QUO VADIS?
THE ENTRY INTO NEW TECHNOLOGIES IN ADVANCED FOREIGN SUBSIDIARIES OF THE MULTINATIONAL CORPORATION

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Abstract. The international business literature has identified the overall emergence of technologically advanced foreign subsidiaries of the multinational corporation (MNC), but little is known about the extent to which individual subsidiaries are able to sustain their contribution to the technological and strategic renewal of the multinational group. This paper takes on this neglected question by empirically investigating longitudinal patterns in advanced foreign subsidiaries' entry into technologies that are new to the entire multinational group. Repeated events analysis that draws upon the complete U.S. patenting by 211 greenfield subsidiaries of 21 Swedish multinationals over the period 1893-2008 reveals accelerated entry into new technologies, but at moderate hazard rates. The results lend support for established theorizing about the evolution of technological capabilities in greenfield subsidiaries, but question extreme views on their growing strategic importance for the MNC. It appears instead that significant additions to the technological and strategic renewal of the multinational group should be discussed in the context of a select number of 'superstar' subsidiaries, not necessarily what are believed to be general developments across all subsidiaries of the MNC.

INTRODUCTION

In an article that marked the beginning of extensive research on foreign technological activity in the multinational corporation (MNC), Robert Ronstadt (1978) suggested an evolutionary pattern by which initial R&D investments in foreign subsidiaries expand into significant capabilities in developing new and improved products for foreign or even global markets. The prediction was the emergence of an increasing number of advanced foreign research and development subsidiaries in the MNC, capable of making substantial contributions to the technological and strategic renewal of the entire corporation. Now some three decades later, it appears that Ronstadt's overall prediction was essentially correct. Research has confirmed an increase in the foreign part of technological capabilities in many MNCs, and accomplished subsidiaries with advanced technological capabilities have become common in the large and well-established MNC (Cantwell, 1989; Dunning, 1994; Reger, 2002; Cantwell & Mudambi, 2005).

Although it is known that as a collective foreign subsidiaries of the MNC have come to make an increasingly significant contribution to its technological and strategic renewal, the literature on the subject contains limited information about evolutionary paths and potential limits to the development of technological capabilities at the level of individual foreign subsidiaries. With few exceptions (Birkinshaw & Hood, 1998a; Cantwell & Mudambi, 2005), the typical perception or "end of story" is the introduction of advanced research and development capabilities and the associated granting of a world product mandate to a foreign subsidiary, after which the subsidiary is implicitly assumed to reach a resting state in its most advanced form. Additional technologies and products may be introduced, some of which represent new additions to the entire multinational group, but the questions when and to what ultimate extent have been left unanswered.

As a result, the ultimate expansion of the MNC's involvement in technological activities in foreign subsidiaries has remained largely unexplored, both from a theoretical and empirical perspective. Consequently, an important aspect of the nature of the MNC has been left uncharted. Addressing the issue is also important from a managerial point of view, especially in light of the increasing importance attributed to innovation and technological renewal of the MNC (Bartlett & Ghoshal, 1989; Hamel & Prahalad, 1994; Dougherty & Hardy, 1996; Verbeke, Chrisman & Yuan, 2007). To sustain innovation and the competitive advantage of the modern MNC, managers must be able to estimate the expected technological contribution from foreign subsidiaries. Critical questions include whether to establish new foreign subsidiaries or rely upon old ones for the generation of new technology, or whether to secure technological renewal mainly through greenfield establishments or through other modes of entering foreign markets.

The present paper addresses the lack of attention to long-term, evolutionary developments in technologically advanced foreign subsidiaries of the MNC. It explores the theoretical drivers behind the evolution of subsidiaries that have originated as greenfield investments and at one point proven their capacity to contribute significantly to the technological and strategic development of the multinational group (Cantwell & Mudambi, 2005). These advanced subsidiaries tend to have a comparatively long history in the MNC, thereby providing fertile ground for testing theoretical predictions about longitudinal developments and uncovering what may be seen as fundamental tendencies in the evolution of the MNC.

Drawing upon the complete U.S. patenting history of 211 greenfield subsidiaries of 21 Swedish multinationals in the 1893-2008 period, we use repeated events analysis to test for patterns in the timing of the subsidiaries' entry into technologies that are new to the entire multinational group. The results show a statistically significant acceleration of entry into new technologies among the subsidiaries, or, in other words, that a large number of prior entries into new technologies increases the likelihood of a rapid entry into additional new technologies. At the same time, the results reveal small numbers of entries into new technologies in most subsidiaries and moderate hazard rates. Overall, the results support theories that from various perspectives address the evolution of technological capabilities in advanced greenfield subsidiaries, but caution against extreme views on their growing technological and strategic importance for the MNC.

The paper is divided into six main sections. The first section reviews the literature on the evolution of technological capabilities in foreign subsidiaries of the MNC, with a specific emphasis on identifying the drivers or mechanisms that have been associated with the technological development of advanced greenfield subsidiaries. It is followed by a section that outlines possible patterns in the timing of entry into technologies that are new to the entire multinational group, and develops the baseline hypothesis about accelerated entry that is empirically tested in subsequent sections. The third section describes the data and data collection, sample, and statistical method. The fourth section presents the results, including additional investigations into the possible existence of curvilinear entry patterns. It is followed by a penultimate section that discusses the observed patterns of entry into new technologies. The sixth and final section contains a summary of the main findings and contributions of the paper, together with some reflections about their implications for views on the nature of the MNC and future research.

LITERATURE REVIEW AND MODEL DEVELOPMENT

The internationalization of technological activity in the MNC and the nature of technological capabilities in foreign subsidiaries have been documented in several related strands of research. A significant part of the literature has been concerned with general trends in the internationalization of technological capabilities in the MNC, including categorizations of different types of foreign research and development units. A more diverse body of literature has captured a set of external and internal drivers that can explain the technological evolution of foreign subsidiaries. The theoretical model developed in this paper draws together those drivers that can be expected to have persistent, cumulative, and long-term effects on foreign subsidiary innovation activity and specifically entry into technologies that are new to the entire multinational group.

The Internationalization of Technological Capabilities of the MNC

Today there is a substantial body of literature on the internationalization of technological activity within the MNC (e.g. Cantwell, 1989; Pearce, 1989; Dunning, 1994; Reger, 2002). Most empirical evidence documents increasing shares of foreign technological activity, although it has been emphasized that the rate of change should not be overestimated (Narula, 2002), particularly among firms originating in large economies such as the United States and Japan (Patel & Pavitt, 1991, 1995; Patel, 1995). Additional empirical evidence shows that the overall level of involvement in foreign research and development depends on factors such as industry and MNC country of origin (Cantwell & Santangelo, 2000; UNCTAD, 2005), as well as differences with respect to the geographical focus of internationalized research and development activities (Cantwell & Janne, 2000).

The general explanation for the internationalization of technological activity is the MNC's initial need to adapt products to local market needs, which in some cases leads on to more sophisticated technological roles and responsibilities among foreign subsidiaries (Wortmann, 1990; Håkanson & Nobel, 1993a; Patel & Pavitt, 1998; Papanastassiou, 1999; Pearce, 1999a; Cantwell & Piscitello, 2000). Additional drivers include slackening supply of new technology from the parent company or inadequate technology for the large foreign markets, the need to provide more challenging work to retain skilled local employees, or the acquisition of "incidental" R&D units (Ronstadt, 1978; Håkanson & Zander, 1986). Over the past few decades, asset-seeking investments (Cantwell & Narula, 2001; Mudambi, 2008) and foreign acquisitions have become a major contributor to the expansion of technological capabilities outside the MNC's country of origin (Zander, 1999).

In addition to the study of the internationalization of technological activities in the MNC, empirical research has produced a number of typologies of foreign research and development units (e.g. Ronstadt, 1978; Pearce, 1989; Håkanson & Nobel, 1993b; Kuemmerle, 1997). These typologies have primarily been concerned with differences in the nature of technological capabilities and activities across foreign subsidiaries. One end of the spectrum is occupied by subsidiaries that essentially help local manufacturing to assimilate and adapt mainstream technology supplied by the home country organization, or what have been referred to as competence-exploiting subsidiaries (Cantwell & Mudambi, 2005). At the other end of the spectrum we find the competence-creating subsidiaries, which actively contribute to the development of the group's technological portfolio, influence the strategic direction of the entire multinational group, and can become part of globally coordinated R&D programs (Cantwell, 1995; Gerybadze & Reger, 1999; Pearce, 1999b; Pearce & Papanastassiou, 1999; Cantwell & Piscitello, 2000). These are the technologically advanced subsidiaries that are of main concern in the present paper, and whose development patterns and ultimate limits have remained comparatively unexplored in the extant literature.

The Drivers behind Advanced Foreign Subsidiaries' Entry into New Technologies

The emergence of increasingly sophisticated technological and strategic roles among foreign subsidiaries of the MNC is mainly caused by two different types of processes and organizational units – (1) the establishment and evolution of foreign greenfield subsidiaries, and (2) the establishment and evolution of foreign acquisitions. This paper focuses on greenfield subsidiaries, as the mixing of greenfield and acquired units would confound two fundamentally different evolutionary paths, both from a theoretical and empirical point of view (Hitt et al., 1991, 1996; Bertrand & Zuniga, 2006)[1]. Greenfield subsidiaries have been the point of departure for most of the theorizing about subsidiary evolution, and because of their comparatively long history in MNCs they provide a good testing ground for predictions and hypotheses about longitudinal developments.

Over time, greenfield subsidiaries tend to develop closer relationships with local firms and become increasingly embedded in their local business environments (Andersson, Forsgren & Holm, 2002). Those subsidiaries that for a number of reasons come to attain a basic level of technological activity will be able to access and take advantage of localized spillovers (Jaffe, Trajtenberg & Henderson, 1993; Almeida, 1996; Mudambi, 1998; Feldman, 2000; Frost, 2001). Taking advantage of these local spillovers may lead the subsidiaries to develop distinct technological capabilities and ultimately gain recognition as "centers of excellence" within the international organization (Chiesa, 1995; Holm & Pedersen, 2000). Improved technological capabilities and enhanced visibility in the local business environment are likely to further increase their attractiveness as partners in local collaborative development work. As each local environment offers a unique set of technological and business opportunities (Pavitt, 1988a; Porter, 1990; Cantwell, 1991), foreign subsidiaries reaching this stage of development will tend to enter and exploit fields that represent new additions to the technological portfolio of the multinational group.

Enhanced degrees of local embeddedness and a proven ability to respond to local business opportunities can trigger virtuous cycles of technological and strategic initiatives at the subsidiary level (Delaney, 1998; Fratocchi & Holm, 1998). Birkinshaw (1999) shows that the formation of distinctive subsidiary capabilities promotes subsidiary initiatives, but he also suggests that accumulating initiatives, however created, have an impact on the formation of distinctive capabilities. In conclusion, it is argued that "[T]hese changes are the result of a development process, in which subsidiary managers gradually build capabilities in their subsidiary and relationships in the head office, which, in turn, leads to a more receptive head-office audience for their initiatives." (Birkinshaw, 1999:29)[2].

Enhanced degrees of local embeddedness and virtuous cycles of technological and strategic initiatives are the initial drivers behind the subsidiary's ability to contribute technologically and strategically to the multinational group. This ability is boosted further by the gradually enhanced combinative capabilities that come with the subsidiary's growing involvement in a number of technologies (Kogut & Zander, 1992). Over time, increasing diversity in the stock of knowledge tends to enhance the creative capability and innovativeness of the subsidiary (Smith, Collins & Clark, 2005). In general terms, technological capabilities transferred from home-country and headquarter units represent the initial resources that allow subsidiaries to respond to business opportunities emerging in the local context. At later stages, when the scope of technological capabilities has been enlarged, enhanced combinative capabilities at the local level will accelerate the subsidiary's entry into new technologies.

Whereas cumulative processes promote the subsidiary's ability to locally recombine different ideas and resources into new products and services, enhanced interconnections and integration of the subsidiary with the overall MNC extend the same processes to the international level (Cantwell, 1995; Gerybadze & Reger, 1999; Pearce, 1999b; Pearce & Papanastassiou, 1999; Cantwell & Piscitello, 2000; Mudambi, 2008). Successful initiatives create visibility in the intra-corporate context and a growing number of possibilities to link up with headquarters and sister subsidiaries in internationally coordinated innovation projects (Ghoshal & Bartlett, 1988; Hedlund & Ridderstråle, 1995). Both local and organization-wide combinative capabilities suggest enhanced abilities to draw upon and recombine an increasingly diverse set of impulses and resources, resulting in a multiplicative effect on the subsidiary's capability to introduce novel combinations and technologies that are new to the multinational group (Phene & Almeida, 2008).

Theoretical Model

The three main drivers behind the evolution of technological capabilities in advanced greenfield subsidiaries of the MNC are summarized in Figure 1. Together, they have a persistent, cumulative, and long-term effect on the subsidiary's likelihood of entry into technologies that are new to the entire multinational group[3]. As suggested by the model, enhanced degrees of local embeddedness and the virtuous cycles of technological and strategic initiatives they tend to generate temporally precede the other two factors, although once in place the three components are expected to work in parallel and mutually reinforcing ways.

At the more fundamental level, a subsidiary's inclination to enter into new technologies is driven by profit motives and the need for continuous innovation to keep pace with and stay ahead of competition. It may also be explained by the quest for power and influence within the multinational group. From the subsidiary's perspective, power and influence translate into independence and freedom from what may be perceived as unwanted strategic, operational, or financial interference from headquarters, or into the ability to influence important strategic decisions in the MNC (Andersson, Forsgren & Holm, 2007; Forsgren, 2008). Either ambition is supported by the development of local business connections and strong and distinctive technological capabilities (Mudambi & Navarra, 2004).

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Insert Figure 1 about here

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In the context of a longitudinal study that covers decades of technological activity and new technology entry at the subsidiary level, it is difficult to accumulate sufficient data to test the full theoretical model. But it is possible to test the model's predicted outcome, which concerns the pace at which foreign subsidiaries enter technologies that are new to the entire multinational group. This paper deals specifically with the issue of rate of entry into new technologies and what it reveals about foreign subsidiaries' longitudinal ability to contribute to the strategic and technological renewal of the multinational group. Expectations about typical patterns in the timing of entry into technologies that are new to the entire multinational group are discussed in the following.

HYPOTHESIS

While the existing literature suggests an overall longitudinal drift into more advanced technological capabilities and roles among foreign subsidiaries, there have been few empirical investigations of the rate and ultimate limits to their technological evolution. The literature has addressed general subsidiary development up to and sometimes through the advanced stages (Birkinshaw & Hood, 1998a, 1998b; Holm & Pedersen, 2000; Cantwell & Mudambi, 2005), but few studies have explicitly explored subsequent patterns in the entry into technologies that are new to the entire multinational group.

Essentially, three alternative patterns in the advanced greenfield subsidiary's entry into technologies that are new to the multinational group can be discerned: (1) constant, (2) accelerated, and (3) curvilinear patterns (Figure 2).

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Insert Figure 2 about here

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The *constant pattern* of entry into technologies that are new to the multinational group is representative of the lack of assumptions or statements about the ultimate limits to the technological development of advanced foreign subsidiaries. It is based on the implicit notion that those foreign subsidiaries which have managed to acquire a world product mandate then reach a resting state in their most advanced and developed form. Although, according to this view, advanced foreign subsidiaries may continue to generate entries into new technologies, these entries are expected to occur at regular intervals. Individual subsidiaries are thus capable of contributing significantly to the technological and strategic development of the multinational group, but they show no tendency to pull it into new and previously unexplored areas at an increasing pace.

While the constant pattern assumes unchanged intervals between entries into new technologies, the literature that from various perspectives deals with the external and internal drivers behind the technological evolution of greenfield subsidiaries predicts an *accelerated pattern*, implying that over time intervals become shorter and shorter. Predictions about accelerated entry into new technologies rest on the three interrelated processes which have been outlined above: (1) The process by which over time the foreign subsidiary becomes more embedded in its local business environment, including virtuous cycles of subsidiary initiatives, (2) gradually enhanced combinative capabilities at the subsidiary level, and (3) the enhanced potential to utilize the intra-MNC network for the production of new technology. Together, these processes can be expected to have a persistent, cumulative, and long-term effect on foreign subsidiaries' entry into technologies that are new to the multinational group.

While accelerated entry into technologies that are new to the multinational group accentuates the opportunities associated with an advanced subsidiary's development, *curvilinear patterns* emphasize the possible constraints imposed by, for example, over-embeddedness (Uzzi, 1997), struggles for power in the MNC (Asakawa, 2001; Yamin & Forsgren, 2006), or path dependency in technological development (Dosi, 1982; Sahal, 1985). These curvilinear patterns may be of many shapes, although, in terms of the length between any subsidiary's entries into new technologies, gradually diminishing or inverted u-shaped patterns are most in line with expectations from the these literatures.

Compared to the drivers that predict accelerated patterns of entry into new technologies, the systematic effects of those associated with curvilinear patterns are more tentative. The literature on over-embeddedness does not involve clear-cut expectations that ultimately over-embeddedness should develop among all firms. In the case of power struggles in the MNC, there is yet to emerge systematic evidence that headquarters routinely intervene when foreign subsidiaries take on more prominent roles in the multinational network, or that virtuous cycles of initiatives at some point will be reversed[4]. Indeed, an alternative response to the emergence of powerful foreign subsidiaries has been the shifting of divisional headquarters abroad, rather than contraction back to the home country units (Forsgren, Holm & Johanson, 1995). While the technology trajectory literature predicts that individual core technologies at some point will run out of steam, it is difficult to estimate the general length of technological cycles at the subsidiary level, and the effect on subsidiaries' ability to instead enter into new areas of technology remains largely unknown[5].

The established literature on MNC and subsidiary development, as summarized in Figure 1, suggests strongest systematic support for accelerating effects on greenfield subsidiaries' entry into technologies that are new to the multinational group. Yet, as it is unlikely that accelerated patterns can be sustained indefinitely, the time period over which acceleration can be sustained is an issue that must be considered. Overall, the long-term process of becoming firmly embedded in local business environments (Zaheer & Mosakowski, 1997) as well as headquarters' interest in continuously monitoring and balancing power accumulated by foreign subsidiaries speak for relatively slowly evolving processes. Observations by Zander and Zander (1996) indicate that in individual foreign subsidiaries cycles of expansion and contraction of technological activity may extend over a period of 50 years or more. For curvilinear development patterns to be systematically observable, the majority of units under observation would then need to display histories that can be followed over at least those time periods.

Baseline expectations about patterns in the advanced greenfield subsidiary's entry into new technologies should thus take into account the length of time periods under investigation. The incremental nature of evolutionary processes, coupled with evidence that points to a relatively recent increase in the degree to which advanced R&D is performed outside the home country of the MNC (Ronstadt, 1978; Håkansson & Nobel, 1993b; Cantwell, 1995; Zander, 1999), suggests that for the majority of units under observation in the present study accelerated entry patterns should be expected to dominate[6]. Accordingly, accelerated entry into new technologies becomes the baseline hypothesis that is empirically tested in this paper:

> **Hypothesis**: Technologically advanced greenfield subsidiaries of the MNC display an accelerating rate of entry into technologies that are new to the entire multinational group.

Yet, it makes intuitive sense that accelerating patterns of entry into new technologies cannot be sustained indefinitely, and that at some distant but unknown point in time the subsidiary's rate of entry will decelerate or be reversed. As theoretical and systematic empirical evidence on the curvilinearity issue is scarce, additional analyses will also explore the possible existence of an inverted u-shaped pattern in the subsidiaries' rate of entry into new technologies. The sample, data and data collection, and statistical method employed to test the hypothesis are presented in the section that follows.

METHOD

Sample

To test for patterns in the entry into new technologies in foreign subsidiaries of the MNC, the paper draws on the complete U.S. patenting history of all advanced greenfield subsidiaries of 21 Swedish multinationals over the 1893-2008 period. A total of 211 subsidiaries with a patenting history were identified, out of which 147 were located in Europe (most importantly, Germany, 19, Switzerland, 16, United Kingdom, 13, Netherlands, 13, Denmark, 13, and Finland, 12), 19 in the United States, and 45 in other countries (most importantly, Canada, 9, Japan, 8, Australia, 6, New Zealand, 4, Mexico, 3, and South Africa, 3). Entry into the dataset could occur at any time during the examined period (for a dataset of similar structure, see Lawless et al., 2001). The sample firms represent a relatively broad spectrum of industries, including, for example, pulp and paper, motor vehicles, pharmaceuticals, and telecommunications equipment. Previous studies have shown that these companies account for a significant and representative number of inventions and R&D expenditure in Swedish industry (Wallmark & McQueen, 1986; Håkanson & Nobel, 1993b).

In order to define the sample firms and subsidiaries in a way that would allow for longitudinal comparisons, a historical examination of each individual firm was conducted, identifying any possible name changes as well as potential changes in ownership through mergers and acquisitions. The data consolidates any patenting by first-order, majority owned subsidiaries for the periods during which they belonged to the parent companies. These subsidiaries were identified through an extensive and systematic search into the history of each individual sample firm, using the publications “Svenska Aktiebolag – Handbok för Affärsvärlden”, “Koncernregistret – KCR”, and “Who Owns Whom – Continental Europe”. Complementary publications, such as publications on company histories, were also used in the consolidation process. The sample firms were followed until 2008, or until they became involved in major international mergers or acquisitions (Appendix A). The organizational effects of these mergers or acquisitions, including the potential reorganization of international research and development activities, thus do not interfere with the current data and analyses.

The empirical analysis is concerned only with foreign subsidiaries that were originally established as greenfield subsidiaries, thus excluding subsidiaries that were added to the sample firms as a result of foreign acquisitions (over the entire period, greenfield as compared to acquired subsidiaries accounted for the majority of all entries into new technologies among the sample firms). It should also be re-emphasized that the data only includes foreign subsidiaries which have once proven their capacity to contribute significantly to the technological and strategic development of the multinational group. Proof of this capacity is that the subsidiaries have been awarded at least one U.S. patent, which by definition requires that inventions be novel, non-obvious, and useful additions to the existing stock of knowledge (for additional methodological notes and comments, see Appendix B).

It is notable that some of the subsidiaries may have been awarded one or several U.S. patents, but never accomplished entry into a technology that was new to the entire multinational group (58 percent of the subsidiaries in the sample). Others are associated with single or multiple entries, but testing for typical patterns in the entry into new technologies requires the inclusion of subsidiaries of all these types in the empirical tests. A stylized representation of the basic types, which also illustrates the different spells or time periods between entries into new technologies that are central to the statistical analyses, is provided in Figure 3.

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Data and Data Collection

The study uses patents as an indicator of technological capabilities and firms' entry into new technologies. Patents are a frequently used indicator of technology and the geographical location of technological activity (e.g. Jaffe, 1986; Archibugi & Pianta, 1992; Almeida & Phene, 2004; Feinberg & Gupta, 2004; Singh, 2007). They possess a specific advantage in that they provide access to consistent and comparable information over extended periods of time. Patenting has been found to correlate highly with alternative measures of technological activity and innovative performance, such as research and development expenditure and new product introductions. In a study comprising a large number of companies in four high-tech industries, Hagedoorn and Cloodt (2003:1375, 1365) found “no major systematic disparity amongst R&D inputs, patent counts, patent citations and new product announcements”, concluding that “future research might also consider using any of these indicators to measure the innovative performance of companies in high-tech industries”.

The present study relies specifically on the firms’ patenting in the United States. The completion of a U.S. patent application requires that the nationality of the inventor be recorded (rather than the nationality of the research unit). Under the assumption that the nationality of the inventor in the majority of cases coincides with the geographical location of invention, it is therefore possible to identify where the research and development underlying the invention was carried out. Thus, for every U.S. patent registered under the name of any of the sample firms and their subsidiaries, it is known whether the patent *originated* in, for example, Germany, the United Kingdom, the United States or any other country[7]. This is an important advantage because company-specific patenting policies (for example, registering the patent under the name of the parent company rather than the inventing subsidiary) could otherwise conceal the correct geographical distribution of technological activity and invention.

One advantage of using U.S. patenting data is that the general attractiveness of the large U.S. market encourages patenting of inventions that are believed to be of relatively high quality and commercial value. The use of U.S. patenting data thereby reduces the risk that accidental or insignificant inventions will bias the results. It has been found that Swedish firms’ patenting in the United States does not differ significantly from patenting in other large markets, such as Germany or France (Archibugi & Pianta, 1992). One potential drawback of using U.S. patenting data is that it tends to inflate the patenting activity by U.S. subsidiaries (because they have a relatively high propensity to patent in what is their home market). Although this increases the relative number of entries and observations that may be associated with U.S. subsidiaries, it should not affect the expected pattern in the timing between new entries. In the current sample, U.S. subsidiaries account for not more than 19 out of the 211 foreign subsidiaries, and they should not have a disproportionate influence on the results.

Although information from patents must be treated with some caution (Schmookler, 1950; Pavitt, 1988b), no substantial biases are anticipated in the present study. Most of the sample firms are active in medium to high-tech industries, where patenting is considered an important competitive device. Patenting propensity varies across the sample firms, causing variation in the number of patents associated with each firm, but this does not in itself affect patterns in the timing of entry into new technologies.

Variables

Dependent variable. The main variable of interest is the timing of a subsidiary's entry into technologies that are new to the multinational group. Entry occurs when the subsidiary is awarded a patent in a patent class in which the multinational group has not been previously active. Time to entry is measured as the number of years between either the subsidiary's first recorded patenting and its first entry into a technology that is new to the multinational group or the number of years between any two successive entries (for example, the number of years between the 1^{st} and 2^{nd} entry into a new technology, or between the 2^{nd} and 3^{rd} entry, etc.). Entry is a distinct event (for subsidiaries which have never entered any technologies that are new to the multinational group no such event is recorded), but any particular subsidiary may have been involved in several entries over time.

Entry into new technologies is measured at the level of about 400 classes of technology as defined by the U.S. Patent Office[8]. For matters of convenience, these classes of technology will be referred to as technologies throughout the paper. At this level of aggregation, it is possible to distinguish between relatively narrowly defined technologies, such as resistors and electrical connectors. Other examples of patent classes include paper making and fiber preparation, chemistry carbon compounds, liquid purification and separation processes, and pulse or digital communications. For the purposes of this paper, the classification should strike a good balance between more aggregate groups (the use of which would result in fewer identified entries into new technologies) and finer levels of aggregation.

Main covariate. The main covariate of interest is the *number of prior entries* into technologies that are new to multinational group. If high numbers of prior entries are associated with a high likelihood of entry into a new technology, this will support the hypothesized pattern of accelerated entry into new technologies among foreign subsidiaries. In practical terms, the statistical models examine whether the number of prior entries into new technologies influences the spell length or time between successive new entries.

Control variables. Although the data ideally should have included several control variables capturing a subsidiary's external and internal environment – for example the munificence and other aspects of the local business environment (Furu, 2000), changes in the overall degree of centralization of the MNC, or levels of competitive pressure – the length of the time period under study in combination with unavailability of data at the subsidiary level precludes the use of a comprehensive set of controls. At the same time, the introduction of control variables on the basis of the existing data is complicated by the fact that many potential measures are expected to evolve together with the main covariate, or the number of previous entries into new technologies by an individual subsidiary.

We nevertheless employed a number of control variables in the model specifications. We included size of the local market as a general proxy for the munificence of the local technological and business environment, which is expected to influence the local subsidiary's ability to branch out into a potentially broadened portfolio of business and technological activity. The size of the local market was measured annually in *GDP* expressed in the log of millions of USD (constant 1990 terms), the data being obtained from the GGDC total economy database (2008). It is expected that large markets offer broader business and technological opportunities than small markets, creating more opportunities to identify and recombine diverse ideas and resources within the local context.

Three industry dummy variables (coded 0 and 1) were introduced to control for industry-dependent effects on the timing of entry into new technologies. These dummy variables were expected to reflect different propensities to centralize R&D activities (Papanastassiou & Pearce, 1998) and exchange knowledge across individual subsidiaries of the multinational network (Randoy & Li, 1998). The first dummy variable captured firms in the *automotive industry* (2 firms), the second firms in *processing industries* such as pulp and paper and steel (4 firms), and the third firms involved in *pharmaceuticals and chemicals* (4 firms). This left a mixed group of sample firms mainly active in mechanical engineering industries, often with a highly diversified product portfolio.

We also included a control variable capturing whether individual subsidiaries entered the risk set during early or late periods of the observation window. The expectation was that advanced foreign subsidiaries that came into existence when MNCs were presumably beginning to adopt more modern organizational forms would experience more rapid entry into new technologies. This *modernity* variable distinguished between subsidiaries that entered the risk set before 1980 and those that entered after 1980 (coded 0 and 1), which is the time period when new trends in the management and organization of traditional MNCs began to be observed and, through the business literature, may have had a reinforcing effect on management practices (Hedlund, 1986; Bartlett & Ghoshal, 1989; Doz & Prahalad, 1991). To a large extent, the modernity variable also gauges the increasingly knowledge-based and competitive environment in which MNCs operate, a trend which has been particularly accentuated from the 1980s and onward (Powell & Snellman, 2004).

Two control variables were introduced to capture the extent to which individual subsidiaries could draw upon sister subsidiaries in developing new technologies. To control for general benefits from technological cooperation within the multinational network (Bartlett & Ghoshal, 1990), we introduced an *internal network* variable measuring the number of additional subsidiaries with proven but not necessarily unique technological capabilities at the time of each annual observation. The variable reflects the collective, accumulated technological capabilities which the subsidiary has potential access to and which in various ways may support its own technological efforts. The variable *technological diversity* captures the extent to which the subsidiary has access to dispersed and differentiated knowledge that may be recombined in the innovation process. For each annual observation the technological diversity variable measures the number of other subsidiaries in the MNC that, according to the data, had produced entry into technologies that were new or unique to the multinational group. These two control variables do not capture or measure actual interaction between subsidiaries, but merely reflect the subsidiary’s potential for becoming engaged in inter-unit collaborative efforts.

To control for the potential effects of national culture on the technological development of foreign subsidiaries, we included a *cultural distance* measure using Kogut and Singh’s (1988) index and the scores of Hofstede’s (2001) cultural dimensions, with the exception of the Confucian dynamism dimension. The cultural distance measure captures cultural dissimilarities between a foreign country and the

MNC home country (which in the present sample is Sweden), which could influence both the ability and desirability to control the technological activities in foreign subsidiaries[9].

Statistical Method

The statistical method is event history analysis. Since subsidiaries may be involved in a number of successive entries into new technologies, the specific method is the analysis of repeated events, using the SAS statistical package (Allison, 1995). Each entry into new technologies represents a distinct event, (the 1st, 2nd,…, Xth entry into a technology that is new to the multinational group by any foreign subsidiary). The first spell is between the subsidiary's first recorded patenting and its first entry into a new technology, although in some cases there is no entry at all over the observed time period (resulting in a right censored observation) and in a small number of cases the first recorded patenting coincides with the entry into a new technology. The subsequent spells are between the subsidiary's successive entries into new technologies. Since all observations end in 2008 (with some variation across the sample firms), the last spell of any sequence of entries into new technologies is typically right censored.

With the development of repeated or recurrent event analysis, there are now several basic models in use (e.g. Therneau & Hamilton, 1997; Kelly & Lim, 2000; Box-Steffensmeier & Zorn, 2002; Ezell, Land & Cohen, 2003; Jiang, Landers & Rhoads, 2006), but the use of previous events as a covariate has received limited attention (Beck, Katz & Tucker, 1998). In the current paper, we applied the renewal or gap time specification of the Andersen-Gill model, or AG model, which is generally recommended in the literature (Kelly & Lim, 2000; Box-Steffensmeier & Zorn, 2002; Ezell et al., 2003; Jiang, Landers & Rhoads, 2005)[10]. We did not apply the Prentice, Williams, and Peterson or PWP models, for the following reasons: in the present data changes in the risk process are captured by the number of prior events, we did not expect the effect of the control variables to change based on event number, event-specific hazards are not a main concern in the paper, and few of the subsidiaries experienced a large number of entries into new technologies[11].

One limitation of the AG model, which it shares with other repeated events approaches (Ezell et al., 2003), is that it does not account for or correct for unobserved heterogeneity[12]. To a certain extent, the homogeneity of the sample firms in terms of geographical origin and organizational traits should have created similar conditions across firms and individual subsidiaries. Also, a number of controls that account for potential industry-dependent effects on the timing of entry into new technologies are used. Finally, all subsidiaries in the sample have reached at least the stage of documented capability to contribute significantly to the technological and strategic development of the multinational group. This would exclude a number of different types of subsidiaries from the analysis, for example those representing only sales subsidiaries or those involved in minor adaptations of existing products and services to local market needs.

The absence of a more extensive set of control variables and the possible existence of unobserved heterogeneity suggest caution in the interpretation of the results (Ezell et al., 2003). Accordingly, we expect the findings to shed but preliminary light on patterns in advanced subsidiaries' entry into new technologies, paving the way for further and more comprehensive empirical investigations into state dependent and unobserved heterogeneity effects.

RESULTS

Descriptive statistics on the sample firms, including entries into new technologies by firm and subsidiaries as well as average spell lengths, are presented in Tables 1 and 2.

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Insert Tables 1 and 2 about here

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Table 1 shows that the numbers of advanced greenfield subsidiaries and entries into new technologies vary considerably across the sample firms. The largest number of foreign subsidiaries accounted for by an individual firm was 53 (median 8). While all of these subsidiaries had proven their capacity to contribute significantly to the technological development of the multinational group, not all of them generated entry into new technologies over the examined time period. The smallest number of entries into new technologies accounted for by an individual subsidiary was 0 and the largest was 41. The majority of advanced foreign subsidiaries across all sample firms never entered into a new technology. Specifically, 89 out of 211 subsidiaries entered into a new technology (the median number of new entries in the former group was 2). The average age of a subsidiary as a technologically advanced or fully developed unit was 21.5 years.

Table 2 shows that the average spell length was just above 18 years for the first entry into a new technology and generally shorter for subsequent entries. It is noteworthy that the first spell includes a number of cases where the first recorded patenting by a subsidiary also represented entry into a technology that was new to the multinational group, and that it also includes a number of cases where patenting subsidiaries never generated entry into new technologies (ending in a right censored observation). After the first entry, event numbers fall off relatively rapidly, which is not uncommon in repeated events studies (e.g. Abu-Libdeh, Turnbull & Clark, 1990).

The correlation matrix in Table 3 reveals mostly modest correlations between the covariates[13]. The variance inflation factor (VIF) was estimated to check for potential multicollinearity issues. With no VIF scores above 3 (Hair, Anderson, Tatham & Black, 1998), the risk of significant misinterpretations of the results because of multicollinearity appears limited.

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Insert Table 3 about here

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The results from the repeated events analyses are contained in Table 4. The first model presents only the results for the control variables, whereas the second and third models add two alternative specifications of the main covariate number of prior entries.

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Insert Table 4 about here

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The first model shows statistically significant effects for six of the control variables. Size of the local market shows a positive hazard ratio, suggesting that large and munificent local markets increase the likelihood of a subsidiary's entry into technologies that are new to the multinational group. The industry dummies accounting for subsidiaries in the automotive industry, processing industries, or pharmaceuticals and chemicals all show hazard ratios below one (although the automotive dummy is not significant at the 5 percent level). The figures suggest that compared to the general mechanical engineering industries, being part of the processing industries or pharmaceuticals and chemicals lowers the subsidiary's likelihood of entry into new technologies by 26 and 50 percent respectively.

The influence from the emergence of modern organizational forms of the MNC or the modernity effect is negative but not significant. The control variable measuring the potential influence from internal network connections shows a negative parameter estimate, suggesting that a large number of advanced sister units decreases the likelihood of a subsidiary's entry into new technologies. For the technological diversity measure the reverse is true, as the existence of sister subsidiaries that have generated entry into unique technologies increases the likelihood of entry into new technologies. The cultural distance measure, finally, shows a significant negative effect on the subsidiary's likelihood of entry into new technologies.

The second model introduces the main covariate, showing a significant and positive relationship between the number of prior entries and the likelihood of entry into technologies that are new to the multinational group. In other words, an increase in the number of prior entries speeds up entry into the next new technology, thus supporting the baseline hypothesis. Yet, while the effect is statistically significant, the hazard ratio reveals that an increase in the number of prior entries by one increases the likelihood of an additional entry by not more than 3 percent. With the exception of the cultural distance variable, significance levels of all other covariates remained unchanged in the second model, and results remain robust throughout a range of modifications of the underlying explanatory model and of the sample firms included[14].

The third model explores the possible existence of a curvilinear entry pattern. It does so by introducing the squared term of the main covariate number of prior entries. The findings are initially consistent with the fact that the number of prior events has a significant, modest inverse u-shaped effect on the likelihood of entry into technologies that are new to the multinational group (less than 1 percent in the downward slope and 16 percent in the upward slope). The goodness-of-fit of the three models is satisfactory and increasing, ranging from a likelihood ratio test score of

151.02 for Model 1 to 170.14 for model 2 and 194.69 for Model 3. In validating the curvilinear model's superiority over the linear model, the goodness-of-fit significantly improved when the square of prior entries was inserted.

However, robustness checks indicated that the curvilinear effect was driven by one particular firm (Alfa Laval), and specifically the impact from its U.S. subsidiary. After an initial gestation period, this subsidiary became technologically very active for several decades, after which technological activity decreased (Zander & Zander, 1996; the descriptive data of Table 2 suggest that for many of the firm's late entries into new technologies the spell length increased compared to previous periods). When excluding this particular firm and subsidiary from the sample, the squared term of the number of prior entries lost its statistical significance (while prior entries remained significant at a hazard ratio of 1.13). Despite the overall increase in fit in Model 3, this robustness check therefore suggests stronger general support for the accelerated than for the curvilinear pattern.

DISCUSSION

The objective of this paper is to explore patterns of entry into new technologies in advanced greenfield subsidiaries of the MNC. The main results suggest the presence of an accelerated pattern of entry into technologies that are new to the MNC, or, in other words, that the time between entries into new technologies tends to become shorter with each successive entry. The findings support established theorizing about the evolution of technological capabilities in greenfield subsidiaries, and remain robust throughout a range of model specifications and sample firms included in the analyses.

At the same time, the observed hazard rates suggest that the ability of the investigated subsidiaries to increasingly contribute to the technological and strategic renewal of the multinational group is limited. Specifically, increasing the number of prior entries by one increases the likelihood of entry into an additional new technology by only a few per cent. In light of the generally low numbers of entry into new technologies displayed by the foreign subsidiaries in the sample, this does not seem to amount to a major influence on the strategic development of the entire multinational group. Yet, there is significant variation in terms of the number of entries across individual subsidiaries, which may suggest that the strategic effects on the multinational group should not be discussed in general terms, but rather in the context of a select number of ’superstar’ foreign subsidiaries (Kappen, 2009).

The relatively slowly evolving process of greenfield subsidiaries’ entry into new technologies resonates with several prior findings in the international business literature. It is known that in many cases initial foreign investments are made on a relatively limited scale (Johanson & Vahlne, 1977, 1990) and expanded by expatriates who over time select and hire employees from the local environment (Barkema & Vermeulen, 1998). Greenfield subsidiaries tend to draw upon and expand already existing firm-specific advantages (Belderbos, 2003), and the path dependency created by technology transfer from home country units will initially keep them in the neighbourhood of already established technological capabilities. Greenfield subsidiaries are also affected by liability of foreignness (Zaheer, 1995), which has proven an enduring barrier to the development of closer and embedded ties with local firms (Zaheer & Mosakowski, 1997).

Apart from the observed effect of the number of prior entries, several of the control variables showed results that were in line with expectations. Large and munificent markets appear to offer better conditions for subsidiaries to develop new innovative technologies, presumably because they give the subsidiary more opportunities to identify and recombine diverse ideas and resources within the local context. Possibly, large markets also come with relatively high degrees of power and influence within the MNC network, and the granting of autonomy which is conducive to technological advancements (Asakawa, 2001; Yamin, 2002; Forsgren, 2008). Results for the industry dummies showed comparatively low propensities to enter new technologies among subsidiaries belonging to the processing industries and pharmaceuticals or chemicals. This result makes intuitive sense, as firms in these industries depend on a few centralized plants and R&D operations, and are involved in products that only to a limited extent are sensitive to the particular demands of local business environments.

Two additional findings require some further comments. First, findings for the control variables that pick up potentially beneficial influences from cooperation with other subsidiaries in the multinational network suggest that a generally larger network of advanced sister units has a negative effect on the subsidiary’s likelihood of entry into new technologies. This unexpected relationship could be explained by enhanced competition for resources as the number of technologically advanced subsidiaries in the multinational network grows. A related explanation would be that over time a growing number of advanced foreign subsidiaries heightens headquarters' awareness of the need to coordinate research activities and avoid duplication of effort throughout the multinational network (Zander, 1998). Tighter control of dispersed technological activities would then narrow the subsidiaries' possibilities to become engaged in explorative efforts, thus slowing down entry into new technologies. In light of the absence of a statistically significant result for the modernity variable, this suggests that at least over the examined time period resource constraints and what may be termed 'conventional paradigms' of MNC management may have superseded the effects of intra-MNC networking (Phene & Almeida, 2008; Verbeke & Kenworthy, 2008).

Second, results for the technological diversity variable suggest that access to a large number of sister subsidiaries that have experienced entry into new or unique technologies increases the likelihood of a subsidiary's entry into new technologies. This could indicate that the ability to recombine geographically dispersed knowledge into novel technologies only emerges with the formation of specialized rather than generally advanced sister subsidiaries. Another interpretation would be that while MNCs generally develop the need to control dispersed research efforts when the number of advanced foreign subsidiaries grows, they remain benign toward the emergence of unique technological initiatives in a select number of foreign subsidiaries. Considering the limited number of subsidiaries in the sample that have experienced large numbers of entry into new technologies, there may be a parallel tendency to concentrate these new technological initiatives to a small group of 'superstar' foreign subsidiaries.

This could suggest that MNCs are rationalizing their internationally dispersed knowledge structures by allocating fewer but more extensive subsidiary mandates. Yet, the current analyses and results are only indicative of this possibility, and more detailed investigations and sub-sample analyses would be required to confirm this suspicion. At least the strategy of allocating extensive mandates only to a few highly active subsidiaries, whether through headquarter decisions or because of strategizing among competing subsidiaries, is not entirely in line with the data. Excluding those sample firms with the most prominent 'superstar' subsidiaries did not cause a reversal in the observed pattern of accelerated entry, suggesting that the extension of subsidiary mandates goes beyond only the most productive units.

Because few of the subsidiaries covered by the sample experienced a larger number of entries into new technologies, there was no robust evidence of curvilinear entry patterns. To the extent these patterns exist, they seem to be associated with a small number of subsidiaries that have a long history in the MNC and also have experienced a significantly lager number of entries than average. Because of the limited number of subsidiaries with a large number of entries and their potentially unique histories, it is difficult to draw any firm conclusions on the basis of the present sample and results. However, one general conclusion would be that among greenfield subsidiaries, patterns of expansion and contraction in terms of entry into new technologies will only be observable over periods that span several decades.

The observed findings have theoretical as well as practical implications. The long-term evolution of technological capabilities in foreign subsidiaries has received mostly implicit treatment in the extant literature, and the present paper connects and supports the different theoretical discussions that have appeared in the international business literature. Specifically, the proposed theoretical model identifies three main factors which can be expected to have persistent, cumulative, and long-term effects on advanced greenfield subsidiaries' entry into technologies that are new to the entire multinational group. With regard to practical implications, the baseline tendencies revealed by the empirical investigation could serve as an anchoring point for managers reflecting upon and designing desired policies for technological and strategic renewal of the MNC. Yet, exactly what these policies should involve remains firm and industry dependent. While a faster and more broad-based entry into new technologies among foreign subsidiaries in many cases would yield strategic benefits (Hamel & Prahalad, 1994; Dougherty & Hardy, 1996), for some MNCs controlled and cautious approaches to technological renewal in the multinational network might prove more desirable.

Whatever approach is taken, the observed hazard rates suggest that managers should have moderate expectations about foreign subsidiaries' ability to contribute to the strategic and technological renewal of the entire multinational group. Especially, the MNC's own transplants in the form of greenfield establishments have at least historically had, and presumably still have, a natural tendency to evolve in an incremental manner. It may then be that foreign subsidiaries and their capabilities have been significantly under-utilized in the evolution of the multinational group, but accounting for the various measures that could be taken to improve the generation of new technologies in the foreign subsidiaries of the MNC is beyond the capacity of the current paper. It may be hypothesized that other ways to achieve technological and strategic renewal are faster or more productive, but investigations of long-term, relative contributions from alternative modes of entering foreign markets, such as foreign acquisitions, joint ventures, or alliances are yet to be carried out more systematically.

A Critical Evaluation of the Findings

Several important limitations must be kept in mind in evaluating the findings and conclusions. First, it must be emphasized that the sample is restricted to a limited, non-random sample. While the firms represent a large and representative proportion of Swedish MNCs, they are not necessarily representative of firms of other national origin. On the balancing side, the sample includes corporations with long and extensive exposure to international markets and international business. With the historically large degrees of operational freedom granted to foreign subsidiaries of Swedish MNCs (Hedlund & Åman, 1984), they should offer a useful testing ground for identifying basic tendencies in the entry into new technologies by foreign subsidiaries.

Second, while the connection between prior entries and spells between subsequent entries into new technologies is robust across various model specifications, limited availability of longitudinal data at the subsidiary level has allowed us to use only crude proxies for factors such as munificence of the local business environment and the number of internal network linkages. Furthermore, control variables such as potential internal network linkages are positively correlated with the number of prior events, primarily because few of the sample firms would withdraw from individual countries (one of the underlying assumptions of the statistical tests is that the sample firms have not withdrawn from a country once a subsidiary has been established there).

Third, moderate hazard rates at the chosen level of aggregation may conceal more rapidly growing involvement within certain technological niches that are particularly important in the local business and technological environments. Hence, a foreign subsidiary may not be registered for a high number of entries into technologies that are new to the multinational group, yet it may produce continuous and possibly accelerated entries within narrowly defined areas of technology. Due to the fact that a study at the level of classes of technology as defined by the U.S. Patent Office does not capture more incremental development of technologies, the temporal patterns of such advancements remain unknown. The results and conclusions must be seen against the applied aggregation of classes of technology, but we suggest that it strikes a reasonable balance between finer categorizations and more aggregate groups. Arguably, the applied level of aggregation corresponds to the types of innovations considered by the extant literature on the technological and strategic renewal of the MNC (e.g. Hedlund, 1986; Bartlett & Ghoshal, 1989; Doz & Prahalad, 1991).

Fourth, it is important to re-emphasize that the paper does not take into account the dynamics associated with foreign acquisitions and their influence on the development of technological capabilities in the MNC. Thus, we have only captured part of the complete story of technological development in the multinational network of the MNC, albeit an important part that has received considerable attention in the prior literature. To measure the full strategic impact of the internationalization of technological capabilities in the MNC, foreign acquisitions must be added to the picture. A preliminary test that was carried out nevertheless suggests that longitudinal patterns in the technological contribution from advanced acquired subsidiaries are not substantially different from those identified among the greenfield subsidiaries[15].

SUMMARY AND CONCLUSIONS

The ultimate limits to the technological activity of advanced foreign subsidiaries of the MNC are only partially understood, and the present paper is a first attempt to identify longitudinal patterns in advanced greenfield subsidiaries' entry into technologies that are new to the entire multinational group. The results reveal statistically significant acceleration of entry into new technologies, but also what must be considered moderate hazard rates. Overall, the findings support theories that from various perspectives have addressed the evolution of technological capabilities in greenfield subsidiaries of the MNC, but question extreme views on their growing technological and strategic importance.

The paper makes three specific contributions to the existing literature. By integrating several branches of research accounted for in the international business literature, it provides a theoretical argument and model for the entry into new technologies in advanced greenfield subsidiaries of the MNC. From a theoretical point of view, we recognize that the model underlying the baseline hypothesis is only partial. We have focused on those drivers and variables in the literature that come with expectations about persistent, cumulative, and long-term effects on greenfield subsidiary entry into new technologies. At any given point in time, a large number of additional but less consistent variables may influence the rate of entry into new technologies, and further research may produce model amendments and refinements which also coincide with what is empirically measurable over extended periods of time.

The paper also provides novel empirical evidence about a hitherto neglected issue in the literature, specifically that of the rate and ultimate limits to the technological development of advanced foreign subsidiaries of the MNC. The overall conclusion, which needs to be confirmed by additional studies that include a broader sample of MNCs of different national origin, is that advanced greenfield subsidiaries do tend to pull the MNC into new technologies at an accelerating pace, but that in most cases this process is quite slow and of moderate significance. More significant contributions to the technological portfolio of the multinational group are reserved for a limited number of 'superstar' subsidiaries, but it may be the case that over extended periods of time these subsidiaries experience growth, maturity, and ultimate decline in the significance of their technological contribution to the multinational group.

Finally, the paper introduces the method of repeated or recurrent events to the field of international business and business studies more generally. It is a method which holds substantial promise for investigations of various phenomena that occur with regular frequency, but which until now has received only marginal attention in the literature. A review and penetration of the technical literature on repeated events is beyond the scope of the present paper, which nevertheless contains references to papers that offer useful guidance on the basic methods that are available. Additionally, the paper provides specific guidance for researchers interested in analyzing the effects of prior events, particularly in the context of the AG model.

It is always somewhat delicate to discuss orders of magnitude, and caution is advisable whenever data are compared over long periods of time, but the relatively slow pace of entry into new technologies identified in the present paper suggests that for most advanced greenfield subsidiaries technological evolution is an incremental process. Despite the overall acceleration of entry into new technologies that is found among the foreign subsidiaries in the sample, limited average numbers of entry and moderate hazard rates convey a picture of MNCs as keeping, as a default, tight control of individual foreign subsidiaries. While current observations do not offer any definitive proof of the true nature of the MNC, at least in the context of greenfield subsidiaries that are "close to home", they speak against extreme views on the MNC's inclination to engage in geographically dispersed knowledge development. Worldwide knowledge development may come about through an increase in the mere number of foreign investments, but perhaps not to an overwhelming extent through the development of individual foreign subsidiaries.

It appears instead that any significant additions to the technological and strategic renewal of the multinational group should be discussed in the context of a select number of 'superstar' subsidiaries, not necessarily what are believed to be general developments across all subsidiaries of the multinational network. The origin, nature, and dynamics of such superstar subsidiaries seem to deserve particular attention in future research. At least among foreign subsidiaries of greenfield origin, these would be the ones that are really able to influence and change the technological and strategic profile of the MNC.

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APPENDIX A

The sample of consolidated Swedish multinational firms

Firm[a]	Principal field of industrial activity	Total number of subsidiaries at risk[b]
AGA (1904) [c]	Industrial gases	7
Alfa Laval (1878)	Separators, agricultural equipment	13
ASEA (1883)	Power generation and distribution equipment	14
Astra (1913)	Pharmaceuticals	18
Atlas Copco (1873)	Pneumatic and hydraulic equipment	13
Electrolux (1910)	White goods, home appliances	17
Ericsson (1876)	Telecommunication equipment	25
ESAB (1904)	Welding equipment	3
Fagersta (1873)	Metals, rock drills	1
MoDo (1873)	Pulp and paper	4
Perstorp (1880)	Chemicals, conglomerate	9
Pharmacia (1911)	Pharmaceuticals	13
PLM (1919)	Packaging material	3
Saab-Scania (1891)	Automotive products, aircraft	2
Sandvik (1862)	Specialty steel and metals, hard materials	20
SCA (1925)	Pulp and paper	10
SKF (1905)	Ball and roller bearings	13
Stora (1888)	Pulp and paper	2
Tetra Pak (1946)	Liquid packaging machinery	10
Trelleborg (1905)	Rubber products, conglomerate	5
Volvo (1915)	Automotive products, food	9

[a] Years within parentheses indicate the year of establishment.

[b] Being at risk means that the subsidiaries in various foreign locations have proven their capacity to contribute significantly to the technological development of the multinational group by means of patenting, but they may or may not have been responsible for entries into new technologies.

[c] AGA was acquired by Linde in 2000 and observations truncated in that year. Other sample firms with truncated observations include ASEA (1988, merged with Swiss Brown Boveri et Cie.), Alfa Laval (1993, acquired by Tetra Pak), Astra (1999, merged with Zeneca Group), ESAB (1994, acquired by Charter), MoDo (2000, acquired by Metsä), Perstorp (2001, acquired by Sydsvenska Kemi), Pharmacia (1995, merged with Upjohn), PLM (1999, acquired by Rexam), Scania (1990, car division acquired by GM), Stora (1998, merged with Enso), Tetra Pak (1993, acquired Alfa Laval), Volvo (1999, car division acquired by Ford).

APPENDIX B
Methodological notes

Patents as proof of advanced technological capabilities: Using U.S. patents as proof of a subsidiary's capacity to contribute significantly to the technological and strategic development of the multinational group runs the risk of including subsidiaries in the sample which only display serendipitous technological discoveries. It has not been possible to estimate the relative proportion of these subsidiaries in the current sample, but only a very small number of the identified subsidiaries were responsible for only one patent over the entire period.

Identification of foreign subsidiaries: The empirical analysis is based on the assumption that, over time, the sample firms have maintained one subsidiary per country (an assumption supported by the historical accounts and information about the international operations of the sample firms presented in annual reports), although in some cases individual subsidiaries may have included several legally separate entities. For many of the observations, it is known that the parent firm has been awarded a U.S. patent that has its origin in a foreign country (assumedly because of corporate patenting policies), and the patenting records do not reveal the organizational identity of the subsidiary performing the actual research. In the analyses, it is assumed that the research underlying a patent with, for example, U.K. inventors was also carried out at the local U.K. subsidiary.

Organizational developments of foreign subsidiaries: Because of the aggregate nature of the data and the length of the time period under investigation, it has not been possible to account for all organizational changes and developments taking place in individual foreign subsidiaries. In some instances, and particularly in the case of subsidiaries in large foreign markets, locally acquired units may have been merged with the operations of the local subsidiary and thus affected its technological capabilities. Specifically, the 'instant local embeddedness' obtained through locally acquired units may have introduced a mechanism of accelerated entry into new technologies which was not considered in the theoretical section of the paper.

It is also possible that some of the patenting by major acquired subsidiaries has been registered under the name of the parent firm rather than that of the acquired organizational unit, which would mean that the data picks up some of the technological activity and new entries associated with acquired rather than greenfield subsidiaries. While it is not possible to know the extent to which this has occurred in the present sample, the patenting records provide ample evidence of extensive patenting by major acquired subsidiaries long after the point of acquisition (these units retain a separate organizational code in the records of the U.S. Patent Office).

In the worst case, the obtained results would reflect the activities of subsidiaries originally established as greenfield units with an added influence from the technological activities of some acquired units. While this would question the study's pronounced focus on the evolution of greenfield subsidiaries, the potential effects may be judged to be marginal. In any event, the results would still reveal some fundamental dynamics of the technological capabilities of foreign units of the MNC.

Period of investigation: Although the data covers the period 1893-2008, the majority of entries into new technologies were recorded after 1950 (more than 75 per cent of the total). It should be expected that the reliability of the data improved over the measured time period, especially as for most firms the United States may have been perceived as relatively distant in the early 20th century (and hence not prioritized as a country in which patents were sought). It is notable, however, that the firm which accounts for most of the observed U.S. patents before the Second World War – Alfa Laval – established large-scale operations in the United States already in the late 19th century.

Adjustments of the final dataset: A number of considerations had minor effects on the construction of the final dataset. Although in 5 cases the last recorded patents in a particular technology had occurred more than 25 years before the subsidiary registered a patent in the associated technological class (in some cases, the last recorded patent had occurred more than

50 years earlier), suggesting that subsidiaries may have been responsible for the re-entry into new technologies, the conservative approach was to exclude all such cases from the data.

In a very limited number of cases, entries into new technologies were initiated by foreign subsidiaries, but in each of these cases the location was different from that of the home location of the subsidiary in question (for example, a German subsidiary entered a new technology, but the nationality of the inventor(s) behind the patent suggested that the underlying research was carried out in the United States). These may be instances where a large and fully developed foreign subsidiary carried out some research-related activities in foreign countries, but they could also be instances where internationally connected or mobile researchers developed patents in units located outside their permanent country of residence. Due to the historically uncertain status of these observations, they were excluded from the dataset.

FIGURE 1

The drivers behind greenfield subsidiary entry into technologies that are new to the MNC group

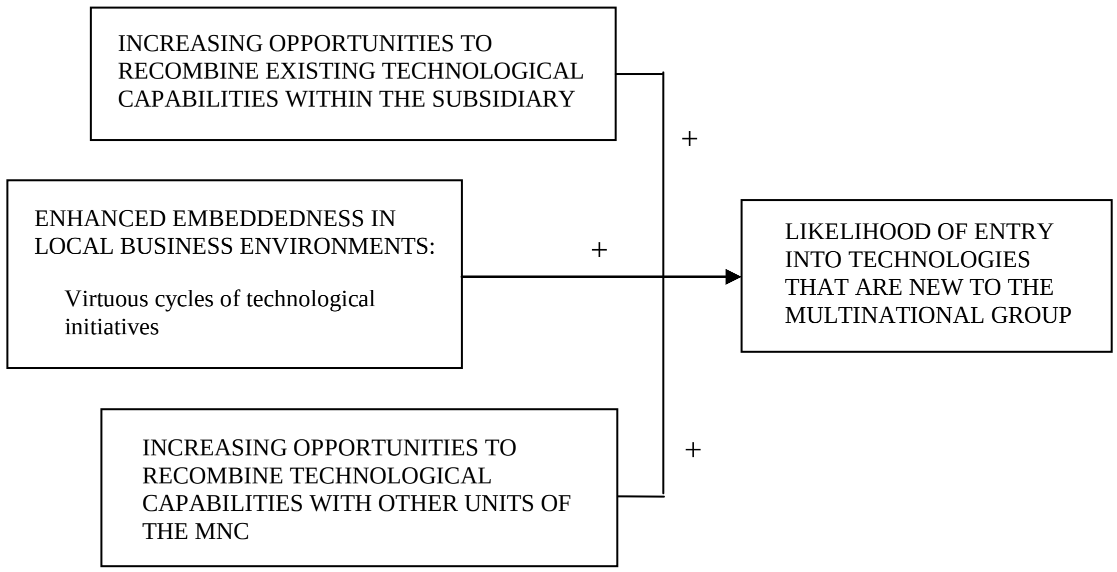
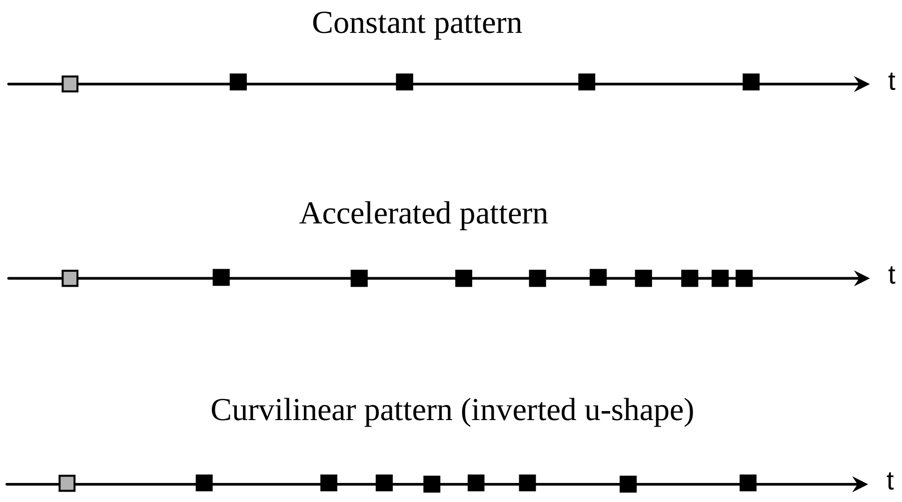


FIGURE 2

Three alternative patterns in the advanced subsidiary's entry into new technologies

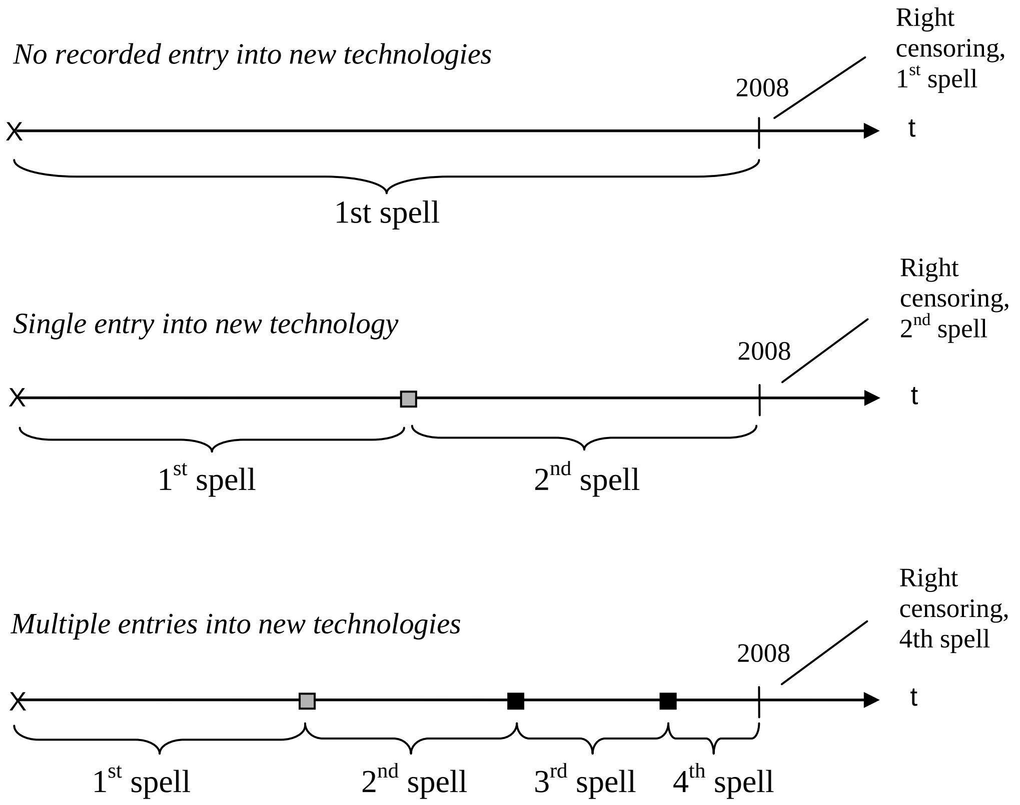


■ (grey) First entry into technology that is new to the entire multinational group.

■ Subsequent entries into technologies that are new to the entire multinational group.

FIGURE 3

Basic types of subsidiaries in the sample



X First recorded patenting by subsidiary.

First entry into technology that is new to the entire multinational group.

Subsequent entries into technologies that are new to the entire multinational group.

TABLE 1
Descriptive statistics, entries into new technologies by sample firm and subsidiaries

Firm	Number of advanced subsidiaries	Total number of entries into new technologies	Largest number of entries by any individual subsidiary	Average age of subsidiary (years, in 2008)[a]
AGA	7	6	4	37.5
Alfa Laval	13	47	41	46
ASEA	14	8	6	27.5
Astra	18	13	5	20
Atlas Copco	13	26	7	35
Electrolux	17	28	7	29.5
Ericsson	25	29	20	32.5
ESAB	3	5	5	11
Fagersta	1	1	1	18
MoDo	4	2	1	25
Perstorp	9	5	2	14
Pharmacia	13	4	2	15.5
PLM	3	2	2	14
Saab-Scania	2	1	1	23
Sandvik	20	35	19	26
SCA	10	15	4	20
SKF	13	53	25	47
Stora	2	0	0	27
Tetra Pak	10	8	5	11
Trelleborg	5	6	2	22.5
Volvo	9	10	4	21.5

[a] Age of the subsidiary is measured from the time of first recorded patenting activity, and in a strict sense measures age as a technologically advanced subsidiary. Last year of observation differs across firms.

TABLE 2
Descriptive statistics, events and spell lengths

Event no.	No. of events	Average spell length[a]	Minimum[b]	Maximum
1	211	18.06	0	99
2	86 [c]	13.51	1	76
3	42	6.81	1	38
4	29	6.24	1	48
5	21	4.81	1	22
6	16	8.06	1	42
7	11	5.64	1	20
8	8	5.00	1	15
9	6	1.50	1	3
10	5	3.60	1	14
11	4	1.25	1	2
12	4	1.25	1	2
13	4	2.50	1	5
14	4	1.00	1	1
15	4	1.00	1	1
16	4	1.00	1	1
17	4	1.00	1	1
18	4	1.75	1	4
19	4	1.25	1	2
20	3	2.67	1	5
21	3	3.00	1	7
22	2	1.50	1	2
23	2	8.00	1	15
24	2	1.00	1	1
25	2	2.50	1	4
26+[d]	16	4.19	1	24

[a] Average spell length (years) includes right censored observations.

[b] Minimum spell length for 1st spell is zero because in some cases the first patent by an individual subsidiary coincides with entry into a new technology.

[c] Three observed entries occurred in a new location in the last year of the period of observation.

[d] All event numbers higher than 25 pertaining to Alfa Laval.

TABLE 3

Spearman correlation matrix and simple statistics [a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Prior entries	1.00								
2. GDP	0.34	1.00							
3. Automotive industry	-0.08	-0.01	1.00						
4. Processing industry	0.03	0.10	-0.06	1.00					
5. Pharmaceuticals/chemicals	-0.05	0.01	-0.09	-0.12	1.00				
6. Modernity	0.07	0.20	0.04	0.10	0.05	1.00			
7. Technological diversity	0.29	0.15	-0.23	-0.10	-0.11	0.49	1.00		
8. Internal network	0.06	0.06	-0.18	-0.26	-0.12	0.53	0.75	1.00	
9. Cultural distance	0.17	0.62	-0.05	0.03	-0.03	0.02	0.05	0.01	1.00
Mean	1.35	12.76	0.04	0.06	0.17	0.70	3.62	9.69	1.15
Std. Dev.	4.38	1.50	0.20	0.24	0.37	0.46	2.65	5.20	0.75
VIF [b]	1.15	1.55	1.15	1.25	1.13	1.71	2.16	2.49	1.35

[a] Correlations greater than 0.03 significant at $p<.05$.

[b] Variance inflation factor scores derived from Model 2, Table 4.

TABLE 4

Gap-time Andersen-Gill partial likelihood models showing the effects of the number of prior entries and control variables on the hazard rate for entry into new technologies [a]

	Model 1		Model 2		Model 3	
Covariate	Estimate	Hazard ratio	Estimate	Hazard ratio	Estimate	Hazard ratio
GDP	0.44*** (0.05)	1.55	0.39*** (0.05)	1.47	0.33*** (0.05)	1.42
Automotive industry	-0.31 (0.33)	0.74	-0.19 (0.31)	0.83	-0.10 (0.30)	1.01
Processing industry	-0.60* (0.27)	0.55	-0.49* (0.24)	0.61	-0.35 (0.22)	0.76
Pharmaceuticals/ chemicals	-0.69*** (0.20)	0.50	-0.58** (0.19)	0.56	-0.48** (0.17)	0.63
Modernity	-0.19 (0.16)	0.83	-0.06 (0.17)	0.94	-0.09 (0.18)	0.70
Technological diversity	0.14*** (0.04)	1.15	0.14*** (0.03)	1.15	0.10*** (0.03)	1.12
Internal network	-0.07** (0.03)	0.93	-0.08** (0.03)	0.92	-0.07*** (0.02)	0.94
Cultural distance	-0.29* (0.14)	0.75	-0.25 (0.14)	0.78	-0.21 (0.14)	0.80
Prior entries			0.03*** (0.01)	1.03	0.15*** (0.02)	1.16
Prior entries^2					-0.00*** (0.00)	0.99
Diagnostics						
Annual obs.	5964		5964		5964	
No. of events	304		304		304	
LR test (d.f.) [b]	151.02*** (8)		170.14*** (9)		194.69*** (10)	

[a] Robust standard errors in parentheses. [b] The LR test statistic is a likelihood ratio test of the included covariates with d.f. being the degrees of freedom. Estimates considered significant at p<.05, p<.01 and p<.001 levels are indicated with *, ** and *** respectively (two-tailed).

NOTES

[1] The focus on greenfield subsidiaries is partially dictated by methodological considerations (see further the section on data and data collection). Whereas the documentation of patterns of entry into new technologies on the basis of patenting records is straightforward in the case of greenfield subsidiaries, it becomes complicated in the case of foreign acquisitions. Specifically, when the MNC acquires an ongoing operation it acquires a stock of existing technological capabilities and technologies (suggesting a sometimes very high number of added new technologies in the year of acquisition), but some of this stock may go undetected because the acquired unit may not have been awarded any patent(s) in the particular year of acquisition. This biases observable patterns in the timing of entry into new technologies, where the expectation is a high number of new entries in the year of acquisition but uncertainty as to whether registered entries into "new" technologies in the following years indeed represent new additions to the corporate portfolio. Mixing greenfield and acquired units in the same type of empirical analysis would therefore confound two different evolutionary paths.

[2] The extant literature offers different interpretations of cycles of subsidiary initiatives, but the effects on technological activities of subsidiaries and predictions about the timing of entry into new technologies are similar. Delaney (1998) and Birkinshaw (1999) suggest that subsidiary initiatives initiate a process of integration within the multinational group, and that well-developed relationships between subsidiaries and headquarters in turn promote further technological advancements and initiatives at the subsidiary level. In contrast, Andersson and Forsgren (1996), Forsgren, Johanson and Sharma (2000), Asakawa (2001), and Forsgren (2008, chapter 6) suggest that higher degrees of local embeddedness lower the possibility to execute corporate control and lead to higher degrees of subsidiary autonomy. Nevertheless, such autonomy has been associated with product mandates and centers of excellence (Forsgren & Pedersen, 2000; Ensign, Birkinshaw & Frost, 2000) and enhanced levels of technological activity and exploration of new fields of technology (Yamin, 2002).

[3] A large number of additional variables can be expected to influence the subsidiary's likelihood of entering new technologies, for example subsidiary manager profiles, overall approaches to organizing and managing the MNC, levels of research and development expenditure, or the intensity of competition. Yet, many of these factors do not translate into persistent effects and cumulative processes (subsidiary managers frequently change, as do overall approaches to organizing and managing the MNC and levels of competition). And while these factors may have an influence on general innovation activity, they do not necessarily promote movements into technologies that are new to entire multinational group.

[4] Birkinshaw and Hood (1998a) suggest that subsidiary initiatives work as a driver behind subsidiary evolution, but add that a weakening relationship between headquarters and the subsidiary can be the source of a loss of charter and capability atrophy. Their approach does not address to what extent charter losses would be expected generally across subsidiaries. Zander and Zander (1996) provide case-based evidence of what appears to be the purposeful shifting of technological mandates from powerful subsidiaries to headquarters within the multinational group. Yet, as in the case of over-embeddedness, evidence of headquarter intervention at a certain point in the foreign subsidiary's development is still to be systematically documented.

[5] The literature on the path dependency of technological development would suggest that advanced foreign subsidiaries may enter certain technological trajectories, typically reflective of idiosyncratic local business environments, which are then adhered to over an extended period of time. At a certain point, the established trajectory may then enter phases of maturity and decline, suggesting that ultimately the time intervals between entries into new technologies will stabilize or lengthen. However, the general length of technological cycles at the subsidiary level will depend on the type of underlying core technology and its

technological potential. The fact that subsidiary units for a number of reasons may exit certain technologies, for example because of strategic re-orientations, also makes it difficult to estimate when the ultimate limits to increasing involvement in new technologies will be reached.

[6] To somewhat precede the empirical investigation, the average age of foreign subsidiaries in the present sample ranges from 11 to 47 years (with a median of 23 years). This refers to the age of the subsidiary as an advanced foreign subsidiary, the count starting from when it has proven its capacity to make significant technological contributions to the multinational group.

[7] A small proportion of all patents in the current dataset would be represented by several inventors of different nationalities. In those cases, the geographical location of technological invention was recorded as that of the first inventor.

[8] The U.S. Patent Office classification is primarily based on the nature and function of the inventions, not their primary adopters. The manual states that arts or instruments having like functions, producing like products, or achieving like effects, are classified together. The functions or effects that are chosen as a basis of classification must be proximate or essential, not remote or accidental (Manual of Classification, Revision No. 1, June 1993, U.S. Department of Commerce, Patent and Trademark Office).

[9] With the progress of cultural distance measures, other indexes than Hofstede's have been developed and used, for example the Schwartz (1994) index, which has been found to at least partly overlap Hofstede's index (Drogendijk & Slangen, 2006) or the approach of clustering countries based on attitudinal dimensions (Ronen & Shenkar, 1985). Although we did not test the Schwartz index, we did test a Euclidian distance index based on Hofstede (2001) (see e.g. Brouthers & Brouthers, 2001; Vermeulen & Barkema, 2001) and the binary approach of clustering foreign subsidiaries and found it to have no significant impact on the observed results.

[10] The renewal or gap time specification was preferred over the counting process specification because of our interest in the number of prior entries as the main covariate and the structure of the data. When prior events or entries are included in the statistical model, the counting process specification tends to associate long spells with high numbers of prior entries, resulting in negative parameter estimates and low hazard ratios for the covariate measuring prior entries, even in cases of strictly accelerated entry processes. Yet, and as is the case in the present data, this effect may be outweighed by a large number of observations with long spells and either one late entry or a right censored observation. As the renewal or gap time specification measures spell length as time from the last recorded event (or, for the first event, time from the subsidiary's establishment as an advanced subsidiary), it generates more direct and unambiguous results concerning the hypothesized accelerated entry patterns. For an extended discussion on the different specifications of the AG model, see Kelly & Lim (1999) and Ezell et al. (2003).

[11] Ezell et al. (2003: 138) suggest that "the AG model is the preferred model when the substantive interest surrounds the overall rate of recurrence through the effect of common parameter estimates, especially when few subjects experience two or more events and when there is a substantive interest in knowing whether the hazard rate is increasing/decreasing with the unfolding of the event process".

[12] The control options available for repeated events analyses are not applicable in the present study because of the relatively large proportion of subsidiaries that experienced no or only a single entry into new technologies. Specifically, the FEPL method suggested by Allison (1995) requires that most observations have a least two events. It discards those observations with no events (i.e. those with only a single censored spell), and also those with one uncensored spell and one censored spell, if the censored spell is shorter than the uncensored spell. Moreover, Allison (1996) provided partial evidence that the FEPL method may not

perform very well in predicting the effects of certain covariates. In particular, covariates such as the number of prior entries tended to be biased downwards with regard to their true hazard rates.

[13] The only exception to modest correlations is that between the internal network and technological diversity measures. For natural reasons, these two are bound to evolve together over time. In the analyses we ran the models omitting one variable at a time, with no significant effects on the results and conclusions.

[14] We explored several different model specifications and also tested for the potential effect of outlier firms and subsidiaries in the sample. The results stayed robust when we checked for potential home country effects by introducing a U.S. dummy, as the data is based on U.S. patent filings. Further, we tested for shorter or longer periods of observation and also tried the exclusion of the four firms with subsidiaries that accounted for large numbers of entries into new technologies (Alfa Laval, Ericsson, Sandvik and SKF), with no substantial changes to the results. Results from using a counting process specification of the AG model showed identical results in terms of statistical significance, with similar hazard ratios.

[15] A sub-sample analysis which also included foreign acquisitions was conducted to rule out the possibility that advanced acquired subsidiaries display patterns of entry that differ substantially from those associated with the greenfield subsidiaries. As explained previously, and while involving some conceptual complications, this analysis had to be conducted at the level of foreign locations. A test covering the period 1893-1990 included both greenfield and acquired subsidiaries and used the same control variables as before (for the combined sample 40 acquired subsidiaries with confirmed U.S. patenting activity were identified). Space limitations preclude a full presentation of the results, but in the combined sample (and at the location level) increasing the number of prior entries by one increased the likelihood of entry into new technologies by 3 percent. The hazard rate for the number of prior entries had about the same confidence interval as that for greenfield subsidiaries only. This suggests that the current findings do not reflect severe selection bias, but a closer examination of potential differences between greenfield and acquired subsidiaries remains to be undertaken.