Management international
International Management
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La innovación inversa y la transferencia de tecnología inversa: Del hecho en China al descubierto en China en el sector farmacéutico

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Volume 19, numéro 4, été 2015

Globalisation des processus d’innovation dans les entreprises multinationales

URI : https://id.erudit.org/iderudit/1043076ar
DOI : https://doi.org/10.7202/1043076ar

Aller au sommaire du numéro

Éditeur(s)

HEC Montréal
Université Paris Dauphine

ISSN

1206-1697 (imprimé)
1918-9222 (numérique)

Résumé de l'article

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Résumé

L'émergence d'un géant comme la Chine bouscule les acquis. La localisation de centres de R&D par des entreprises multinationales dans les pays émergents modifie les perspectives et crée un véritable changement de paradigme en termes d'innovation et de transfert technologique. Dans cet article, nous confirmons d'une part cette tendance mondiale déjà évoquée dans les études précédentes et nous démontrons que les multinationales peuvent maintenant choisir les pays émergents comme un lieu stratégique pour externaliser la R&D. D'autre part, nous allons plus loin en montrant empiriquement les phénomènes d'innovation inverse et de transfert technologique inverse dans le secteur pharmaceutique.

Mots clés : Innovation, innovation inverse (inversée), transfert technologique, compagnies pharmaceutiques, Chine.

Abstract

The emergence of a giant like China changes the landscape. The potential localization of multinational companies' R&D centers into emerging countries changes the analytical perspective. This phenomenon moves the knowledge frontier and creates a real paradigm change in terms of innovation and technology transfer. On the one hand, we confirm the global trend of knowledge sources implied in previous studies and we demonstrate that multinationals might now choose emergent countries as a strategic place to externalize R&D. On the other hand, we go further by empirically showing the phenomena of reverse innovation and reverse technology transfer in the pharmaceutical sector.

Keywords: Innovation, Reverse Innovation, Technology Transfer, Spillovers, Pharmaceutical Companies, China

Resumen

La aparición de un gigante como China molesta a los que ocupan el espacio. La ubicación de los centros de I&D de las empresas multinacionales en los países emergentes modifica las perspectivas y crea un cambio de paradigma en términos de innovación y transferencia de tecnología. En este artículo, confirmamos por un lado esta tendencia mundial ya evocada en estudios anteriores y demostramos que las multinacionales pueden ahora elegir los países emergentes como un lugar estratégico para externalizar I&D. En segundo lugar, vamos más allá al mostrar empíricamente los fenómenos opuestos de la innovación inversa y la transferencia tecnológica inversa en el sector farmacéutico.

Palabras claves: innovación, innovación inversa, transferencia de tecnología, compañías farmacéuticas, China

Our paper is about R&D internationalization, and the conjunction between reverse innovation and reverse technology transfer in the pharmaceutical industry in China.

The emergence of the Chinese, Indian and Brazilian giants is characterized by the impressive expansion of their middle class. This phenomenon corresponds to a second stage in the globalization process[4] (Trimble, 2012) and re-

1. Corresponding author. We would like to thank CIRANO and the GMT Research Group (Polytechnique Montreal) for their support. We also thank the Social Science and Humanities Research Council (SSHRC) for their financial support. The usual caveats apply.

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4. The emergence of some countries as China implies the outsourcing of specific global value chain stages (Baldwin, 2012).

sults in the birth of new and huge markets for multinational companies (MNCs). In this context, China seems to stand out as the key new market since it represents more than 300 millions of consumers (Friedman, 2012). This key market is certainly attractive for MNCs from advanced economies.

However, to conquer these consumers, firms must create new products and services (clean-slate innovation) to fulfill specific local needs (Govindarajan & Ramamurti, 2011; Govindarajan & Trimble, 2012; Immelt, Govindarajan, & Trimble, 2009). As highlighted by Trimble (2012), selling advanced economies' products with no – or small – adjustments is inadequate.

In this perspective, MNCs might be interested in opening R&D centers in China in order to develop new products fitting the local needs. As a result, this conjunction between the presence of these R&D centers and the consideration of local needs leads to local innovation. Then, the products developed locally might be brought back to advanced economies. Called reverse innovation, this new phenomenon has been first introduced theoretically by Immelt, Govindarajan, and Trimble (2009). An innovation is called reverse when first developed for and adopted in the developing world (or emerging world) before "spreading" to the advanced economies (Ramamurti and Govindarajan, 2011).

Moreover, it might also be possible for MNCs to learn from local firms (via local collaborations). In the literature on technology transfer, it is often assumed that firms from the south can learn from firms from the north (Aitken & Harrison, 1999; Djankov & Hoekman, 2000; Haddad & Harrison, 1993; Javorcik, 2004; Kokko, Tansini, & Zejan, 1996; Wang, 2005; Wei & Youssef, 2012; Young & Lan, 1997). However, there is today a large number of MNCs from emerging countries. This changes the global competitive landscape (Ramamurti & Singh, 2009), in particular in the pharmaceutical sector (Chittoor & Ray, 2007). Local firms might have an advantage in terms of time, market penetration and knowledge of the local needs. Hence, it can be useful for firms from the north to collaborate with local firms to gain access to strategic information. Therefore, reverse innovation and reverse technology transfer (knowledge transfer from emerging economy firms to advanced economies' MNCs) are intrinsically linked.

The contribution we make in this paper is part of the strategy and international business literature and more precisely the internationalization of R&D activities (global knowledge management). The process of R&D internationalization and its evolution through time is already well documented in the academic literature. However, these studies are concentrated on firms from developed countries having R&D affiliates mostly in the Triad region (Gassmann and von Zedtwitz, 1999; Gerybadze and Reger, 1999; Kuemmerle, 1997; von Zedtwitz, Gassmann, and Boutellier, 2004). The emergence of a giant like China motivates new research either to validate the existing research positions or to create new ones. Although we confirm the global trend of knowledge sources (Filippaios, Papanastassiou, Pearce, & Rama, 2009; Gassmann & von Zedtwitz, 1999; Gerybadze & Reger, 1999; Kuemmerle, 1997; Maximilian von Zedtwitz & Gassmann, 2002a; Maximilian Von Zedtwitz, Gassmann, & Boutellier, 2004), we show that MNCs might now choose emergent countries as a strategic place to externalize their R&D.

Indeed, the localization of MNCs' R&D centers into emerging countries changes the analytical perspective. This phenomenon moves the knowledge frontier and creates a real paradigm change in terms of innovation and technology transfer. Reverse innovation and reverse technology transfer open the way for a new analytical framework assuming that innovations are first developed to fulfill local needs (thus adopted by the developing world first) and then are brought back to the developed world.

Our research question stands as an extension of these statements and can thus be formulated as: **"Does China now stand as a new key center for innovation and, if it is the case, what are the implications in terms of innovation and technology transfer? In other words, do we really observe reverse innovation and reverse technology transfer?"**

The rest of the paper is organized as follows. The next section presents the review of the literature, followed by the methodology. We then use qualitative methods to empirically test the new paradigms of reverse innovation and reverse technology transfer. We finally discuss our results and conclude.

Literature Review

The literature review can be separated into two major parts. On the one hand, we investigate the academic literature focusing on the evolution of the localization of R&D centers and R&D internationalization. On the other hand, we highlight the academic literature on the new concepts of reverse innovation and reverse technology transfer.

R&D internationalization

R&D internationalization is becoming a major source of competitive advantage for multinationals (Almeida, 1996; Awate, Larsen, & Mudambi, 2015; Hansen & Løvås, 2004; von Zedtwitz & Gassmann, 2002b). With the intensification of competition, R&D internationalization is fast becoming a competitive necessity for science and technology-based businesses (Moitra, 2004). However in 2005, the report of the United Nations Conference on Trade and Development indicates that on a total of 2,584 affiliates across the world, 85 percent of them were located in the Triad (Western Europe, United States, Japan) and only 10 percent in developing countries (including Africa, Latin America, the Caribbean and Asia) (United Nations conference on trade and development, 2005). In light of these facts, it is understandable that the bulk of the literature on R&D internationalization has focused on issues concentrated in the developed world.[5] Very few studies address R&D internationalization issues regarding developing countries. For example, von Zedtwitz, Gassmann, and Boutellier (2004), identifying the drivers of R&D globalization and the possibility for multinationals to benefit from the full potential of global innovation, discussed very briefly the question of R&D internationalization in developing countries: "The rapid increase of performance compared to costs leads to the paradoxical phenomenon that some R&D sites in developing countries leapfrog technological generations and install more advanced infrastructure than the R&D headquarter." Also, Filippaios, Papanastassiou, Pearce, and Rama (2009), exploring the strategic internationalization of R&D activities of the world's 100 largest food and beverages (F&B) multinational enterprises in 1996 and 2000, argued that overseas R&D laboratories or technological affiliates can also undertake creation activities of genuine knowledge from capitalizing on the scientific heterogeneity fostered in individual host countries as well as distinctive demand conditions. However, even if the possibility to locate R&D centers in developing countries is quickly raised, their results suggested that such companies still favor locating their most important R&D centers in the Triad. Finally, Awate, Larsen and Mudambi (2015) published very recently an in-depth comparison of R&D internationalization strategies (more specifically knowledge flows) between an advanced economy multinational and an emerging economy multinational. Their work inherently suggests that MNCs from advanced economies open R&D subsidiaries in emerging markets, but also that MNCs from emerging markets are now strong enough to export their activities to the developed world. Thus:

Proposition 1: Consistent with a new global trend in R&D internationalization, emerging countries now stand as key centers for innovation.

Reverse innovation and reverse knowledge transfer

Relying on these fundamentals, some interesting questions arise. If MNCs from advanced economies start to open R&D centers in emerging countries, what are the innovation process implications? This being asked and considering the potential local skills, the same question should be asked about technology transfer. Immelt, Govindarajan, and Trimble (2009) and Govindarajan and Ramamurti (2011) started to address these changes with the new theoretical concepts of reverse innovation and, by extension, reverse technology transfer.

The concepts of reverse innovation and reverse technology transfer represent an important shift by considering the new implantation of R&D centers in emerging and developing countries as a very recent strategic move for MNCs. Immelt, Govindarajan, and Trimble (2009) define reverse innovation in opposition to glocalization. Glocalization is the process whereby multinational firms develop excellent products in domestic markets and then distribute them around the world with minor modifications to adapt to market conditions. An innovation is called reverse when first developed for and adopted in the developing world (or emerging world) before "spreading" in the industrial world (Ramamurti and Govindarajan, 2011).

Glocalization allows companies to have the perfect balance between a global scale (to minimize costs) and their adaptation to local conditions (to maximize their market share). However, it is not anymore the best option in today's world (Immelt, Govindarajan, and Trimble, 2009). The emergence of giants as China changes the needs and reverse innovation is a direct result. This implies some significant changes in corporate mindsets (Govindarajan & Trimble, 2012): (1) the questioning of principles attached to glocalization hindering reverse innovation and the recognition by decision makers that success in emerging economies requires a fresh start with global rather than local issues; (2) the movement of workers, power and money where the growth is - in the developing world; (3) the creation of a culture of reverse innovation in the company through the development of local activities, the immersion of employees and the nomination of local officials; (4) the creation of a distinct set of activities for branches of the company in developing countries, with separate financial results and a focus on growth metrics. Govindarajan and Trimble (2012) also propose management techniques to promote reverse innovation: (1) giving full powers to local teams so that they can act as new companies in their search for innovations; (2) enabling local teams to take advantage of possible local partnerships to increase overall resources of the company; (3) managing reverse innovation initiatives as disciplined experiments, with willingness to resolve critical issues quickly and at low cost.

Von Zedtwitz, Corsi, Søberg, & Frega (2015) recently proposed a typology of global innovation including reverse innovation. Hypothesizing that each phase of the innovation process (ideation, product development, primary target market introduction, and subsequent secondary market introduction) can take place in different geographical locations (Jaruzelski & Dehoff, 2008; United Nations conference on trade and development, 2005), they provide a mapping of global innovation flows that proposes a subset of reverse innovations.

5. Important works, among others in this field, include Kuemmerle (1997), Gassmann and von Zedwitz (1999), Gerybadze and Reger (1999).

The recognition of the existence of reverse innovation leads to an actual change in the direction of classical studies on technology transfer. Indeed, two major new ideas emerge: (1) the existence of reverse innovations implies that western MNCs operating in emerging countries can learn from local businesses; (2) the existence of reverse innovations also means that western MNCs can learn from new MNCs from emerging countries when installed in developed countries. In this case, there is reverse technology transfer, as described by Govindarajan and Ramamurti (2011): there is a real opportunity for western MNCs established in emerging countries to acquire new knowledge, learn new business models, new management practices or even new "adapted" technologies from their local competitors, suppliers or even their local customers.

The literature on technology transfer and externalities (or spillover effects) is not totally consensual (Javorcik & Spatareanu, 2005). However, most studies have a similar assumption: technology transfer goes from the north to the south. Technology and productivity level being higher in the north, intuition suggests a technology transfer from top to bottom.[6] Unfortunately, this also involves the belief that northern firms have nothing to learn from those in the south (Govindarajan & Ramamurti, 2011). The concept of reverse innovation (and therefore R&D capacity building by MNCs and collaborations between local firms and MNCs in emerging countries) has changed these paradigms. Similar to north-south spillovers, **south-north spillovers** can occur through observation or the recruitment of qualified employees who worked in MNCs from emerging countries. They can also be generated by the provision of new knowledge, new technologies, new processes, new management techniques and marketing through partnerships and collaborations.

In terms of articles with empirical evidence of reverse innovation and reverse technology transfer, it is only the beginning of this literature. Zeschky, Widenmayer and Gassmann (2014) examined the question of how multinationals organise their international R&D for reverse innovation and highlighted the importance for MNC's subsidiaries to be based in a resource-constrained environment. Corsi, Di Minin and Piccaluga (2014) explained that reverse innovation could be associated with internal resistance and the risks of cannibalizing its existing products. Judge et al. (2015) analyzed how users from developing countries could be *lead users* in the confection of a wheelchair. Finally, Winter and Govindarajan (2015) highlighted some lessons for multinationals in terms of engineering reverse innovation.

In the health sector, Syed, Dadwal, and Martin (2013) recognized the importance of this phenomenon, explaining that a growing number of leaders and practitioners see a flourishing future for reverse innovation in global health systems (Syed et al., 2013). DePasse and Lee (2013) combined the concepts of reverse innovation and innovation diffusion in order to build a theoretical model supporting reverse innovation in global health systems. More specifically, they integrated innovation concepts (reverse innovation, innovation adoption, innovation spread and its acceleration) to create a new reverse innovation model including four steps: (1) problem identification; (2) low income countries innovation and spread; (3) crossover; and (4) high income countries innovation and spread. Their model is represented by a normal distribution graph showing the dynamics of innovation spread. However, their study is limited to theoretical assumptions and does not give any empirical evidence of the phenomenon.

In terms of reverse technology transfer, a pioneering paper published by (Wei, Liu, & Wang, 2008) explored mutual spillovers between MNCs from emerging and western MNCs. The authors showed that technology and knowledge transfer from seven Chinese multinationals have much improved the productivity of western MNCs operating in China.

Our work stands in the extension of this stream of the literature and tries to fulfill the empirical gap about reverse innovation and reverse technology transfer. Doing so, it also enriches the R&D internationalization literature by showing that sources of knowledge are now more and more sought in emerging countries. Thus:

Proposition 2: When MNCs open R&D centers in emerging countries, they practice reverse innovation and, while collaborating with local firms to benefit from their knowledge, they generate reverse technology transfer.

Methodology

To support both propositions, we choose to focus on a more precise field in terms of industry and in terms of geography. As suggested by the trend of the literature (Syed et al., 2013), we have decided to concentrate on the health sector and, more particularly, the pharmaceutical industry. Indeed, pharmaceutical companies are very R&D sensitive as this stage represents the most expensive and time-consuming part of the industry global value chain (DiMasi, Feldman, Seckler, & Wilson, 2010; Mestre-Ferrandiz, Sussex, & Towse, 2012; Paul et al., 2010; Pharmaceutical Research and Manufacturers of America, 2013). These factors make intellectual property (IP) protection very crucial for this industry. Moreover, pharmaceutical companies are going today through an important R&D productivity crisis leading them to rethink their business models (Booth & Zemmel,

6. To only cite the last studies on the subjects: (Aitken & Harrison, 1999; Djankov & Hoekman, 2000; Haddad & Harrison, 1993; Javorcik, 2004; Kokko, Tansini, & Zejan, 1996; Wang, 2005; Z. Wei & Youssef, 2012; Young & Lan, 1997)

2004; DiMasi, Hansen, & Grabowski, 2003; Juliano, 2013; Light & Lexchin, 2012; Mestre-Ferrandiz et al., 2012; Munos, 2009; Pammolli, Magazzini, & Riccaboni, 2011; Paul et al., 2010; Scannell, Blanckley, Boldon, & Warrington, 2012). According to a McKinsey & Company report, 13 of the 20 largest global pharmaceutical companies have established R&D centers in China and several have also announced major coming investments in the manufacturing industry (Le Deu, Parekh, Zhang, & Zhou, 2010). This is why we have also chosen China as our geographical area of interest. Many advanced economy companies now opt for partnerships with local firms (Daemmrich, 2013). The pharmaceutical industry also allows us to test our reverse technology transfer hypothesis as the Chinese are now particularly active in this industrial sector (Hughes, 2010b; Qi, Wang, Yu, Chen, & Wang, 2011).

Our methodological design is based on the hypothetico-deductive approach. Our methodology follows two steps: one quantitative and one qualitative. The combination of qualitative and quantitative methods is called mixed methods research or, as defined by Venkatesh, Brown, and Bala (2013), the third methodological movement. The use of this type of methodology is increasingly accepted and valued by the scientific community (Caruth, 2013). Venkatesh et al. (2013) outlined specific mixed methods research qualities in science, including the possible development of hypotheses arising directly from a first method and the possibility to test these hypotheses via a subsequent method. This is exactly our case as the quantitative validation of the first proposition (China is now a new world-class laboratory for research and development) leads to the emergence of the hypothesis of changes in terms of innovation and technology transfer. We can then test proposition 2 (reverse innovation and reverse technology transfer) with a subsequent qualitative method.

Quantitative Approach

We started our research by a quantitative approach to measure innovation in China via patent publications. Indeed, patents are recognized as innovation proxies (Hagedoorn & Cloodt, 2003) and also as technology transfer measures (Keller, 2004). Three levels of patents are observed: (1) patents in general, (2) patents in the pharmaceutical field and, finally, (3) patents published by the ten largest pharmaceutical companies having recently invested in China. Patent data made available by the World Intellectual Property Organization (WIPO) and the Office of Chinese intellectual property (properly named State Intellectual Property Office of the P.R.C.) (SIPO) allowed us to find numbers about these categories. Extracting, sorting and formatting the data allowed us to show the rise of innovation in China. WIPO provides a statistical database on issued patents. It also provides the "Patentscope" tool, an improved search engine that extracts specific data on patents. SIPO also offers an English search engine for patents in the world and a Chinese search engine for patents in China. These patents may also be delivered elsewhere in the world, but patents filed in China are required to be in Chinese. The language of study was Chinese for this part of our research since patents are tracked by the name of the applicant in Chinese[7].

Qualitative Approach

As aforementioned, to test our second proposition, we use a qualitative approach. Reverse innovation and reverse technology transfer represent new concepts that describe very recent progressive practices for organizations. The choice of a suitable methodology was therefore of great importance in this context. Indeed, quantitative data or even proxies to measure reverse innovation do not exist and the novelty of these phenomena limits the sample size. However, we believe it is in the interest of the business world and also the research community to better understand these concepts and their implications for business strategies, particularly in the pharmaceutical environment, where R&D is a significant part of the value chain. The qualitative axis therefore seems interesting to the extent that quantitative data are limited. The word *qualitative* means putting emphasis on the qualities of entities, processes and the explanation of a phenomenon that is not examined or measured experimentally in terms of quantity, amount, intensity or frequency (Denzin & Lincoln, 2005).

Given these limitations, we chose to use the **content analysis** developed by Krippendorff (2012) and the coding system specified by (Gioia, Corley, & Hamilton, 2012). By choosing the exploration and validation of reverse innovation and reverse technology transfer phenomena, especially for the pharmaceutical sector, we naturally imposed a theoretical framework. That being said, we remained as much as possible open-minded to the extent that, at the beginning of the study, we did not know whether we would be able to support our propositions. In addition, we also remained open to the emergence of any new reverse innovation criteria, potentially emerging from our study, that could be added to the list we had previously established.

For the content analysis, we collected on the Internet all the available material related to China for the ten largest world pharmaceutical companies between 2009 and 2014 in both English and French. This material mainly includes official discourse that it was possible to capture through specialized Internet media, media interviews with senior Asian pharmaceutical officials, company websites, annual reports and, finally, interviews conducted face to face with related stakeholders in the sector. The information was sought and analyzed until saturation (redundancy of the

7. For further information on the translation, see Appendix A at http: // warin2.cirano.qc.ca/wp-content/uploads/2015/09/Appendix.pdf

elements). To conduct the content analysis, all documents gathered were analyzed one by one using NVivo software. We tried to verify, through the discourse analysis, what were the new recent strategies implemented by the biggest pharmaceutical companies. The tables below present the research method used to retrieve our data.

All texts found between 2009 and 2014 inclusive were analyzed. This material can be summarized in table 2.

TABLE 1

Method used to collect information

Browser	Keywords used for saturation
Google	R&D + pharmaceutical + China
	R&D + «company name» + China
	Interview + «company name» + China
	Reverse innovation + pharma + China
	Technology transfer + pharma + China
	Reverse innovation + «company name» + China
	Technology transfer + «company name» + China

TABLE 2

Material used for the content analysis

Type	Number
Specialized press with official discourse reported	36
Specialized press with interviews reported	6
Total	**42**

We then established an analysis grid through the identification of specific reverse innovation and reverse technology transfer criteria. We identified seven criteria characterizing a company practicing reverse innovation and three criteria that involve reverse technology transfer. Of course, we do not claim that this list is exhaustive, and other features could also be associated with this type of strategy. Our criteria are described in the table below.

It was then possible to identify any relevant material to deepen the understanding of new strategies being developed by these pharmaceutical companies in China. It is important to note that to state whether or not a company is practicing reverse innovation (or reverse technology transfer), it is not necessary that it meet all the criteria. Indeed, these strategies can be implemented gradually. When a company meets one of the criteria, it is possible to note a change in strategy (compared to conventional strategies such as innovation or usual glocalization). These criteria were transcribed in the NVivo software (a qualitative software for data analysis). The Open Coding technique was used, directly holding respondents' words or phrases, which had a link with R&D, innovation or technology transfer in China. Thereafter, each sample extracted from the text was associated (through the analysis grid) to a criterion (in our case, the criteria of reverse innovation and reverse technology transfer that we previously developed) (see Figure 1).

Moreover, since NVivo allows for a recording of identified criteria, a weighting equal to the sum of these accounts was completed. Although it could not be associated with an accurate measure of the value of each criterion, it nevertheless gave us a representation of the importance of each concept. A graphic strategy was also used to represent the phenomena that arise.

From *Made in China* to *Discovered in China*

Stylized facts about China's R&D and Patents

Before starting the patent quantitative analysis, we think it is relevant to highlight some major facts about China, notably the recent evolution of the country in terms of R&D efforts. Since 2010, China is the second largest country, after the United States, in terms of R&D investments, with a total of 178 billion U.S. dollars (the United States has invested 403 billion U.S. dollars for the same period) (Wu, 2012). China ranks first in terms of researchers, with a total of 2.9 million people working full time in R&D in 2011 (about double the number of researchers in the United States) (Wu, 2012).

In 2012, for the first time in its history, Chinese residents represented the majority of patent applicants in the world (World Intelligence Property Organization, 2013). SIPO is also the largest recipient of patenting requests in the world with 560,681 requests made by Chinese residents against 460,276 applications in the United States (World Intelligence Property Organization, 2013). In terms of patent applications, China surpassed Europe in 2004, and the United States for the first time in 2011 and since then.[8] In 2012, there were 652,777 patents filed in China against 542,815 in the United States. For patent grants, China is still slightly behind the United States, but the trend suggests an imminent catching up. In 2012, there were 253,155 patents granted in the United States against 217,105 in China.

8. We used two databases: (1) the World Intellectual Property Organization (WIPO) database; (2) the Chinese Intellectual Property Office (SIPO) database. The database built by the World Intellectual Property Organization (WIPO) allows us to measure the evolution of innovation in China compared to Canada, the United States and Europe, but also to other emerging countries such as Brazil and India.

TABLE 3

Reverse innovation and reverse technology transfer criteria[9]

Reverse innovation criteria	Abbreviation	Description	Key authors
1- Emergent market targeted	Target market	Will to develop products for emerging countries needs	Govindarajan & Ramamurti (2011); Govindarajan & Trimble (2012)
2- Localization in emerging markets	Localization	Localization effort of R&D centers in emerging countries	
3- Innovations originality	Originality	Search for new, original and innovative solutions adapted to the country's needs	
4- Prices optimization	Optimization	Will to optimize price/quality/ functionality of the products	
5- Local needs identification	Adaptation	Search for local staff or collaboration/ partnerships with local firms to better define the real local needs	
6- Delegation of authority to local subsidiaries	Power	Will to provide local teams with enough power to ensure leverage at the top company level	
7-Innovations made for emerging countries flow uphill to the developed world	Flow uphill	Current or future will of a possible return of products developed in emerging countries to developed markets	

Reverse technology transfer criteria	Abbreviation	Description	Key authors
1- Local capacities recognition	Recognition	Recognition of local capacities already existing in the emerging country	Agarwal, Gupta, & Dayal (2007) ; Belderbos, Van Roy, & Duvivier (2013); Blomström & Kokko (1998); Hoppe (2005); Javorcik & Spatareanu (2005); Keller (2004); Kokko, Tansini, & Zejan (1996); Maskus (2003); Vaidyanathan (2008); Wang (2005); Wei & Youssef (2012); Young & Lan (1997).
2- Local labor force employment	Employment	Will to employ locally trained individuals to benefit from knowledge transfer with employees relocated.	
3- Collaborations with local firms	Collaboration	Research of collaborations/partnerships to benefit from local knowledge	

An important question remains: Does measuring the number of patents truly reflect innovations made in China? Indeed, the recent economic rise of the country over the last ten years has represented a growing motivation for western companies to patent their innovations in China. In other words, to determine whether China is really a new attraction for R&D, it is important to take a closer look at the number of patents filed by residents and non-residents (Xie & Zhang, 2014). A much larger number of patents filed by non-residents could be simply related to the fact that western researchers now seek to protect their inventions in China (Hu, 2010). In contrast, a large and growing number of patents filed by Chinese residents proves the country's research capacities (Hu & Jefferson, 2009).

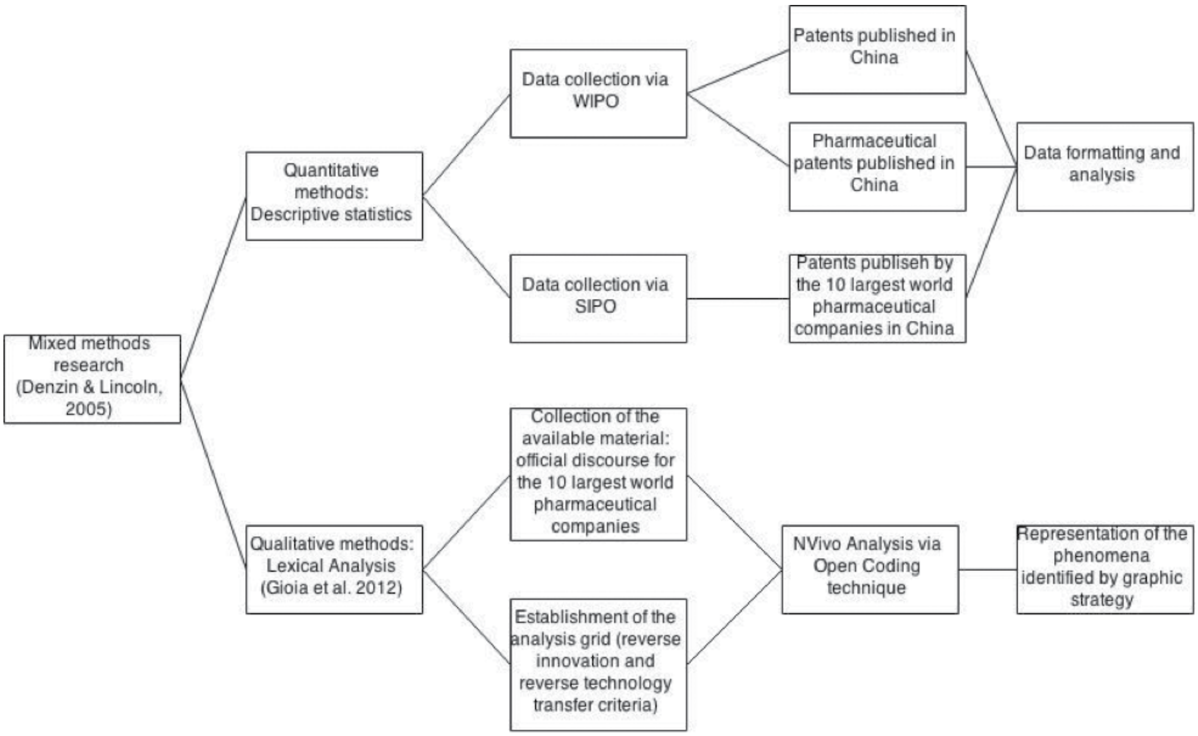
Stylized facts about the pharmaceutical sector in China

If we look more specifically at the pharmaceutical sector, some stylized facts about China should also be mentioned before starting with the analysis. In 2011, China ranked third in the global pharmaceutical market (Qi, Wang, Yu, Chen, and Wang, 2011). By 2015, China is expected to be the second largest pharmaceutical market after the United

9. Govindarajan & Ramamurti, 2011; Govindarajan & Trimble, 2012; Agarwal, Gupta, & Dayal, 2007; Belderbos, Van Roy, & Duvivier, 2013; Blomström & Kokko, 1998; Hoppe, 2005; Javorcik & Spatareanu, 2005; Keller, 2004; Kokko et al., 1996; Maskus, 2003; Vaidyanathan, 2008; Wang, 2005; Z. Wei & Youssef, 2012; Young & Lan, 1997

FIGURE 1

Methodological design used in our study



States (Hughes, 2010b). This sector is the eighth largest industry in China in terms of R&D expenditures and the fourth in terms of profits relative to expenditures (Wu, 2012). Total drug sales in China reached 69 billion U.S. dollars in 2011 and are estimated to be around 100 billion U.S. dollars in 2013 (Business Monitor International, 2012). Some analyses predict that health spending in China could grow to more than a trillion dollars in 2020, which would triple the 2010 amount and bring the spending share to 7% of GDP (Le Deu et al., 2010). Moreover, since the mid-1990s, expenditures on prescription drugs increased with an annual growth rate of around 20% (World Bank, 2010). In 2010, prescription drugs accounted for 40% of health spending (compared to about 12% for other countries such as France, Germany, Japan or the United States) (Daemmrich, 2013). Indeed, changes in lifestyle, dietary habits and the environment accompanying industrialization and rapid economic growth in China resulted in an epidemiological transition (Daemmrich, 2013).

Patent analysis in the pharmaceutical sector

In terms of patent application for the pharmaceutical sector, the results are more complex to interpret. In terms of the quantity of patents filed and issued, the pharmaceutical industry ranks 5th out of the 35 largest industries in China (World Intelligence Property Organization, 2013). Since 2000, the number of patents in the pharmaceutical sector has constantly been growing, evolving from about 2,500 to 22,500 between 2000 and 2012. After western countries, it is interesting to note that China is today the first emerging country welcoming pharmaceutical researchers (World Intelligence Property Organization, 2013).

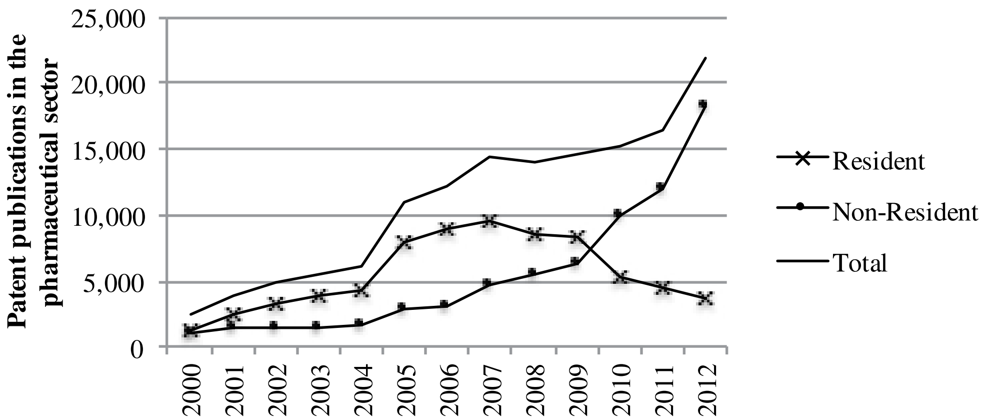
If we look at the patent applicant's origin (see Graph 1), the pattern may, at first, be somewhat confusing. Indeed, despite a significant increase in the deposit (and delivery) of patents in the pharmaceutical sector since 2004, the number of patents filed by Chinese residents is decreasing, while the number of patents filed by non-residents is largely increasing.

Since 2009, the number of patents filed by residents became much lower than the number of patents filed by non-residents. However, this phenomenon does have a logical explanation, which also introduces the second part of our article. Indeed, the WIPO classification of patents filed by residents or non-residents is based on the following concepts:

> "The residence of the first-named applicant (or inventor) recorded in the IP document (e.g. patent) is used to classify IP data by country of origin. (…)

GRAPH 1

Changes in the number of pharmaceutical patents filed by residents and non-residents in China between 2000 and 2012.



Sources: WIPO, 2014; own computation.

A resident IP filing refers to an application filed by an applicant at its national IP office. For example, an application filed by an applicant resident of Japan at the IP office of Japan is considered a resident filing for Japan IP office data. Similarly, a non-resident filing refers to an IP application filed by an applicant at a foreign IP office. For example, an application filed at the IP office of China by an applicant residing in France is considered a non-resident filing for China IP office data. The IP grant (registration) data are based on the same concept."

WIPO methodology: http: //www.wipo.int/ipstats/en/general_info.html

Patents filed by pharmaceutical industries, developed by researchers residing in the country of origin of the company or not, always have the company itself as the first inventor or the first applicant. In other words, even if Pfizer has an R&D facility in China, makes an innovation and files a patent at the Intellectual Property Office in China, the said invention will be classified as a patent filed by a non-resident as the first name on the document will be global Pfizer based in New York.

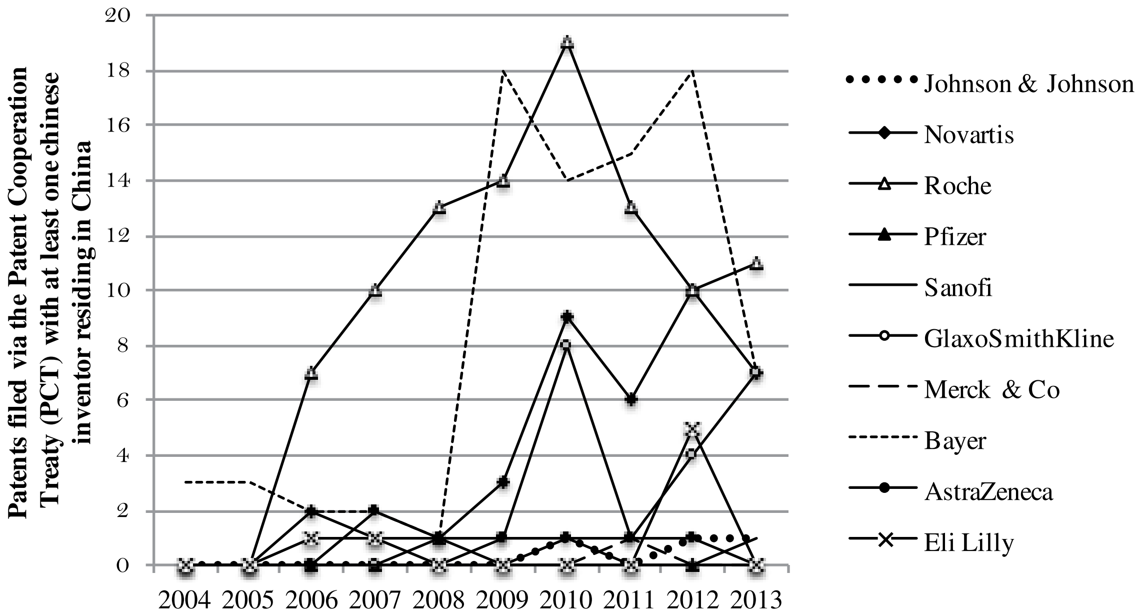
It seems that foreign pharmaceutical companies have filed an important number of patents in China, especially since 2009. Given the classification methodology used by WIPO (described above), there are four potential interpretations of this observation: (1) foreign pharmaceutical companies protect their patents – developed abroad – in China, in order to protect their property locally (we see in the second part of the article that many large pharmaceutical companies have opened R&D centers in China), and then continue to work locally on these innovations; (2) R&D centers recently opened in China by the major pharmaceutical industries have already started to produce and protect their local advancements (in drug discovery, patenting can start very early in the research process, although it is advantageous to patent as late as possible to ensure the longest protection) (Paul et al., 2010); (3) companies protect their innovations in China by the precautionary principle; (4) all the above assumptions.

In an attempt to clarify these questions, we conducted two subsequent searches. First, to determine whether the amount of R&D performed by large western pharmaceutical companies in China is growing, we used the Patentscope search tool developed by WIPO. Graph 2 shows the evolution of patents filed in China by the ten biggest pharmaceutical companies (based on their income, see Table 3 for details) and for which there is, in the list of inventors and applicants, at least one Chinese resident whose addresses (main and work) are listed as being in China. This work validates that these western companies do not only patent innovations made abroad (in their country of origin for example), but also innovations resulting from research carried out in China, or at least in partnership with the Chinese.

Here, it is important to note that Patentscope provides the information for patents filed through the Patent Cooperation Treaty (PCT). The PCT helps applicants to obtain patent protection internationally. By filing one international patent application, applicants may seek protection for an invention simultaneously in 148 countries around the world without redundancy. It is then up to the worldwide different offices to issue or not these patents. More and more companies (particularly MNCs) use this shortcut and,

GRAPH 2

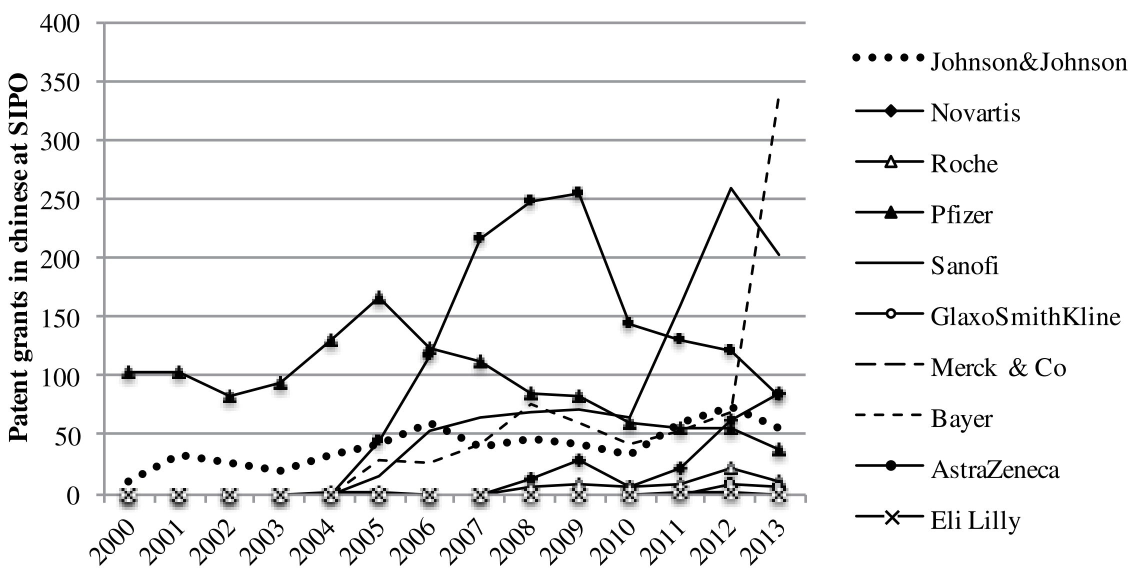
Patents filed by big pharmaceutical companies and for which there is at least, in the list of applicants and inventors, one Chinese resident.



Sources: WIPO, 2014; own computation.

GRAPH 3

Evolution of the number of patents filed in Chinese by the ten biggest western pharmaceutical companies over the last decade.



Sources: SIPO, 2014; own computation

today, Asia represents 58.4% of all patent applications worldwide, in contrast to the lower shares received by IP offices in North America (23.6%) and in Europe (13.5%) (World Intelligence Property Organization, 2013). The data in the following chart are valid within the limits described above. Except for Bayer Pharmaceuticals, no activity took place before 2005. However, since 2005 and particularly since 2008, all these big companies seem to have filed at least one patent for which one of the inventors was a Chinese living in China. Although irregular, this new tendency seems to continue.

We then observe the evolution of the number of patents filed at the State Intellectual Property Office in China (SIPO) for the ten largest pharmaceutical companies in the world. This information is only available in Chinese on the official SIPO website. It was therefore necessary to find the Chinese translations for each firm and then examine each patent to keep only the relevant information (see Appendix A)[10]. The following graph (see Graph 3) represents the evolution of patents filed in Chinese and granted by the SIPO for each company over the last decade. The numbers are almost null before 2005 (except for Johnson & Johnson and Pfizer). However, since 2005, we can observe an increase of patents in Chinese granted to these companies (innovations are required to be written or translated into Chinese to be filed at SIPO and then properly protected in the country). This growth may result from patents related to innovations made in the west then filed in China (in an idea of continuity), but also from patents related to innovations directly made in China in the companies' new R&D centers.

The previous two analyses do not allow us to stricto sensu validate our propositions. However, the research activity of the pharmaceutical industry is moving to China since 2005 and this activity is not limited to systematic protection or precautionary protection of innovations previously made in advanced economies.

Furthermore, it could also be interesting to study the evolution of the number of patents filed abroad by Chinese pharmaceutical companies. This information can be directly extracted from the WIPO database. This number has been constantly growing to pass from about 35 patents in 2000 to approximately 570 in 2012.

As aforementioned in the stylized facts, we observe the decline of R&D in the pharmaceutical sector in advanced economies. At the same time, R&D activity is rapidly growing in China, especially since the mid-2000s. Firms from advanced economies open R&D centers in China. Moreover, they collaborate more and more with local firms to get some advantages in terms of time, market penetration and knowledge about the local needs. Related to our second proposition, the questions are now (1) whether we observe reverse innovation and (2) whether reverse innovation is accompanied by reverse technology transfer.

Reverse Innovation and Reverse Technology Transfer

For the scope of our study, we chose to focus our analysis on the ten largest global pharmaceutical companies in terms

TABLE 4
Ten biggest pharmaceutical companies in term of revenue for 2013

Rank	Top 10 Pharmas	Origin	2013 revenue (billions of US $)
1	Johnson & Johnson	United States	71 312
2	Novartis	Switzerland	57 920
3	Roche	Switzerland	52 307
4	Pfizer	United States	51 584
5	Sanofi	France	45 078
6	GlaxoSmithKline	England	44 146
7	Merck & Co	United States	44 033
8	Bayer	Germany	25 969
9	AstraZeneca	United States	25 711
10	Eli Lilly	United States	23 113

Source: Annual reports of the companies

10. http: //warin2.cirano.qc.ca/wp-content/uploads/2015/09/Appendix.pdf

of revenues for 2013. Indeed, these companies account for about half of the global market in the sector.

As aforementioned, the material used for our content analysis mainly includes all the official discourses it was possible to capture through specialized Internet media, media interviews with senior Asian officials, and pharmaceutical companies' websites. A first intuition would have been to look at companies' annual reports. However, and surprisingly, we could not find any information related to the strategies they intend to implement in China. All companies are insisting on the importance of emerging countries and particularly China for their business, but they do not reveal any details in terms of investments or strategies.

Before analyzing the results for each of the criteria that characterized the concepts of reverse innovation and reverse technology transfer (see Table 3 in the Methodology section), we propose to verify the second criterion of reverse innovation: the localization of the company in the

TABLE 5

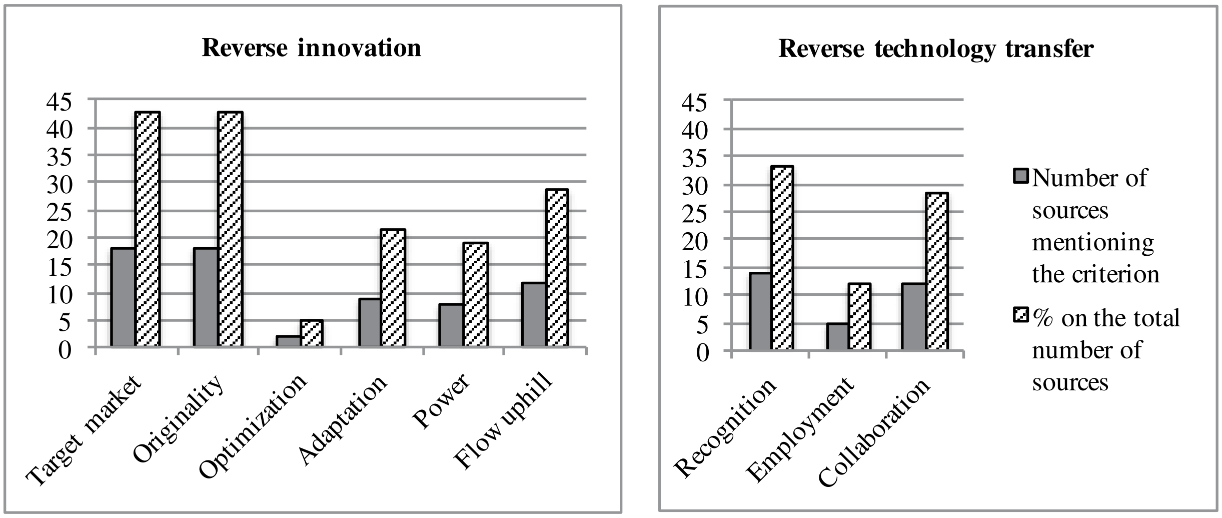
R&D center opened in China by the ten big pharmaceutical companies

Big Pharmas	R&D centers in China	Opening date	Research topics
Johnson & Johnson	**Asia R&D Center** Shanghai	2009	Cancer, infectious diseases, metabolic diseases
Novartis	**The Novartis Institute of BioMedical Research** Shanghai, Zhangjiang High-Tech Park	2008	Infectious disease linked to the most common cancers in Asia, research in chemistry and biomarkers
Roche	**Roche R&D Center** Shanghai, Zhangjiang High-Tech Park	2004 and 2008	Between 2004 and 2008: medicinal chemistry services to international teams. Since 2008: research on innovative medicines (early stages of development) for virology and oncology
Pfizer	**Pfizer Asia Research** Shanghai, Zhangjiang High-Tech Park	2006	Research on liver diseases and tuberculosis.
	Wuhan	2010	Extension of the Shanghai R&D center
Sanofi	**China Discovery platform** Shanghai	2010	Neurological diseases, diabetes and cancer
GlaxoSmithKline	**GSK Global R&D Center** Shanghai, Zhangjiang High-Tech Park	2007	Neurodegeneration with a focus on multiple sclerosis, Alzheimer and Parkinson diseases
Merck & Co	Beijing, Wangjing Park	2014 (expected)	Vaccines and diabetes
Bayer	**Global Scale R&D Center** Beijing	2010	-
AstraZeneca	**Innovation Center China (ICC)** Shanghai, Zhangjiang High-Tech Park	2007 then extended in 2012	Cancer with a focus recently extended to research on respiratory diseases
Eli Lilly	**Lilly China Research and Development Center (LCRDC)** Shanghai	2012	Innovative medicines for diabetes

Source: Hughes, 2010b and information available in specialized press articles.

GRAPH 4

Number of sources mentioning each criterion and percentage on the total number of sources (analysis using the NVivo software).



emerging market (criterion 2). It was, in our sense, irrelevant to identify the rhetoric associated with this criterion since it can be validated as a fact. The localization is a key criterion for reverse innovation. A first work was therefore to identify the existence of R&D centers in China for the big pharmaceutical companies. Table 5 summarizes the available information.

It is therefore possible to conclude that all these big pharmaceutical companies have recently opened R&D centers in China. All of them already had production sites or clinical trials in the country (usually for more than ten years). However, it is only very recently that they have invested in basic research in China. To better understand this strategy, it is now useful to continue with the content analysis of the official discourse collected.

According to our reading grid established above, six criteria remain to be examined for reverse innovation (target market, originality, optimization, adaptation, power, flow uphill) and three criteria for reverse technology transfer (recognition, employment, collaboration).

The 42 sources selected were analyzed and the following graphs (see Graph 4) show the occurrence of each criterion emerging from the reading.

First of all, we could see that all the criteria emerged largely in the material analyzed. About reverse innovation criteria, target market, originality and flow uphill are the most discussed concepts in the official discourse, with respective scores of 43%, 43% and 29% of the sources in which they are mentioned. For reverse technology transfer, recognition and collaboration seemed privileged with 33% and 29% of the sources in which they are respectively mentioned.[11] Originality and employment criteria are less highlighted, with scores of about 5% of the sources in which they are mentioned. The following tables cover some of the most relevant citations for each criterion.

It is also possible to make the same analysis, but by pharmaceutical company. The following Kiviat charts (see Graph 5) illustrate the differences between firms. The goal here is to show whether the company has, at least once, mentioned one of the criteria defined. It is important to note here that comparing scales would mean that the more a company mentions a criterion, the more it practices reverse innovation and/or reverse technology transfer. This finding may be biased by the level of media coverage and the number of articles published per company.

As already mentioned, companies do not have to fill all the criteria to be qualified as practicing or willing to practice reverse innovation or reverse technology transfer.

In terms of general results, according to the above graphs, it is then possible to note that the majority of companies meet at least three (3) of the reverse innovation criteria (+ criterion 2, since they all have R&D centers in the

11. For further information about results of the content analysis with NVivo, see Appendix C at http: //warin2.cirano.qc.ca/wp-content/uploads/2015/09/Appendix.pdf

TABLE 6

Selected quotations to illustrate reverse innovation criteria, extracted directly from the analyzed material

Reverse innovation criteria	Sample (selected quotations)
Target market	"The mission of EMIC is to develop new and affordable products addressing the specific consumer needs of emerging markets." (Johnson & Johnson) The facility specialises in basic research and development and focuses on the discovery of new drugs such as small molecule and biological medicines. The facility mainly develops drugs for diseases prevalent in China. (Novartis) R&D chief Marc Cluzel says in a statement that the new R&D center will help Sanofi develop therapies specifically for the Chinese population. (Sanofi) "Rather than trying to find a use for approved medicines that were developed for a non-Asian phenotype, the move is to discover and develop medicines specifically to treat Asian diseases." (GSK) Its R&D centre in Beijing would pay special attention to drugs for diabetes, hypertension, and liver and gastric cancers, diseases which have high prevalence in China. (Bayer) AstraZeneca has a center in Shanghai focused on cancers more common in Asia. (AstraZenaca) The goal of the LCRDC is to discover innovative diabetes medicines with novel mechanisms of action that can be tailored specifically for the Chinese population to delay the progression of the disease. (Eli Lilly)
Originality	"When you have a country like China that is so big that you have clusters of populations that live in fairly remote areas and cannot easily get prescriptions refilled or have regular check-ups, you have to think about what is the most appropriate dosage form and the right formulation to deliver benefits." (Johnson & Johnson) "We want to focus on treating serious diseases, gaining a critical mass of understanding and critical insights that will guide our research and clinical development," continued McCracken. "We want to develop first-in-class or very highly differentiated drugs, and we want to be able to predict who is going to respond to these drugs." (Roche) In addition to the establishment of development functions, we will also launch the Global Drug Discovery Innovation Center here in Beijing where our scientists will expedite new innovative approaches together with our Chinese partners. (Bayer) "We're not going to replicate what has been done in the West. We will try to innovate and transform how we do R&D. " (AstraZenaca) Lilly's R&D chief Jan Lundberg said the firm will be looking at diabetes "in new and different ways. " (Eli Lilly)
Optimization	"The mission of EMIC is to develop new and affordable products addressing the specific consumer needs of emerging markets." (Johnson & Johnson)
Adaptation	The division headed by Lee recently started to collaborate with the Tianjin Medical University Cancer Institute and Hospital to study pharmacogenetics and biomarker research in oncology with a particular focus on cancers that have a high incidence in Asia that may not have been as aggressively studied as some other cancers. (Johnson & Johnson) We have a diversified leadership team, with Americans, Europeans, and local Chinese, with a global view and strategic vision, which they combine with local insight and networking connections that work very well together. (Pfizer) In addition to the establishment of development functions, we will also launch the Global Drug Discovery Innovation Center here in Beijing where our scientists will expedite new innovative approaches together with our Chinese partners. (Bayer)
Power	CNIBR is expected to be the third largest R&D center for Novartis, after the R&D center in Cambridge, Massachusetts, U.S. and the facility at the Novartis headquarters in Basel, Switzerland, and to become the largest comprehensive R&D center in China. (Novartis) Zang said GSK had provided its China center with plenty of resources and the power to decide on the direction of neuroscience research. (GSK) Today, to give you a sense of how important China is for Lilly, in 2011, the 150 top executives, who usually meet in Indianapolis - it has been this way for as long as I've been in the group – met for the first time outside the US. They came to Shanghai, which gave me the chance to accommodate the logistics for 150 of my colleagues! (Eli Lily)

Flow uphill	"We are confident that our expanded investment in R&D will result in innovative therapies for patients in China and other countries nurtured by the growing scientific excellence in China." (Novartis) The facility also specializes in discovery chemistry and biomarker research. It combines the latest drug discovery methods with traditional Chinese medicine to develop drugs for the Chinese population and worldwide population. (Novartis) He said the newly formed unit is working with academic TCM experts in China to develop new TCM products for the benefits of patients in China and the rest of the world. (GSK) The medicines and vaccines developed in Beijing would not be targeted at China or Asia, said Kim, but at a global market, without saying which diseases the center would focus on. "(What) we will be looking to do in China, as we do throughout the world, is identify opportunities to develop drugs to treat diseases that would be applicable globally." (Merck & Co) "Together with AstraZeneca's world class scientists, we hope to understand the mechanisms of the disease better and ultimately develop novel medicines to benefit patients – not only in China but worldwide." (AstraZeneca) "We will do this by looking at diabetes in new and different ways and through collaborations with local academic research centers and partners that enable us to link Lilly scientists with scientists in China. With an eagerness and optimism to explore new theories about disease development and progression and potentially translate this to tailored diabetes medicines, I believe we will make a difference for people with diabetes, in China and around the world." (Eli Lilly)

Chinese territory) and observe at least one reverse technology transfer criterion (except for Merck & Co., as its R&D center is not completed and was only expected for 2014).

In terms of specific results, we find two interesting trends to support proposition 2: (1) a first trend about reverse innovation and (2) a second trend about reverse technology transfer. Let us start with the first trend about reverse innovation: criteria 1, 3 and 7 are ranked high by companies. For instance, Eli Lilly is quoted first, directly followed by GlaxoSmithKline, on research for new solutions for emerging countries' needs (criterion 3). Johnson & Johnson, AstraZeneca and Bayer show a strong desire to develop products for emerging countries' needs (criterion 1), as well as to have innovative solutions adapted to the countries' needs (criterion 3). Another interesting result is that most of the companies mentioned in our sample weigh criterion 4 very low, which is about price optimization. This criterion is not part of their discourse. However, almost all the companies show an interest in criterion 7, which is about their future will of a possible return of products to advanced economies. Bayer is leading the trend on this criterion, followed by Eli Lilly, Roche, and Novartis.

Let us now have a look at the second trend about reverse technology transfer. Criteria 8, 9 and 10 are of particular interest for this analysis. For instance, Roche, Bayer and AstraZeneca rank very high in terms of collaboration with local firms and benefits from local knowledge (criterion 10)[12]. Bayer and Pfizer, followed by AstraZeneca, GlaxoSmithKline, are high in terms of local capacity recognition (criterion 8). Another interesting result is that, so far, local labor force employment is not ranked high (criterion 9).

The question asked in our paper was mainly whether big pharmaceutical companies were beginning to practice reverse innovation and reverse technology transfer in a country where R&D was more and more stimulated (in our case, China). Based on these results, even if the intensity differs, it seems clear that all the big pharmaceutical companies have started to establish this kind of strategy. We do believe it is the beginning of a new trend considering both (1) the Chinese economy and its huge consumer base and (2) the trend illustrated in our quantitative analysis on top of the results from the qualitative analysis.

Discussion and Conclusion

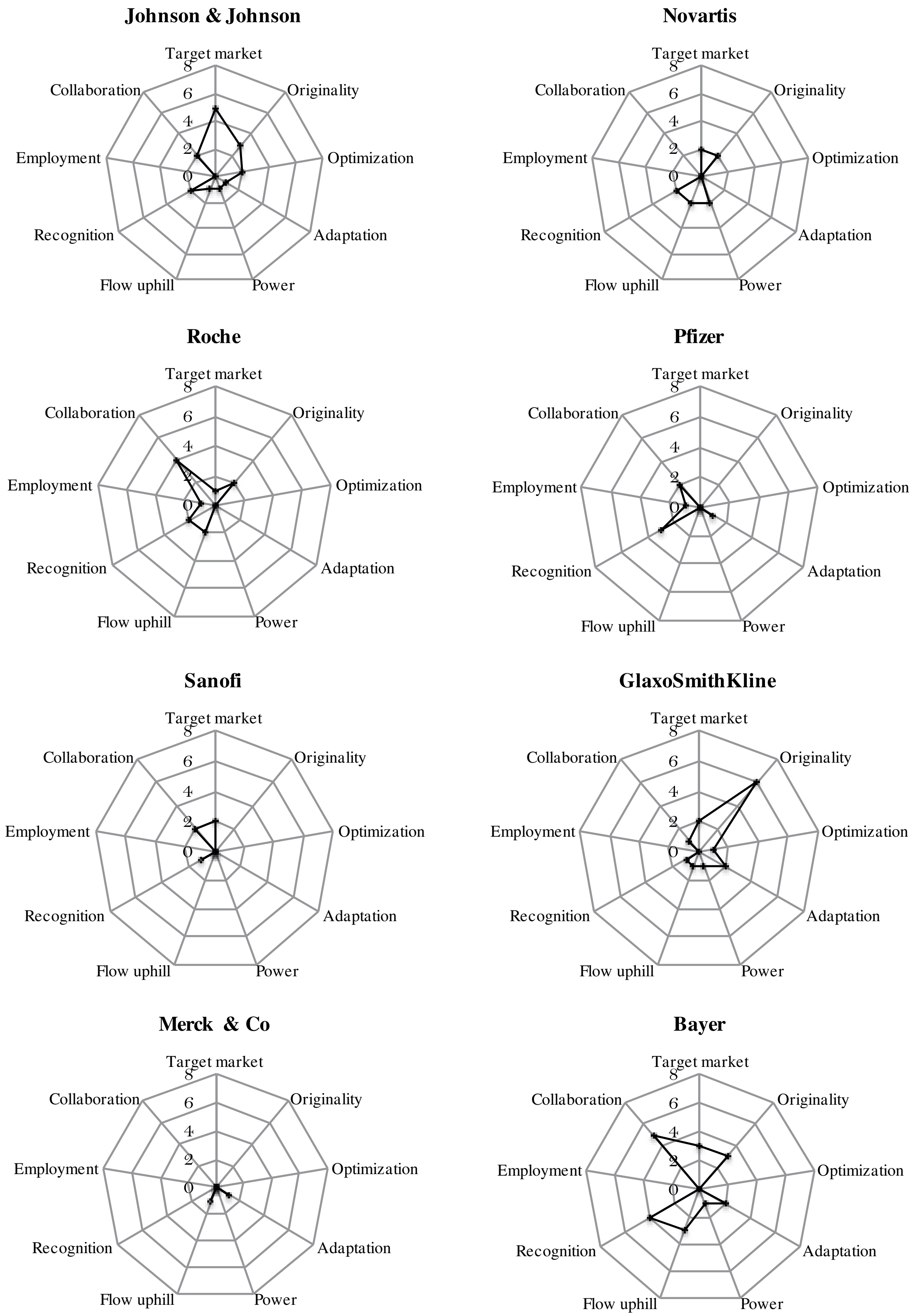
Our analysis tests two propositions: (1) China is moving from being the world factory to becoming a new world-class laboratory for research and development, in particular in the pharmaceutical sector, and (2) in this context, when multinational pharmaceutical companies open R&D centers in China, they practice reverse innovation and, while collaborating with local Chinese firms to benefit from their knowledge, they generate reverse technology transfer.

From a theoretical perspective, our contribution is in line with the literature on the transnational organization (Bartlett & Ghoshal, 1990; Bartlett & Ghoshal, 1988), its developments about R&D internationalization in developing countries (Filippaios et al., 2009; von Zedtwitz & Gassmann, 2002b), and the more recent works about reverse innovation (Govindarajan & Ramamurti, 2011; Govindarajan & Trimble, 2012; von Zedtwitz et al., 2015). It is noticeable that in previous studies on R&D internationalization, complementarity between the knowledge

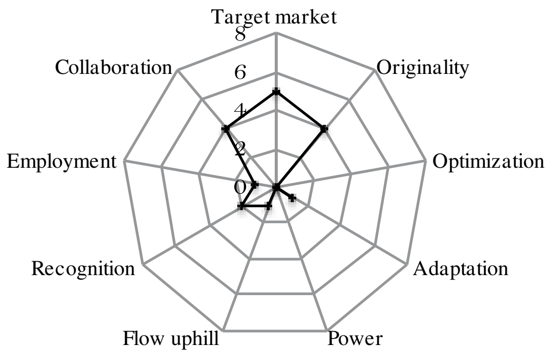
12. For more examples of alliances and partnerships between western Big pharmas and Chinese organisations, see Appendix D at http: // warin2.cirano.qc.ca/wp-content/uploads/2015/09/Appendix.pdf

GRAPH 5

Kiviat graphs representing each pharmaceutical company involvement in reverse innovation and reverse technology transfer.



AstraZeneca



Eli Lilly

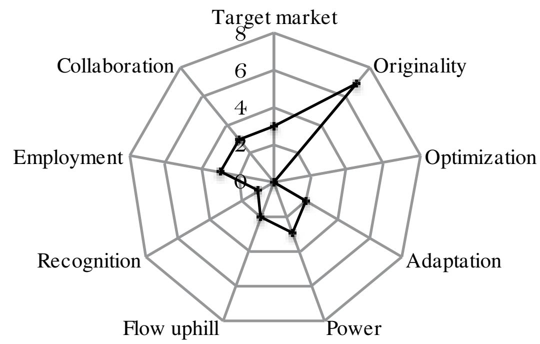


TABLE 7

Selected quotations to illustrate reverse technology transfer, extracted directly from the analyzed material

Technology transfer criterion	Sample
Recognition	"Our goal is to invest in research and development in the region, fuel entrepreneurship, and tap into Asia's vast scientific excellence and talent to foster new therapeutic approaches for the region and the world." (Johnson & Johnson)
	"We are confident that our expanded investment in R&D will result in innovative therapies for patients in China and other countries nurtured by the growing scientific excellence in China." (Novartis)
	Pfizer noted that its Wuhan operation will liaise with local research institutes and universities "utilising the rich resources of local talent and existing industry capabilities to develop research collaborations". (Pfizer)
	"We believe that China bears tremendous potential in terms of innovation. "
	"China is home to a large pool of skilled medical and scientific talents. "
	"We are excited about the opportunity to collaborate with the excellent scientists at Peking University." (Bayer)
Employment	The LCRDC, which employs approximately 150 scientists and staff, hired primarily from China. (Eli Lilly)
Collaboration	"We're taking a unique approach in Asia by actively seeking out and collaborating with the numerous exciting research institutions in academia and industry and building a strong network of researchers throughout the region to create a virtual R&D community. " (Johnson & Johnson)
	"As we span the value chain from discovery to early development in China, we need to continue to hire the brightest talent and collaborate with the best biotech organizations, as well as the top academic and clinical institutions. We already have several collaborations with local institutes and are continuously developing our external network." (Roche)
	Pfizer noted that its Wuhan operation will liaise with local research institutes and universities "utilizing the rich resources of local talent and existing industry capabilities to develop research collaborations". (Pfizer)
	"With the group in Tianjin, we tested the water to see how successful discovery research in China could be. We realized that the collaboration was really good, so we have since established a systematic way of looking for opportunities." (Sanofi)
	"We think we can leverage our recent acquisition of Steigerwald in combination with Dihon's herbal TCM expertise and pipeline to benefit both these areas, which have a different but related heritage." (Bayer)
	"Our goal is to work closely together with our Chinese partners to support China conducting their own R&D activities and at the same time we will be able to strengthen our own R&D capabilities." (Bayer)
	Under the terms of the agreement, scientists from Shenzhen University Health Science Center's Nephrology and Urology Center will work in collaboration with teams from AstraZeneca's Innovation Center China in Shanghai, bringing together complementary skills that will harness and foster medical innovation. (AstraZeneca)
	Today Lilly and Covance announced a new agreement to establish a diabetes discovery partnership in China. Under this agreement, Covance's wholly owned entity in China will provide the LCRDC with a range of services, including pharmacology studies, pharmacokinetic screening and other preclinical research to test and evaluate potential new diabetes medicines. (Eli Lilly)

developed by the subsidiaries and headquarters (Filippaios et al., 2009) is often suggested. In our case, we do not find strong evidence of complementarity. Indeed, about the pharmaceutical sector in China, we observe more of a substitution phenomenon illustrated by China becoming a new leader in terms of patents, R&D centers, etc. In this regard, our findings may illustrate one of von Zedtwitz et al., (2015)'s managerial implications, which is that "only the most experienced MNCs are able to systematically benefit from reverse innovation." Pharmaceutical MNCs are very experienced and thus are good candidates for strong reverse innovation, which is also an element in favor more of the substitution phenomenon than the complementarity one. This phenomenon is also a fertile ground for reverse knowledge transfer.

Our mixed methodology was particularly interesting to highlight the new position of China in terms of R&D, but also to support our second proposition about innovation and technology transfer. Indeed, these two phenomena are very new and, as no data or proxy are yet available to measure their existence, qualitative research was necessary.

About our first proposition, the mixed methodology was useful in two ways. Firstly, based on WIPO and SIPO data, our first results allowed us to show that China is today an important player in terms of R&D, in particular in the pharmaceutical sector. We argued that not only there were more patent applications in China than in any other country, but also that Chinese residents generated these patents. This reality implies that the biggest impact in terms of innovation is not from abroad, but from local firms. We also highlighted that multinational pharmaceutical companies were starting to publish patents in China and that Chinese were also increasingly active abroad in this sector. Secondly, we also used a qualitative approach to verify whether the ten biggest pharmaceutical companies in the world were implementing a strategy change in terms of R&D practices. Eventually, the content analysis allowed us to confirm that all of them have started to shift their strategy by establishing R&D centers in China. Both these quantitative and qualitative analyses (mixed methodology) support our first proposition, while providing a useful background for the validation of our second proposition.

About our second proposition, the content analysis showed that innovation in the pharmaceutical sector in China leads to reverse innovation and reverse technology transfer. Indeed, the criteria related to reverse innovation and reverse technology transfer are all mentioned (at a more or less important frequency) in the official discourse of these companies.

Indeed, to summarize, target markets, localization and originality are the criteria most mentioned by companies. For these big pharmaceutical companies, choosing China as the next target market for their innovations reflects their willingness to direct their future research to first meet Chinese needs. The emphasis on originality in the development of new pharmaceutical products underlines the willingness to use innovation strategies not already used before. It seems that companies want to innovate based on locally available resources, such as traditional Chinese medicine. Bayer, recently buying one of China's largest pharmaceutical companies specialized in traditional medicine,[13] is a good example of this phenomenon. Pharmaceutical companies also seem willing to develop new treatments for diabetes, more suitable to the Chinese in terms of composition, but also in terms of dosage and packaging (Hughes, 2010a, 2010b). The price optimization is of very little attention. It is not clear whether the local R&D actually costs less and if developed drugs can then be sold at lower prices. However, measures of drug reimbursement implemented by the Chinese government might suggest that companies have little to worry about this issue. All companies also seem inclined to employ Chinese labour and to form strategic partnerships to better understand local needs. At this level, these alliances often take place with universities that already have a good knowledge of the local contemporary research boundaries. The power that is given to R&D centers opened by the big pharmaceutical companies in China is not really discussed. However, interviews and official statements reported in the press and investigated here are almost always those of Asian directors or Asian R&D vice-presidents. The importance of these positions suggests a degree of autonomy from the headquarter for these new research centers (or at least a certain importance of these facilities as they seem to require senior positions). Finally, eight out of ten companies talk about bringing the innovations made in China to developed countries (or to "the world"). This last criterion ensures that we are well in the presence of reverse innovation. It may be too early, or only in process, to have concrete examples of products resulting from this new strategy. However, it seems that it is at least one of the next important challenges facing these companies. Beyond their new reverse innovation strategies, big pharmaceutical companies benefit from local technology transfer. Chinese pharmaceutical companies are now very active in terms of innovation: between 2003 and 2010, 25 candidate molecules per year were approved to enter into clinical phase by the China Food and Drug Administration (CFDA) and an average of four drugs per year were subsequently approved for sale to the public (some of these drugs are approved and also protected in the United States and Europe) (Qi et al., 2011). Although pharmaceutical R&D has been slow to develop in China, government incentives have helped the development of this sector. In 2008, the government launched the New Drug Creation and Development Program, thereby injecting 960 million U.S. dollars to accelerate research and domestic drug dis-

13. http: //www.reuters.com/article/2014/02/27/us-dihon-bayer-idUSBREA1Q0LO20140227.

covery (Hughes, 2010a). Although advanced economies' MNCs certainly have knowledge to transmit to China, nine out of ten of them recognize that they have to learn from Chinese expertise, for example in terms of Chinese traditional medicine. Indeed, they are all engaged in alliances and partnerships with local organizations and continue to call for greater collaboration (see Appendix C and D)[14].

The limitations of our study are embedded in our methodological choices. Indeed, as we did not observe on-site implementation of the strategies described in official speeches, it is impossible for us to confirm that these companies "are doing what they say." It would be great for further research to confront our findings with field research to check the internal validity.

Another limitation is that we cannot generalize our findings to other sectors. Indeed, our study is solely based on the pharmaceutical sector. However, we believe the methodology presented in this paper can be replicated to study another sector. Contingency elements should also be considered such as the nature of the technology, the global innovation flows (ideation, development, market introduction), etc. (United Nations conference on trade and development, 2005).

With this paper, we tried to open the way for more in-depth studies in this direction and to show the path for future research in this area, and in particular for case studies. Further work may focus on a company in a less sensitive sector than pharmaceuticals that is willing to give information about its reverse innovation process in China. In this case, interviews with key actors and/or participative observation could be an interesting methodology to enrich the field.

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