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R&D Offshoring and Clustering Dynamics in Pharmaceuticals and Biotechnology: Insights from the Chinese Case

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Abstract: This paper focus on the clustering dynamics based on/supported by R&D offshoring trends as exemplified by the biopharmaceutical sector in China. It suggests two baselines of the institutional arrangements appropriate to initiate *innovation-based clusters*: (1) emphasis on the linkages and expansion in global innovation networking, and (2) focus on breeding regional innovation networks and enterprise's embeddedness. Above, especially in pharmaceuticals and biotechnology, these two-dimension baselines are closely intertwined and develop by means of R&D offshoring and clustering dynamics, as it is demonstrated by the case study of interaction and co-evolution between Chinese and multinational pharmaceutical companies (MPCs).

Keywords: *R&D Offshoring, China, Clustering Dynamics, Pharmaceuticals, Biopharmaceutical Innovation*

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1. Introduction

Better aligned with the sources of competitive advantage, innovation clusters capture important linkages in terms of technology, skills, information, marketing and customer needs that cut across firms and industries, and what's more, concern deeply the direction and pace of innovation. The dynamics underlying innovation and knowledge creation/diffusion/accumulation processes take place within a multi-spatial framework (Hamdouch and Moulaert, 2006). Seemingly, the decomposition of high-tech industrial chains is both extending globally and penetrating locally. Therefore the resources of innovation dynamics are involving more intricate factors both from long distance and based on geographical, organizational and institutional proximity. On the one hand, while manufacturing has been moved to developing countries, R&D offshoring is more characterized by the huge number of white-collar jobs that are being relocated abroad, and at a tempo and scale never witnessed before. China and India are particularly well positioned to attract foreign high-tech companies[3]. On the other hand, the technological-institutional-economic structure of innovation clusters is guided temporally and spatially, by the interdependency, the embeddedness and the co-evolution dynamics of the technological, industrial and environmental factors (Depret and Hamdouch, 2007) specific to R&D offshoring attraction, absorption and adaptation.

From the perspective of competitive coalitions between the home and host R&D offshoring, clustering self-enforcement has been still accelerating and adapting along the path dependency of technological innovations, in that "even the electronic exchange of codified knowledge (especially if not yet published or legally protected) between distant actors usually requires a minimum of previous direct or physical contacts which initiate mutual recognition and cross-identification of the potential 'corresponding' actors, and permits also to establish some trustworthy basis for further relationships" (Hamdouch, 2007, p. 8). On account of R&D offshoring that could bring in more technological spillovers than FDI manufacturing, speed up human capital transformation and industrial structure escalation, developing/emerging countries compete against one another for attracting multinational companies (MNCs) and giving them incentives to transfer their sub-branches overseas related to more key technologies and R&D activities, expecting therefore more effective spatial diffusion and localized innovation from MNCs technology transfer. Meanwhile, MNCs have gradually built a close connection with local enterprises, government and utility agencies, universities and research centers in order to forger their localized coordinating innovation networks based on the low-cost clusters on formation stage and shift the manufacturing base into R&D offshoring centers. Accordingly, MNCs compete against more and more

[3] On this, see for example "The next wave of offshoring" published in *Far Eastern Economic Review* (Meredith, 2005). This article pointed out that tens of thousands of Silicon Valley's $65,000 a-year computer-programming jobs are on the move, and well-paid R&D work is quickly being shipped to low-cost China and India. Even accounting and lawsuit firms are sending tax and lawsuit preparation work offshore.

following or catching-up "peers" for making a full use of local cheap and qualified human capital together with brand new modern facilities and take continuative advantage and control of global innovation clustering effects.

These clustering dynamics based on/supported by R&D offshoring trends are perfectly exemplified by the biopharmaceutical sector in which the new "technological frontiers" superpose the new "geographical borders" brought about by globalization (Depret and Hamdouch, 2000; Hamdouch, 2002).

The purpose of this paper lies in suggesting two baselines of the institutional arrangements appropriate to initiate *innovation-based clusters*: (1) emphasis on the linkages and expansion in global innovation networking, and (2) focus on breeding regional innovation networks and enterprise's embeddedness. Above, especially in pharmaceuticals and biotechnology, these two-dimension baselines are closely intertwined and develop by means of R&D offshoring and clustering dynamics (He, 2005, 2007), as it is demonstrated by the case study of interaction and co-evolution between Chinese and multinational pharmaceutical companies (MPCs).

The remainder of the paper is structured as follows: Section 2 outlines the specificities of pharmaceuticals and biopharmaceutical innovation. Then Section 3 explores the R&D offshoring and clustering patterns in pharmaceuticals and biotechnology by synthesizing crucial insights stemming from the empirical research literature. Building on this, Section 4 underlines clustering dynamics in biopharmaceuticals as a process coevolving with globalization-fragmentation of markets on the basis of a case study within the context of R&D offshore to China. Finally, Section 5 concludes the paper by drawing some pathways for further research on this topic.

2. The specificity of innovation in pharmaceuticals and biotechnology

According to the latest international classification standard on high-tech industries, pharmaceuticals rank not only as one of the biggest sum of international trade among 15 industries, but also medicine, the main product of pharmaceuticals, as one of the fastest increasing rate of international trade among 5 products (Zhou and Rao, 2001). What's more, pharmaceuticals are more characteristic of the huge investment on R&D. The statistics from the Stanford Institute of Industrial Classification Standard concluded that the ratio between R&D investment and sales income in pharmaceuticals accounts for 12.8% by contrast of the general 3.9% average rate characterizing the other industries. At the first glance, the high investment ratio on pharmaceutical R&D must be closely correlated with its competitive advantage that is actually encapsulated in more systematic and dynamic factors.

The particularity of pharmaceuticals, along with the characteristics unique to the health care marketplace, distort the typical supply and demand relationships in most markets, and accordingly develop a relatively atomized, fragmented and segmented market. This interactive and intricate process is veined traceably to connect relevant parameters within *Table 1* underlying a previous research work (Depret and Hamdouch, 2000).

Table 1: *The general characteristics of the pharmaceutical industry*

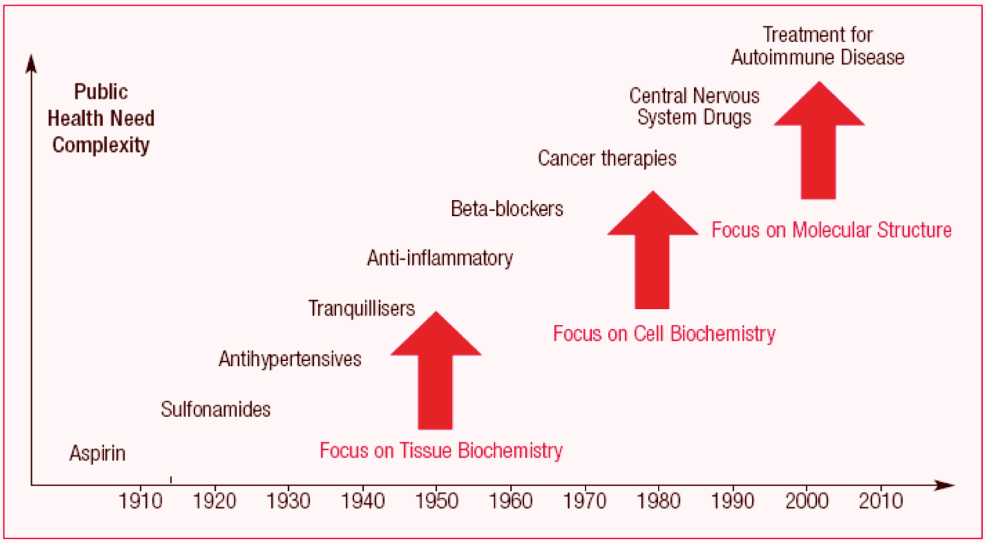
	Pharmaceutical Drug		***Industry Market Structure***	
Out-line	**A specific good**		**A relatively atomized, fragmented and segmented market**	
Description	**Supply**	***Under supervision and regulated all along the value chain***	**Global**	Oligopolistic, but highly dispersed
	R&D	"Good Laboratory (Clinical) Practices"	**National**	**Market fragmentation:** The industrial environment is heterogeneous from one country to the next
	Approval	A.M.M. in France, FDA procedures in USA		
	Production	"Good Manufacturing Practices"		
	Distribution	Specific conditions of access to advertising.		
	Demand	***At the heart of health and reimbursement systems***	**Local**	**Greater specificity:** a) National statutory practices and health safety policies; b) Cultural and human differences in clinical practice; c) Heterogeneous modes of financing and consumption; etc.
	Inter-mediaries	a) Wholesalers, b) Patient-general practitioner pair, c) Financing agencies	**Company**	**Market segmentation:** a) By drugs, on the type of intellectual property rights applicable (Patent versus Me-too), and the terms of sale (Prescription or not). b) By therapeutic category, on which technological and industrial competition between companies takes hold.

Source: Adapted from Depret and Hamdouch (2000)

Along the industrial logic demonstrated in *Table 1*, the interests of pharmaceutical companies and those of the public, patients and the health care system often overlap but they are not identical. The continued need for new innovative medicines and vaccines is surging forward to fight current, emerging and evolving health challenges: increased regulatory control, price bargaining pressure by managed health care networks, greater competition in drug treatment options, the much greater complexity of modern drug molecules, etc.

Along the temporal logic, the specificity of biopharmaceutical innovation stems from public health complexity, characterized by such ongoing developments as the epidemiological and demographic transitions, disease evolution, or drug resistance as represented in *Figure 1*. In this context, ensuring the continuity of medicines innovation is critical for the ever-growing public health needs not only to improve the existing armamentarium of therapies and treatments but also to create new medicines by virtue of continued R&D efforts.

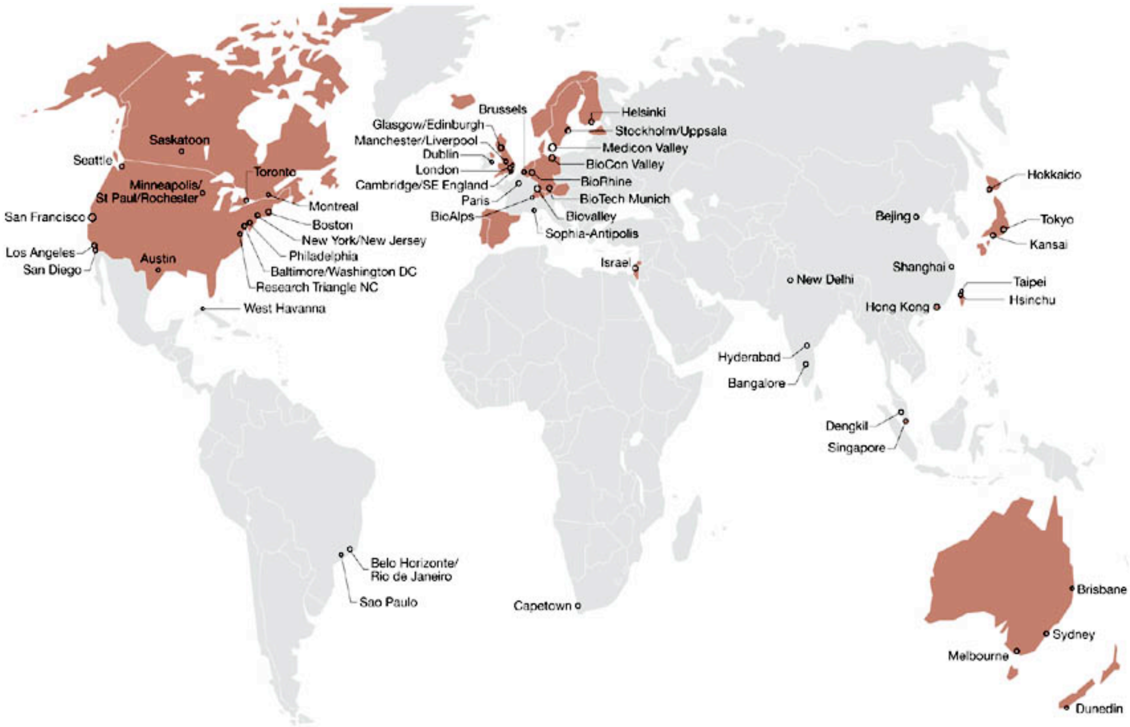
Figure 1: *Dynamic continuum of medicines innovation through time*



Source: IFPMA (2004)

Along the spatial logic, pharmaceutical clusters increasingly mix a pattern of localized learning with a dynamics of external learning because the latter has crucial impact on the former through the R&D cooperation with international actors and the deployment of multiple innovation sources in order to get access to global circuits of knowledge creation and diffusion. As demonstrated in *Figure 2*, the countries colored in brown rank highly in the Growth Competitiveness Index 2004-2005 of World Economic Forum and the black circles represent select biotechnology and life sciences clusters. It is in fact through a powerful network of partnerships with prestigious *academic institutions, venture capitalists, and service providers* that the life science sector positions itself amongst the most R&D intensive and innovative industries and concentrates its industrial chain decompositions at the global level round those key innovation clusters by its much higher threshold and more systematic dynamics. As a result, shifting to the development and manufacture of biologically-based drugs appears more risky and complex especially in the context of more and more R&D offshoring to several main cities in several developing countries like China and India whose urgent task on hand focuses on systematically reorganizing their existent local biotechnology and bioscience clusters with more interregional and international innovation coalitions to attract/absorb/accumulate more external advanced knowledge with relation to all the heterogeneous, fragmentary as well as interactive parties such as R&D, manufacturing, regulatory and sales/marketing groups etc.

Figure 2: *Select global biotechnology and bioscience clusters*



Source: Rinaldi A. (2006)

In order to examine the debate about how clusters evolve with R&D offshore systematically, the paper elaborates the following *hypotheses*:

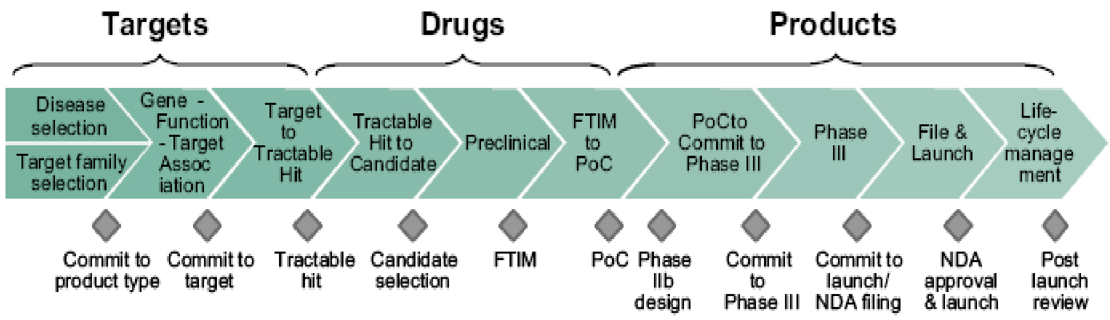
1. Globalization emphasizes the linkage and expansion of manufacturing and innovative network on the global level.
2. Regionalization points out the cultivation of innovation network within a region and the embeddedness of firms.
3. The more a country/area is dynamically engaged in an effective clustering dynamics, the more its competitiveness is increasing in attracting R&D offshoring in high-tech industries and in turn the more the clustering dynamics and competitiveness are likely to be fostered.

3. R&D offshoring and clustering dynamics in pharmaceuticals and biotechnology: Synthesis of empirical research modes

In the light of the radical transformation of the technological-institutional-economic structures that characterizes it, biopharmaceutical innovation seems specific as well. If there were one single lesson to be learned from the development of the biopharmaceutical industry since the 1899 discovery of aspirin – the first wonder drug –, it would be that innovation in this sector can never be taken for granted and usually needs to be encouraged through enlightened public policy choices that balance risk with incentives (IFPMA, 2004).

During the last three decades, the industry started a deep transition to "guided" drug discovery or "drug development by design" (*Figure3*), a research methodology that drew heavily on advances in molecular biochemistry, pharmacology and enzymology in the seventies.

Figure 3: *Development of a drug from target identification to post-launch product review*



Source: House of Commons, Health Committee (2005)

At the same time, the complexity and the increasing R&D and commercialization costs implied by this new innovation dynamics (Hamdouch and Depret, 2001) translate in two major trends at the industry and company levels:

- First, the pharmaceutical and biotechnology industries have moved to sizable consolidation through mergers and acquisitions owing to enhanced buyer power, increased competition from generic and "me too" drugs, the rise of biotechnology as an alternative research approach, increased government pressure, rising research cost, and a rash of major patent expirations dramatically that changed the growth and profit outlook of pharmaceutical companies.

- Second, multinational pharmaceutical companies (MPCs) consider nowadays the offshoring of R&D activities as an effective way for reducing the actual cost of research, for compressing the period of drug development, and for exploring more diversified research paths. Starting with the comparatively high volume, low value work of clinical research, offshore drug-discovery industry in developing/emerging countries has moved across the value chain to provide services in the preclinical phase, especially in the area of chemistry services. Moreover, local biotech companies have become capable in providing manually intensive but highly skilled outsourcing services including nucleotide sequencing and synthesis, protein expression, and library construction. A few players are also beginning to provide services in the area of molecular biology and bioinformatics.

As a matter of fact, with surprising speed R&D has joined manufacturing as one of the key areas for offshoring. In biopharmaceuticals (but also in ICT), innovation globalization comes into being a visible reality through the widespread of MNC's R&D institutions in emerging economies (He, 2005; Cockburn, 2007). As a result the industrial district and cluster model, although representing a specific form of local agglomeration of firms, is evolving towards more open spatial configurations that involve growing external, remote linkages. Nowadays many districts or clusters have transformed into complex systems with "multi-scaled" boundaries (Hamdouch, 2007, 2008), which influence the international markets and are in turn influenced by district firms' position and control within global commodity chains (Belussi et al., 2006).

The complex clustering dynamics is composed of sub-dynamics like market forces, political power, institutional control, social movements, technological trajectories and regimes. Drawing from the empirical studies on both such US and European pharmaceutical companies who operate offshore and such offshore destination countries as China and India (Pore, Yu and Cooney, 2006), the *Medicon Valley* case (Moodysson, 2007) has been a *R&D intensive clustering paradigm* within the dynamics of biopharmaceutical innovation whose trajectory and inflection points are guided, temporally and spatially, by the interdependency, the embeddedness and the co-evolution of the technological, industrial and environmental factors specific to the pharmaceuticals and biotechnology (Depret and Hamdouch, 2007).

The reasons for the differentiated patterns of evolution of the biopharmaceutical industry across countries, especially after the advent of the Molecular Biology Revolution, are still controversial. There is little question, though, that institutional factors seem to have played a decisive role. Indeed, from its inception, the evolution of the pharmaceutical industry has been tightly linked to the structure of national institutions. More generally, ever since the mid-Seventies the American, British and Swiss companies appear to have gained significant competitive advantages *vis-à-vis* European firms, including the German most competitive ones (Gambardella, Orsenigo and Pammolli, 2000). And traditionally the Continental European (except Germany and Switzerland) and Japanese biopharmaceutical industries have been much less oriented toward radical innovation than to strategies based on imitation, production and marketing mainly for the domestic market.

By contrast with the widespread view according to which innovation and R&D collaboration require (as a compulsory condition) "geographical proximity", it is increasingly recognized that more or less geographically distant actors can engage in "strong links" and manage sustained interactions within a productive and/or innovation process that requires continued collaborations or exchanges with close-complementary partners in terms of knowledge, competences or expertise (Ernst, 2006; Hamdouch, 2007; see also Preissl and Solimene, 2003). For multinational firms, the critical geographies for innovation may therefore extend over large regional, interregional or even international scales. This suggests that the relationship between geography and innovation actually depends on the very nature of the information and knowledge-based interactions, which embrace within a co-evolutionary model of the clustering dynamics characterizing industries submitted to radical transformation of their technological-institutional-economic structures (Hamdouch and Moulaert, 2006; Depret and Hamdouch, 2007).

In order to reflect the essence of this phenomenon, the McKinsey Global Institute proposes the term "global resourcing" defining it as the "decision of a company to have a location-insensitive job performed in a demand market (market where the product is sold), in a border zone (near shore), or remotely (offshore)"[4]. International outsourcing is indeed one possible business model amongst other alternatives when a company offshores some of its activities instead of operating them locally.

The advantages and disadvantages of each alternative "global resourcing" operational model are shown in *Table 2*.

Indeed, the more mature the market is, the easier it will be for a firm to approach it individually. On the contrary, collective strategies and coalitions tend to increase when the market in question is insufficiently mature (biochips, proteomics, pharmacogenomics, gene therapy, etc.), or hardly accessible (China, India, etc.). Forming coalitions and networks thus enables pharmaceutical companies to solve or attenuate the dilemma of tight/broad specialization (Hamdouch and Depret, 2001) within the framework of strategies for renewing drug portfolios, going around barriers as regards entry or strategic watch. New therapeutic and/or geographic markets thus become more accessible to a greater number of firms. (Depret and Hamdouch, 2000).

[4] McKinsey Global Institute (2005), *Emerging Global Labor Markets*, *Part 1*, McKinsey & Company, June

Table 2: *Advantages and disadvantages of offshoring models*

	Description	Pros	Cons
Outsourcing	Outsource part of R&D value-chain activities to a local vendor, a Contract Research Organization (CRO), or Government research institutions	"Time to test water"; Broadened experience; Cost savings; Exit flexibility	Limitation of lower complexity work because of Intellectual Property (IP) concerns; Risk of lower quality when using new vendors
Partnership or alliance	Provide scientific training and management oversight to a local vendor	Control over quality with management oversight; Better communication and trust owing to the longer-term relationship	The possibility that a partner taking capabilities elsewhere as a service provider; The possibility of the management-training effort being leveraged by competitors
Captive investment	Build an R&D center from scratch	Larger commercial benefits; Control over assets, skills, knowledge, and culture; Quicker advancement into more complex work; Fewer IP concerns	Lower cost savings; Potential political and regulatory risks

Source: Adapted from Mridula et al. (2006)

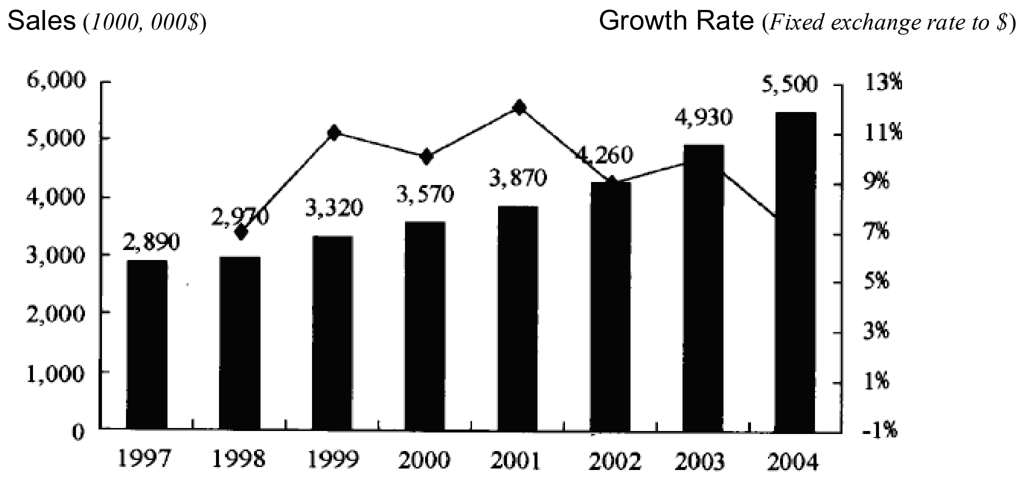
4. R&D Offshoring and Clustering Dynamics in Pharmaceuticals and Biotechnology: The Case of China

According to the statement of *The 11th Five Years Development Planning of Pharmaceutical Industry* (National Development and Reform Committee of China, 2006), the developing tendency and statistics in global pharmaceutical industry have been expressing its general characteristics in salient points as follows:

- *The global pharmaceutical market is under the full control of USA, Europe and Japan while the new emerging countries seem to be a notable trend on fast increasing rate.*

USA, Europe and Japan as the top three pharmaceutical markets in the world amount to 87.7% of the global market share. Except the North American market extending at a steady speed, most regional markets are soaring both on scale and at speed. To compare and contrast the statistics of growth rate in 2005, Europe pharmaceutical markets added up to 7.1% and Japan has reached its top point to 6.8% since 1991. Latin America held the growth rate of 18.5%. Asia Pacific Area and Africa markets increased by 11%. China is expected to be the 7th biggest pharmaceutical market before 2009 due to its soaring growth of 20.4% and its three-successive-year records for increases of more than 20%. The statistic source from IMS Health in *Figure 4* (Xu, 2005) confirms that such differentiated uncertainties and pressures on drug market as decedent drug price, medicine safeness and regulation adjustment slow down the speed of sales increases, but the whole shares keep ascendant owing to the new market growth particularly from China and India and the new biotechnology applied to health.

Figure 4: *The World pharmaceutical market by drug sales from 1997 to 2004*



Source: Xu (2005)

- *The great-scale multinational groups give main impetus to pharmaceutical globalization so far as the top 50 pharmaceutical groups of origin totally from USA, Europe and Japan are concerned. Meanwhile a worldwide R&D offshoring network is in the ascendant.*

The particular aspect of domestic pharmaceutical markets sidesteps the competitive game and makes the industrial environment heterogeneous from one country to another in spite of globalization. With a new tendency to being extended to upstream market competition, to be reconfigured in the form of intra and inter-coalitions and networks strategic games, and to quickly evolve along with technological innovations, the opening of new market “frontiers” and successive concentration operations (Depret and Hamdouch, 2000), the proportion of R&D offshoring in pharmaceuticals at the global level summed up 16.3 billion dollars in 2005 and is expected to be 36 billion dollars in 2010 with an increase rate per year of 16.3%.

- *Biotechnology is becoming the critical technological platform of new drugs’ R&D, the competition focus on MPCs’ strategy and the key point for preferential-policy makers inclined to encourage more investments on the innovation supply.*

> *Paradoxically the demand size of patent expiry drugs keeps on surging for the raison that the patents of some "blockbusters" successively expired to fall into the public domain and the governments burdened with increasing healthcare expenses take opportunity to expand them on the healthcare lists.*

> New biotechnology techniques applied to health enable the development of more effective drugs that are less expensive and launch on the market more quickly and, more particularly, improve intervention no longer on the effects of a pathology but on its causes and make an alternative to the chemistry paradigm. Both drug and therapeutic market segmentation can mainly be explained by technological change and market globalization and, more precisely, by the persistent and amplified uncertainty with which pharmaceutical companies have been confronted. Thus, the increase in size permitted by M&A seems to be less of an objective in itself than a means for seeking new partners so as to master the competitive regime brought about by the structural changes in progress in this industry (Depret and Hamdouch, 2000; Hamdouch and Perrochon, 2000; Hamdouch and Depret, 2001).

In this context, MPC's R&D offshoring to developing/emerging countries has become a strategic major trend in organizing their innovation processes (Bardhan and Jaffe, 2005; McCormack et al., 2007). According to the *AT Kearney Offshore Location Attractiveness Index* survey in 2004, India and China are currently two most popular offshoring locations for their cost advantages and the depth and breadth of offshoring experience and people skills (on this, see e.g. Thomas, 2007). In addition, China and India are also ranked top and second position in both the AT Kearney FDI attractiveness index and the *Country Attractiveness Index for Clinical Trials*[5]. As these economies develop, they are experiencing growth in their domestic markets as well, with both multinationals and domestic companies involved in this growth. The largest players in each market are listed in *Table 3*.

[5] AT Kearney (2005), FDI Confidence Index, *Global Business Policy Council*, Vol. 8, 40 p.

Table 3: *The top multinational and domestic pharmaceutical companies by market share in China and India*

	China	India
Multi National	Pfizer Inc Astra Zeneca plc Roche AG Novartis AG GSK plc Bayer AG	Glaxo Smith Kline Pharma Ltd. Pfizer Sanofi-Aventis Abbott Novartis Wyeth Merck Astra Zeneca Janssen-Cilag Infar India
Domestic	Shanghai Pharmaceutical Group Co., Ltd. Guangzhou Pharmaceutical Holdings Limited Tianjin Pharmaceuticals Group Corporation Yangtze River Pharmaceutical Group Harbin Pharmaceutical Group Co., Ltd. Shijiahzhuang Pharmaceutical Group Co., Ltd. North China Pharmaceutical Group Corporation Beijing Double-Crane Pharmaceutical Co., Ltd. Northeast Pharmaceutical Group Co., Ltd.	Ranbaxy Laboratories Cipla Ltd Dr Reddy's Laboratories, Ltd. Wockhardt Ltd. Nicholas Piramal India Ltd. Sun Pharmaceuticals India Ltd. Lupin Ltd. Aurobindo Pharma Ltd. Cadila Healthcare Ltd.

Sources: Data monitor[6], Ernst and Young[7], CPCI[8]

Offshore R&D helps the MPCs to build a close relationship with local government, institutes and hospitals. As a result, it allows MPCs to consolidate their positions in the local market as an important part of their global strategy. As demonstrated in *Table 4*, in addition to the advantage of cost and natural resources, China offers a wide sample of the human gene pool and patient pool. Data on different populations will become increasingly important as the industry shifts from making traditional blockbusters to producing drugs that are targeted at patients with specific genetic polymorphisms.

[6] Data monitor (2005), Pharmaceuticals In china, *Industry Profile*, Dec.
[7] Ernst and Young (2004), Industry Defining Facts and Events, *Progressions 2004 Global Pharmaceutical Report*, New York: Ernest and Young International Publishing
[8] China Pharmaceutical Chain Industry Report (2006), *Research in China*, Aug., 158p.

Table 4: *R&D Offshoring Dynamics to China*

MPCs	Driving Force	Strategic Vision
Pfizer	Set a R&D center in Shanghai	Support biometrics profitable to developing new drugs
Glaxo-Smith-Kline	Worked with Chinese scientific and research groups such as Shanghai Institute of Material Medica (SIMM) in the filtration and development process of an approximate 10,000 herbal medicines; Carried out $7-million collaborative projects.	Investing in R&D projects in China
Novo-Nordisk	Set up its $10 million center in 1997 and conducted research in industrial biology and pharmaceuticals that focused on natural resources; Designated China as its global center for competency in microbial protein expression in 2000	Double its staff in the next 2-3years to 60 scientists; Evolve from a highly skilled biotechnology provider to an innovator; Target identification for cancer and inflammatory diseases
Roche	Invested more than $10 million in a new R&D center of its own in Shanghai's Zhangjiang High-Tech Park in 2004; Currently 40 scientists conducting basic chemistry in compound generation	Step into traditional Chinese medicine research to gradually develop more comprehensive R&D capabilities
Servier, Norvatis, Sanofi-Aventis	Serious investigations into compounds from traditional Chinese medicines	As the basis for drug discovery
Astra-Zeneca	Set up a clinical trials operation in China in 2002; Announced a $374,000 three-year partnership with Peking University's Guanghua School of Management to fund the China Center for Pharmacoeconomics in 2003	Outcomes Research in programs aimed at supporting the reform of China's health care system
Lilly	20% of its chemistry work in China with one quarter of cost in the U.S. or Western Europe; Helped start a lab in Shanghai in 2003	Predict 20% to 30% of clinical research in China and India

Source: Autors, adapted from Data Monitor[9] and CPCI Report[10]

With regards to knowledge creation and offshore, the clustering dynamics play a key role in acquiring international competitiveness for every country; however, it differentiates on account of the difference in economic performance and sectoral specialization of national and trans- (sub-) national systems of innovation[11]. From this point of view, China is reasonably advanced in clinical trials and lower-complexity chemistry work but less so in preclinical and biology-based drug discovery.

[9] Data Monitor (2005), Pharmaceuticals In china, *Industry profile*, Dec.
[10] China Pharmaceutical Chain Industry Report (2006), *Research in China*, August, 158p.
[11] In the case of China, Liu and Buck (2007) show how the absorptive capacity of indigenous firms plays a key role in benefiting from R&D offshore by MNCs.

To facilitate foreign investment in pharmaceutical and biological areas, many Life Science Parks, such as Shanghai Zhangjiang Life Science Park described in *Table 5*, were established. These parks serve as a discovery-outsourcing platform and offer MPCs basic amenities and fiscal and regulatory incentives. With relation to development path, the high-tech parks are aiming at transplanting clusters via recruitment and incentives at the beginning of establishment, usually by virtue of preferential policies and reduction of land fare. Such spatial agglomeration is of great frailty. When the location advantages such as land cost, labor force, and preferential policies etc. change, the cluster will decline quickly with the cluster firms migrating outside. If the high-tech parks are expected to grow into real innovation hubs, there is a need to examine critically the stated reasons for public policy intervention in regional clusters, as well as to analyze what might be sound policy instruments adapted to different circumstances (He, 2005).

Table 5: *Bio-clustering dynamics in Shanghai*

	Shanghai
Firms	446
Employees	1447
Take-off	2006[12]
Current Stage	Embryonic
Tendency	Growing
Depth	Shallow
Strengths	No significance, yet
Weaknesses	As a discovery-outsourcing platform and offer MPCs basic amenities and fiscal incentives.
Spatial aspects	No spatial significance, yet
Future prospects	Government places a strong emphasis on development of biotech sector; Targeted strategies for development of biotech cluster

Source: Compiled by the authors with the methodology of GEMACA II[13] reports (2002), and the data from http://www.ccper.com/Article/yqglyqgl/200701/20070110150256.html

By looking at the high-tech parks (or Technology Parks" in China) from the lens of innovation incentive mechanism, ideal clustering evolution not only fosters strong connections relevant to market, inter-firm collaboration and institutional infrastructure but also attracts more regional/national/international knowledge organizations involved in innovation co-operation[14]. With more R&D offshore to China, the

[12] *Development and Reform Committee of China* licensed Shanghai to develop *the national Bio-industrial base* in 2006, but Shanghai zhangjiang Life Science Park was initiated and gradually facilitated from 1996.

[13] GEMACA II (2002), Growth Sectors / Clusters in Dublin, London, Paris and Rhine Ruhr: Synthesis and recommendations, *Group for European Metropolitan Areas Comparative Analysis, Second Project Report*, July, 51 p.

[14] On the role of Technology Parks in spurring clustering dynamics and economic growth at the regional level in China, see for example Hu (2007).

high-tech park becomes an agglomeration more strongly linking R&D, industrial, and educational institutions together. As an inherent mechanism, knowledge-based integration shifts imitation to autonomous innovation. An example in point of Chinese manufacturing industry demonstrates how the developed areas in China — such as the Yangtze Delta — can directly build on the system of industrial structure dominated by the knowledge based economy, therefore striding over the productive factors driven stage (see *Table 6*).

Table 6: *The impact of industrial clustering evolution on the process of industrialization in China*

Average GDP per person ($)	**Industrialization Stage**	**Incentive Mechanism**	**Location Advantage**	**Manufacturing aim and FDI orientation**	**Typical Case in china**
Below 1200	*Prophase*		*Low-cost resources, low paid labor force*	*Raw-material excavation, rough manufacturing*	
1200～2400	*Initial*		*Cheap and skilled labor, manufacturing capability*	*Labor-intensive outward manufacturing, assembling by OEM*	*The OEM mode has been carried out generally in the coastal areas since 1980's*
2400～3500	*Middle*	*Investment driven*	*Utilize manufacturing base, existing stock of technology, and*	*Large-scale manufacturing industrial base*	*MPC's manufacturing base of Jiangsu in the area of the Yangtse Delta*
3500～4800	*Later*	*Innovation driven*	*Utilize manufacturing system, skilled human resources, innovation capability, information network, advanced R&D resources, and clustering effect*	*Hi-tech based manufacturing and R&D offshore base of MNCs*	*R&D center of Roche and Pfizer in Shanghai Zhangjiang Life Science Park; the China Center of Asra-Zeneca with Perking University for Pharmacoeconomics; and top MPC's flagship/regional headquarters in Shanghai*

Source: Adapted from He, 2005

As a main R&D offshore host country, China should have developed a number of frontier technologies in the biological sector by 2020, such as target-finding, designing of species of animals and plants as well as pharmaceutical elements, genetic operation and protein engineering, dry cell-based human tissue engineering, and new-generation industrial biological technology. As a result, more R&D offshore from MPCs to China could lever its learning capabilities by spillovers and spin-offs in the life science parks, which in turn should enlarge clustering effects depending on geographic proximity with involving more organizational, cognitive and institutional dimensions[15].

On the part of MPCs, offshore R&D activities not only provide the MPCs with a larger global market for their services and a more flexible approach to capacity and pipeline management, but also facilitate the progress in science and technology of offshore countries. For example, the traditional Chinese medicine — that lists a total of 12,807 medicinal materials derived from natural sources, about 5000 of which may have some clinically proven efficacy in China[16] — needs offshore R&D to help investigating with the techniques of modern drug discovery and meanwhile expands MPCs' alternative sources of compounds. Far from being a zero-sum game, China should foster the completer institutional environment encouraging more flexible and efficient competitive coalitions on more frontier technologies which are expected to play a guiding role in the development of science and technology and for future upgrades of high-tech and emerging industries reflecting a country's innovation capability.

5. Conclusion

Based on the case study of China — which perfectly illustrates that MNCs prefer to offshore to regions with creative or strategic assets to those manufacturing bases with more fragility —, this paper has tried to identify some crucial paths of ongoing R&D offshoring and clustering dynamics in the pharmaceutical and biotechnology industries. It therefore suggests, for every company or country, that R&D offshoring and clustering dynamics play nowadays a key role for capturing and accumulating learning/innovative effects in the context of the sharper as well as more multidimensional and uncertain global competition at work in high-tech industries such as biopharmaceuticals. This strategic challenge emphasizes, in turn, the need for a company or a location to attract/absorb/adapt the more advanced innovation resources for distant as well as close partners through forming (or, at least, belonging to) flexible and multi-tasking competitive coalitions.

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[15] Another key factor in ongoing the clustering dynamics within high-tech industries in China (but also in India and Taiwan) is the crucial role played by "Returnees" in carrying new knowledge and experience, and in connecting local entrepreneurs to major companies and leading clusters in the countries where they have been educated (and where they also often started and developed their own businesses).See, among others: Bresnahan, Gambardella and Saxenian (2001); Saxenian (2006).; Zweig, Siu Fung and Vanhonacker (2006).

[16] For the detailed discussion on the Theme of traditional Chinese medicine, please refer to Nie X(2004) http://www.ebiotrade.com/newsf/2004-12/200412794152.htm

With respect to these changing qualitative and quantitative features of global competition and the various uncertainties it bears, further research needs focusing on benchmarking the R&D offshoring and clustering dynamics both specific to differentiated industrial chains of global distribution/decomposition of production and innovation activities, and related to welfare improvements satisfying all the parties. Further theoretical research efforts are also needed towards better understanding and formalizing the very processes and mechanisms underlying R&D offshoring and clustering dynamics. Finally, strong empirical work commitments, based on sound and coherent methodologies, are crucially still lacking at the geographical as well as the sectoral level.

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