A real options theory of multicountry patenting under uncertainty

(work in progress)

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Abstract

Recent studies have showed that multinational firms increasingly pursue multicountry patenting strategies. This article provides novel insights and empirical evidence on the effect of uncertainty on the incentive to adopt such strategies. While the antecedents of multicountry patenting in multinationals have been addressed (e.g., manufacturing integration), as well as specific benefits pointed out (e.g., heterogeneity of knowledge), we still lack a full understanding of the drivers of firm decisions to pursue these strategies. In fact, other studies point out the continued preference for in-house, single country patenting. Using real options logic, we develop and test a set of hypotheses examining the impact of multicountry vs. single country patents on the value of a firm's portfolio of market entry options based on transfer costs in pharmaceutical multinationals. Consistent with our model, we show that market uncertainty has distinct effects on incentive to follow certain patenting strategies.

Keywords: Multinational Firms, Real options, Patents, Market entry

1. Introduction

The capacity of firms to build and sustain competitive advantage in a business environment that is marked with fierce competition at a global scale and decreasing product life cycles rests on their ability to patent technological innovations (Artz et al., 2010; Patel et al., 2014). Firms may innovate using single country or multicountry strategies (Berry, 2014), individually or in collaboration with various partners such as fellow units, universities or research centers (Arora, Belenzon & Rios, 2014; He and Wong, 2004). Despite a growing body of empirical evidence suggesting that firms increasingly rely on multicountry strategies (Berry, 2014; Patel et al., 2014; Van de Vrande, 2013), many facets remain unclear. One is a firm's propensity to opt for multicountry as opposed to a single country innovation strategy. This is particularly relevant considering other studies argue for a home country bias in innovating (Belderbos, Leten & Suzuki, 2013). Also, most studies in the field relate the benefits of multicountry patenting to the diversity of knowledge it brings *internally* to the firm which is argued to positively affect the firm's future innovating potential. We adopt here a complementary perspective focusing more on *external* market benefits from following multicountry patenting. We argue that multicountry patenting improves the value of a firm's portfolio of market entry options by lowering the transfer costs should the multinational firms decide to enter a given geography.

A key feature of multicountry patents is their cross-country, collaborative nature. Consequently, a distinctive advantage (vis-à-vis single country patents) is the heterogeneity of cross-country, partner specific knowledge that is combined through the collaborative relationship, which is likely to result in a valuable and patentable outcome (Berry, 2014). In line with the extant literature, we examine multinational enterprises (MNEs) in the pharmaceutical industry. Because MNEs consist of a global network of subsidiaries and hence have direct access to different markets (Gupta & Govindarajan, 2000), they face an alternative between patenting in (a) one specific location, e.g., in a subsidiary, headquarter or with external partners operating in the same country ["single country patenting"], or (b) at two or more locations (or IP regimes), collaboration cases where two or more

subsidiaries which operate in different countries or subsidiary(s) and a partner(s) operating in different countries ["multicountry patenting"]. We analyze herein the incentives of multinational firms (MNEs) to pursue single vs. multicountry patenting, i.e., we focus on the location aspect of patenting. Patents enable the inventor firm to capture the returns from his investment (reward theory) in the market that the patent system covers (Kitch, 1977). Specifically, patents give technology leaders a first-mover advantage in a particular market (Lieberman and Montgomery, 1988). They define the exclusive property right which restrict early stage rivalry thus enabling the innovating firm to maximize their rents by commercializing the innovation (Kitch, 1977). However, these advantages are location specific and may be short-lived as patents offer weak protection, they are difficult to enforce in the international arena and easy to invent around, or they have transitory value in the current relentless race to patent (Lieberman & Montgomery, 1988). Moreover, R&D literature argues that imitators could duplicate patented innovations for a portion of the cost and within a relatively short period (Mansfield, Schwartz & Wagner, 1981). Since the development of patents itself includes a variety of costs beyond R&D investment such as patent application costs, marketing and costs for achieving economies of scale (Agarwal & Ramaswami, 1992; Hood & Young, 1979), the firm compensates for these costs with the potential market share of the new patented innovation, with the ultimate goal of higher firm market value (Griliches, 1981).

The value of market access a patent secures (for a limited time), depends on specific market dynamics, which are uncertain. We model the market-entry decision in analogy with the *option to invest* in the terminology of real options. A multinational firm holds a portfolio of such options it can execute. Because a generic patent is not a perfect match with demand in a specific geography, the MNE incurs a *transfer cost* upon market entry. We argue that the patenting strategy pursued by a MNE will affect the transfer costs it would incur upon entering a specific country. If a MNE develops a patent in the UK (single country patenting), we can reasonably expect that the transfer cost to adjust the patent to the e.g. German (or EU) market requirements will be less than the transfer cost to adjust to the market requirements of the e.g. US or Chinese market. By contrast, if the MNE

follows a multicountry patenting strategy, the patent will be less country specific: it will be less adapted to the requirements of the UK market (which implies a larger transfer cost than in the single country patenting strategy) but more adapted to the requirements of the Chinese market (with a transfer cost lower than in the single country patenting strategy).

In this paper, we show that whether the MNE pursues a single vs. a multicountry patenting strategy leads to distinct payoffs upon market entry. In turn, this affect the value of the MNE's portfolio of market-entry options. We examine the drivers of the choice between single and multicountry patenting strategy, especially the country-specific market growth rate, the market risk and the correlation coefficient between the two markets. It obtains that if the growth is large and market risk is limited in the home country, then the MNE should purse a single country patenting strategy. Otherwise, it should follow a multicountry patenting strategy.

2. Theoretical background

2.1. The benefits and costs of single country and multicountry patents

A patent is a legal document issued by an authorized governmental agency which gives the holder (usually the inventor) the monopoly right to solely utilize the new device or process which is the subject of the patent for a certain time in a certain market, enforceable by law (Griliches, 1998). Patents balance the incentive for firms to innovate while ensuring dissemination of knowledge to the society and are granted (only) if the innovator provides public authorities with sufficient information on the innovative content to allow researchers to replicate and leverage on it. Also, patents enable first-mover advantages in a specific market, particularly when the technological advantage is a result of R&D expenditure (preemptive patenting) which is the case in the pharmaceutical sector (Lieberman & Montgomery, 1988). Firms in the pharmaceutical sector are able to sustain the advantage more than firms in other sectors because the imitation is more costly and imitators must go through the same regulatory approval procedures (Lieberman & Montgomery, 1988).

The benefits and costs of different patenting strategies have been discussed in the management of innovation literature. *Single country patents,* either in the home (headquarter) or host country (where the subsidiaries operate), are described as the dominant strategy, especially in case of core knowledge projects (Belderbos, Leten & Suzuki, 2013; Di Minin & Bianchi, 2011). Here, the firm centralizes the intellectual property management function and thereby reduces the risk of knowledge spillovers to competitors (Di Minin & Bianchi, 2011). Another advantage is reduced coordination costs of international R&D and maintaining the embeddedness of firm's R&D in a country's innovation systems (Belderbos, Leten & Suzuki, 2013). MNEs also develop patents in the home country of their subsidiaries (Frost, Birkinshaw & Ensign, 2002; Lahiri, 2010) if the subsidiaries which have a range of internal and external sources available to learn from and the capabilities to absorb and utilize them, which is only possible by operating in close proximity of the sources (Birkinshaw & Hood, 1998; Cohen & Levinthal, 1990; Phene & Almeida, 2008). Firms also collaborate with various local stakeholders such as universities; there is proof that collaborations have a positive impact on firm patenting activity (Cassiman, Golovko & Martínez-Ros, 2010; Jaffe, 1989), and suppliers and clients (Nieto & Santamaria, 2007) as well as specialist knowledge providers (Tether & Tajar, 2008), especially relevant in an agglomerated, knowledge intensive country environment (Cantwell & Piscitello, 2002). Single country patenting has drawbacks because it builds on homogeneous behaviors across individuals from the same group, with similar backgrounds. The expertise available within one location might be recycled, which often lead to redundant ideas and processes (Berry, 2014; Burt, 2004).

Alternatively, MNEs may opt for multicountry patenting strategies, namely via a collaboration among at least two partners (which can be fellow subsidiaries or external partners) from at least two different countries (Berry, 2014). MNEs have a unique organizational setting enabling them to engage in such patenting strategies (compared to domestic firms operating in just one country). Combination and sharing diverse knowledge across borders often help build difficult-to-replicate advantages, particularly relevant in industries with rapid technological change and if the innovations

are costly and complex (Berry, 2014; Patel et al., 2014). Compared to single country patents, multicountry patents bring together a wider pool of technological knowledge; the knowledge acquired along the way is more likely to be utilized in subsequent firm innovations (Berry, 2014). Since countries have diverse knowledge reservoirs based on national differences in technical activity (Chung & Yeaple, 2008), multicountry patents bring together diverse clusters of know-how, which also enables further innovations within MNEs (Birkinshaw & Hood, 1998; Kogut & Zander, 1993; Yamin & Otto, 2004).

However, effectively governing cross-country collaborative relationships in case of a multicountry patenting strategies makes them strategies costly (Berry, 2014). Furthermore, the knowledge and new practices accessed through the collaborations may be difficult to transfer throughout the MNE network (Szulanski, 1996), rendering of ability to future patents uncertain. Finally, accessing a mix of knowledge from different countries can also create inefficiencies and duplication of ideas (Berry, 2014).

2.2. The real option value of single country and multicountry patents under economic uncertainty

A country will be an attractive in terms of knowledge creation if the local market is sizable, local scientific and educational infrastructure abound and the intra- and inter-industry spillovers are likely to benefit the company (Cantwell & Piscitello, 2002). Also, firm characteristics affect the choice of locational origins of knowledge creation. For instance, if the capability of the unit to create knowledge is higher, it is more likely that the particular unit will create more knowledge in its host country (Birkinshaw & Hood, 1998; Frost, 2001). Furthermore, when the MNE does not possess strong headquarters knowledge creation potential, it will choose to create more knowledge in host countries (Belderbos, Lykogianni & Veugelers, 2008; Kogut and Zander, 1993). However, a country's IPR regime can be a significant deterrent of host country knowledge creation because of difficulties in maintaining control over the MNEs' most valuable knowledge (Mansfield & Lee, 1996). The

negative effect of weak IPR and the risk of unintended outgoing spillovers of MNE knowledge is highest in countries where the domestic companies are direct competitors of the MNE (Belderbos, Lykogianni & Veugelers, 2008), in which case it is less likely that the firm will create knowledge in that particular host country.

We view two distinct facets of regulatory risks. On the one hand, lengthy administrative procedures may create unnecessarily delays (time lags), that defer the introduction of product innovations, with the innovator reaping the benefits at a latter point in time (hence a lower present value). On the other hand, while patents arguably provide temporary monopoly rights, there have been instances where patent holders did not manage to enforce this right in a court of justice, with rivals utilizing the patent information to replicate the innovation and compete head-on with the patent holders.

We model the market-entry decision in analogy with the *option to invest* in the terminology of real options. Risk or economic uncertainty arise from the business environment.

3. Model and hypotheses

A MNE is operating in two locations. It is headquartered and conduct centralized R&D activities in the "the home country" (country 1) and has a subsidiary in the "host country" (country 2). While the value of each local marketis known at the outset (x_i at time $t = 0$), its future value ($X_i(t)$ at time t) is stochastic. We introduce the notations $x = (x_1, x_2)$ and $X_t = (X_1(t), X_2(t))$ and assume that $(X_t, t \geq 0)$ follows a two-dimensional geometric Brownian motion of the form

$$dX_t = \mu\, X_t\, dt + \Sigma\, X_t\, dB_t,$$

where $\mu = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}$ is (the vector of) market-specific growth rates μ_i and $\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_1\sigma_2\rho \\ \sigma_1\sigma_2\rho & \sigma_2^2 \end{pmatrix}$ is the covariance matrix, with σ_i being the market-specific risk (standard deviation) and ρ is the correlation between the two markets.

The MNE incurs transfers costs $k = (k_1, k_2)$ upon entering the markets. These costs differ depending on whether the MNE follows a single country (k^S) or a multicountry patenting strategy (k^M). While single country patenting presents a lower transfer cost in the home country (here $k_1^S = 3$), entering the host country is more expensive (here $k_2^S = 5$). By contrast, the firm derives a more hybrid, less country specific patent from pursuing a multicountry patenting strategy; we assume the transfer costs are $k_1^M = 4$ to the home country as well as for the host country ($k_2^M = 4$).

Once the patent is secured, the MNE holds a portfolio of real market-entry options. Single vs. multicountry patenting offer different profile for the value of the market-entry option portfolios because the firm would incur differ transfer costs in each setting. These options are modelled as European call option with maturity t. The value of the portfolio is

$$C(x, k) = \sum_{i=1}^{2} E[e^{-rT} \max\{X_i(t) - k_i, 0\}],$$

with r (> 0) the appropriate discount rate.. We develop an algorithm (in Mathematica) to solve this problem. The above also admits a closed-form solution. Codes are available upon request.

Figure 1 depicts the portfolio values in case of singlecountry vs. multicountry for a set of parameter values. We see that for low demand in the home country ($x_1 < \bar{x}_1$, the multicountry patenting strategy dominates. This is because, if the firm follows the latter strategy, it benefits from a lower transfer cost when entering the host country. By contrast, if demand proves stronger in the home country ($x_1 \geq \bar{x}_1$), then the MNE is better off following a singlecountry strategy. The threshold $\bar{x}_1$ is an indifferent point, whose value depend on parameter choices. In the subsequent, we conduct comparative statics to assess the impact of key demand parameters (especially, demand growth and country-specific risk) on the incentive to pursue a multicountry patenting vs. a single contrunty patenting strategy.

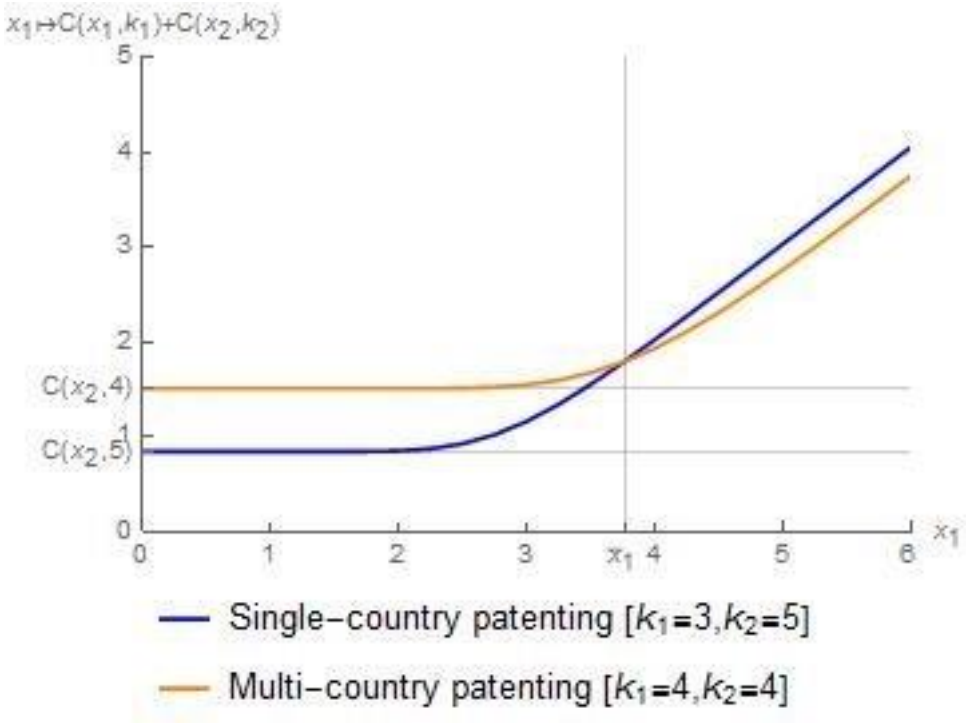

Figure 1: Value of portfolio of real options

Parameter values: $k^S = (3,5), k^M = (4,4), \mu = (0.03,0.04), (\sigma_1, \sigma_2) = (0.2,0.3), \rho = 0.3, x_2 = 5\ \ T = 1.$

Figure 2 illustrates the effect of changing demand growth rates on the threshold at which the single-country patenting strategy starts dominating. We see two monotonic relationships. If demand in the home country increases at a higher rate (μ_1/μ_2 increases), then the MNE is more likely to benefit from a single country patenting strategy. By contrast, if the growth rate (μ_2) increases in the host country (μ_1/μ_2 decreases), then the incentive to follow a multicountry patenting strategy improves.

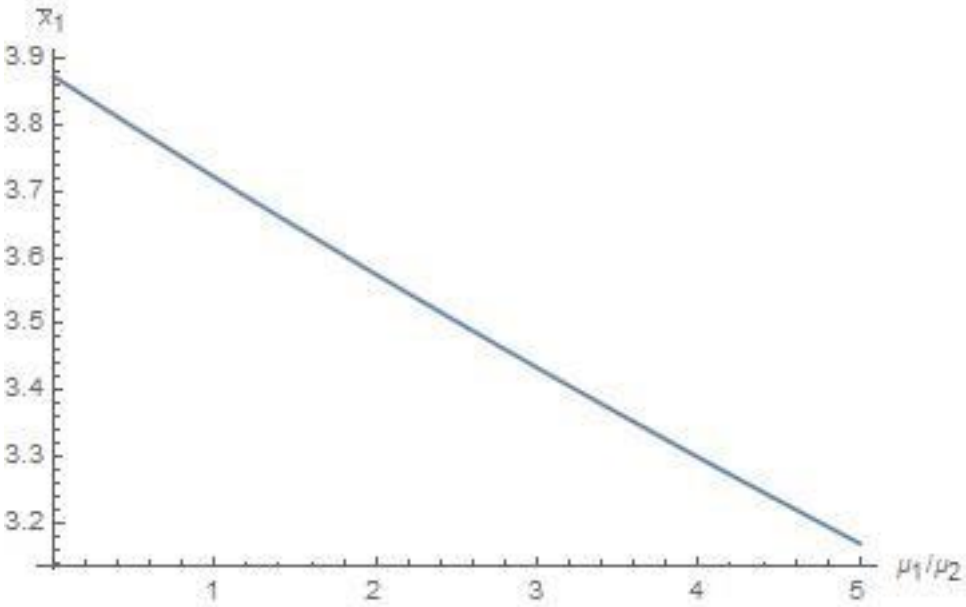

Figure 2: Sensitivity of demand threshold $\bar{x}_1$ to demand growth assumptions
Parameter values: $k^S = (3{,}5), k^M = (4{,}4), (\sigma_1, \sigma_2) = (0.2{,}0.3), \rho = 0.3, x = (4{,}5),\ T = 1.$

Figure 3 depicts the demand threshold $\bar{x}_1$'s sensitivity to the country-specific risk parameters σ_1 and σ_2. It appears that larger risk in the home country (larger σ_1/σ_2) is beneficial to the muticountry patenting strategy, while larger risk in the host country (lower σ_1/σ_2) is detrimental.

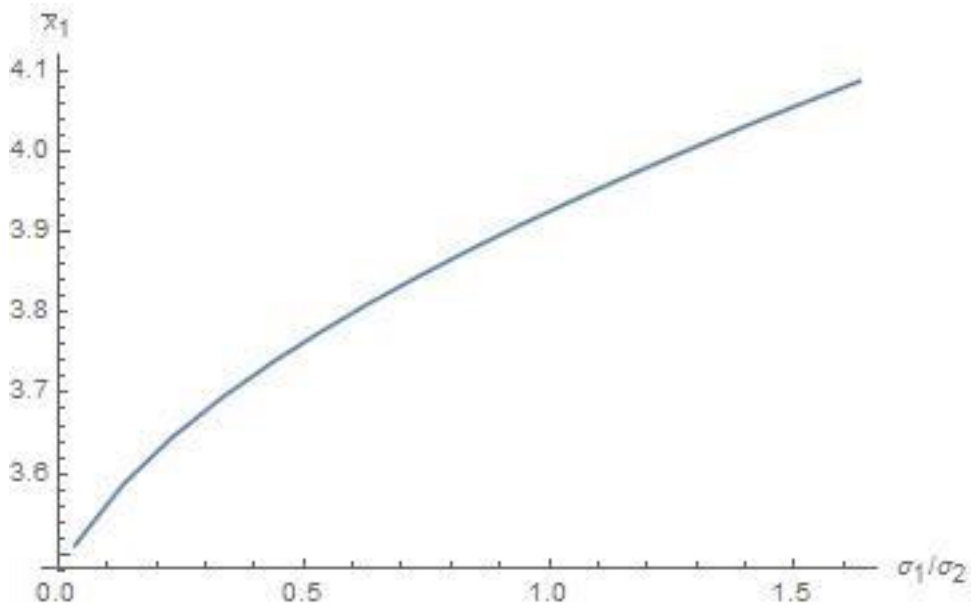

Figure 3: Sensitivity of demand threshold $\bar{x}_1$ to country-specific risk assumptions
Parameter values: $k^S = (3{,}5), k^M = (4{,}4), \rho = 0.3, x = (4{,}5),\ T = 1.$

Based on the above, the hypotheses are:

H1: The incentive to pursue a multicountry patenting strategy diminishes when demand in the home country gets larger but improves if demand in the host country consolidates.

H2: The incentive to pursue a multicountry patenting strategy deteriorates as the market prospects in the home country improves, but appreciates when demand is expected to grow at a stronger rate in the host geography.

H3: The incentive to pursue a multicountry patenting strategy improves when demand prospects are more uncertain in the home country but deteriorates when demand prospects are more risky in the host country.

4. Data and methodology

We selected 50 pharmaceutical companies ("the sample") based on a number of criteria. First, these firms need to be headquartered in one European Union (EU) country. Second, they must have two subsidiaries (or more) operating in a foreign country. Third, at least one of their patents can be considered multicountry. Finally, we ranked the companies in terms of latest revenues and select the top 50 on the premises that larger firms are more likely to engage in complex patenting (Van de Vrande, 2013).

We used two databases: Bureau Van Dijk Orbis and these European Patent Office (EPO) Espacenet. These sources have been used extensively in the extant literature (e.g., Arora, Belenzon & Rios, 2014; Cui & Jiang, 2012 for the Bureau Van Dijk Orbis database, and Grimpe & Hussinger, 2014; Wagner, Hoisl & Thoma, 2013 for the EPO). The Bureau Van Dijk Orbis database provides a data on the firms' financials and organisational structure. It applies for our particular study because it lists all subsidiaries (and operating countries) for each multinational, a piece information needed to match with the patent information. For each multinational, we derived all first level unit information which served as a base for identifying each patent by each unit and headquarters. We checked for all patents assigned to each headquarters and first level unit of each MNE for the ten year period, following prior approach (Arora, Belenzon & Rios, 2014). We complement with the use of the EPO Espacenet database on EU patents. Leveraging on the assignee information, we identify the country origins of each patent (as in Arora, Belenzon & Rios, 2014). We consider 15 years of data (from 2001 to 2015). Table 1 below presents the variables and data sources.

Table 1. Variables and data sources

Level	Variable (general)	Proxy	Data source
Industry	Market uncertainty	Volatility in sales	

Firm	Sales	Total Turnover/Revenue (US$)	Bureau van Dijk Orbis
	Tangible Assets	Total Assets, Tangible (US$)	
	Intangible Assets	Total Assets, Intangible (US$)	
	R&D investment	R&D expenditure (US$)	
	Employees	Number of employees	
	Subsidiaries	Number of subsidiaries	
	Patents	Number of patents, total	European Patent Office
	Single-country patents	Number of patents, Single-country	
	Multicountry patents	Number of patents, Multicountry	
Country	Transfer costs: Geographic distance	Distance between the capital cities	Calculated using www.geobytes.com
	Transfer costs: Cultural distance	Kogut and Singh CD Index (CDI)	Kogut and Singh (1988)
	Transfer costs: Administrative distance		

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