships between articles and patents, studying the linkages between scientific research and technology to reveal the process of knowledge transfer. In contrast to the links between science and technology, the linkages among science, technology, and industry are largely under-studied. To explore the linkages among science, technology, and industry, this paper proposed a framework based on main path analysis. Similar to many previous studies [1,9,10], this paper taken scientific publications and patents as proxy of scientific research and technical development respectively. Moreover, in this work, products are regarded as proxy of industry. In order to verify the feasibility and effectiveness of the framework, this paper used the DrugBank database in pharmaceutical industry as a dataset and built on the work of Xu et al to construct a heterogeneous network among articles, patents, and drugs after identifying drug mentions in scientific publications and patent documents. The SPLC algorithm of main path analysis is used to extract the developmental paths from the heterogeneous network. After empirical analysis, the following conclusions were drawn: (1) The discovered development paths indeed encode the linkages among science, technology, and industry; (2) The development modes of the pharmaceutical industry are mainly divided into three types: the mode promoted by only science, only technology, and science and technology simultaneously; (3) The drugs can promote knowledge exchanges between science and technology. However, this study only taken the pharmaceutical industry as the research case. In order to fully explore the linkages among science, technology, and industry, it needs to be extended to other fields.

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