Research Policy 43 (2014) 669–682

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Superstar inventors—Towards a people-centric perspective on the geography of technological renewal in the multinational corporation

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ARTICLE INFO

Article history:
Received 15 May 2012
Received in revised form
11 November 2013
Accepted 6 December 2013
Available online 25 January 2014

Keywords:
Technological renewal
MNC
Subsidiary
Inventive activity
Inventors

ABSTRACT

This paper develops a people-centric perspective on the geographical dispersion of technological renewal in the multinational corporation (MNC). We contend that a large proportion of all foreign technological advancements can be attributed to a handful of individual inventors, suggesting a blockbuster effect of subsidiary technological development. This suggests that analyses carried out at the subsidiary or firm level disguise significant yet largely unexplored variation in the technological contributions made by individual members of these foreign units. To support this proposition, the paper draws upon an original data set that comprises all of the advanced foreign subsidiaries of 21 Swedish MNCs between 1893 and 2008, and follows their patenting activity in order to document the distribution of inventive activity, both across and within individual subsidiaries. The findings at the subsidiary level show that the distribution of technological activity and contribution to the overall multinational group is significantly skewed; the paper then empirically explores the assumption that a similar distribution also applies at the level of individual inventors. The results point to a pattern whereby most inventors make only occasional and limited technological contributions and, instead, more significant numbers of new technological discoveries are attributable to a select group of exceptionally inventive individuals. In the light of the results, we suggest the fruitfulness of applying a people-centric perspective on the sources of sustained competitive advantage of the MNC, the management of geographically dispersed capabilities in the multinational network, and the geographical sources of technological renewal in the MNC.

1. Introduction

In economic geography, international business, and international economics, firm strategies that involve international dispersion of specific activities of the value chain are crucial as they can determine both value added and value subtracted (e.g., Grossman and Rossi-Hansberg, 2008; Mudambi, 2008; Buckley, 2009). Historically, the disaggregation of the value chain has been perceived as being mostly applicable to activities with low knowledge intensity; in other words, it has been seen mainly as a production phenomenon (Kogut and Chang, 1991; Head et al., 1995). Over the years, however, the process has also come to involve more sophisticated activities such as research and development.

Since Ronstadt's (1978) pioneering work on the technological evolution of foreign units of the multinational corporation (MNC), research has emphasized the increasing importance of foreign units for the technological and strategic development of the firm. The trend has been one of increasing spatial distribution of foreign technological activity, alongside more elaborate and advanced systems for managing and integrating internationally dispersed research and development capabilities (e.g., Cantwell, 1989; Pearce, 1989; Dunning, 1994; Zander, 1998; Reger, 2002; UNCTAD, 2005). It has now become almost axiomatic that the network of geographically dispersed units is critically important for technological upgrading and sustained competitive advantage of the MNC. While geographic dispersion implies spatial separation, and therefore also an increase in spatially related transaction costs within a MNC (Singh, 2008; Beugelsdijk et al., 2010), the potential benefits of global technology sourcing create incentives to invest in the expansion and integration of geographically dispersed capabilities (Dicken and Malmberg, 2001).

Recent contributions to this stream of research have offered a refined and partially contradictory picture of how foreign

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http://dx.doi.org/10.1016/j.respol.2013.12.003

subsidiaries contribute to the technological and strategic development of the MNC. Phene and Almeida (2008) present evidence suggesting that, from the subsidiary's point of view, knowledge absorption from other units of the multinational network plays a comparatively limited role for the scale and quality of innovation. Blomkvist et al. (2010, 2012) find that, in terms of entry into new technologies, advanced greenfield subsidiaries usually make relatively modest contributions to the development of the entire firm. Instead, it appears that significant technological contributions can be attributed to a limited number of 'superstar subsidiaries', defined as units that, over extended periods of time, make exceptionally large contributions to the technological and strategic renewal of the multinational group.

These findings suggest significant heterogeneity at both the firm and subsidiary level, although such diversity has typically been downplayed in the literature on the sources of technological renewal of the MNC. Assumptions about heterogeneity resonate with the literature on star economics and the blockbuster effect (e.g., Rosen, 1981; Adler, 1985; Wallis, 2005; Sorensen, 2007; Hendricks and Sorensen, 2009; Brouthers et al., 2012), which suggests that it is not uncommon for exceptional individuals to dominate their particular field of activity and that stardom exists where transactions require knowledge. This would also imply that analyses carried out at the firm or subsidiary level disguise significant yet largely unexplored variation in the technological contributions made by individual inventors of these foreign units. Such a perspective finds support in a growing stream of research, which has started to question general levels of analysis and has instead emphasized the neglected role of micro-organizational levels and individuals in business research (Felin and Foss, 2005; Foss et al., 2010; Zander and Zander, 2010; Coff and Kryscynski, 2011; Tallman and Chacar, 2011).

The present paper pursues and empirically assesses the notion of heterogeneous foreign contributions to the technological development of the multinational group. Using a sample of 368 foreign subsidiaries in 21 Swedish MNCs, the paper shows that the distribution of technological activity and contributions across these subsidiaries is significantly skewed. We then empirically explore the assumption that a similar distribution applies also to inventive activity at the level of individual inventors. Detailed analysis of the patenting activity in a sample of exceptionally inventive foreign subsidiaries shows that the majority of the inventors in these subsidiaries only make occasional and limited technological contributions, and that more significant numbers of new technological discoveries can be attributed to a select group of highly productive inventors. In line with the blockbuster phenomena and observations from other contexts (Narin and Breitzman, 1995; Ernst et al., 2000; Zucker and Darby, 2001; Brouthers et al., 2012), this latter group of 'superstar inventors' appears to be the one that really drives foreign contributions to the technological development of the multinational group.

By investigating the questions where and by whom technologies of MNCs are developed the paper makes three distinct contributions to the literature. First, it documents the skewed distribution of technological capabilities within the multinational organization and presents original empirical evidence on the importance of exceptionally inventive superstar inventors for the MNC's technological development. Secondly, it answers the call for more extensive research on the micro-foundations of firm activities (e.g., Felin and Foss, 2005; Foss et al., 2010; Zander and Zander, 2010) in an organizational context that has traditionally favoured conceptual and empirical approaches at more aggregate levels. Finally, it responds to the call for empirical research that examines knowledge management within firms from a knowledge creation rather than knowledge exploitation point of view (McFayden and Canella, 2004; Mudambi et al., 2007). To the extent that the results apply generally to other highly inventive foreign subsidiaries of the MNC, they suggest that it is fruitful to examine the sources of competitive advantage, the managerial practices of the MNC, and the geographical sources of innovation at more disaggregated levels than have typically been used in prior research (Almeida et al., 2011; Tallman and Chacar, 2011).

2. Literature review

An extensive body of literature has documented the geographical dispersion of technological activity of the MNC. At the firm level, most studies have revealed increasing shares of foreign technological activity (e.g., Cantwell, 1989; Pearce, 1989; Dunning, 1994; Reger, 2002; UNCTAD, 2005); however, it has been noted that the pace of change should not be overestimated, particularly among firms originating in large economies such as the United States and Japan (Patel and Pavitt, 1991, 1995; Patel, 1995). Accordingly, the geographical boundaries for innovation activity have loosened and it is now generally believed that innovation can occur throughout the network of units that constitute the MNC.

Within firms, increasing shares of foreign technological activity are partly explained by evolutionary processes among foreign subsidiaries, which become more embedded over time in their local economic environments (Andersson et al., 2002; Ivarsson, 2002). Economists generally agree that knowledge is largely geographically bound (e.g., Jaffe et al., 1993; Audretsch and Feldman, 1996; Almeida and Kogut, 1999) and that geographical proximity influences the risk of localized spillovers (Branstetter, 2006; Gittelman, 2007). Therefore, over time, subsidiaries can gradually enhance their ability to detect and effectively respond to local economic opportunities, which in some cases leads to the granting of a world product mandate and formal recognition as a 'centre of excellence' within the multinational group (Chiesa, 1995; Holm and Pedersen, 2000). Among subsidiaries that reach this stage of development, virtuous cycles of technological and strategic initiatives (e.g., Birkinshaw and Hood, 1998), together with combinative capabilities that involve other units of the international network, may accelerate the capacity to make substantial technological contributions to the MNC's technological portfolio (Gerybadze and Reger, 1999; Pearce and Papanastassiou, 1999; Pearce, 1999; Cantwell and Piscitello, 2000).

While the strength and significance of these developments vary with the MNC's country of origin, they have shifted the overall momentum of technological and strategic initiatives towards foreign subsidiaries of the multinational network. Modern thoughts about MNC organization have emphasized how advanced foreign subsidiaries and peripheral locations should indeed play an increasingly important role for the MNC's strategic and technological development (Prahalad and Doz, 1987; White and Poynter, 1990; McCann, 2011), which implies associated changes in the role and functions attributable to headquarters units (Parkhe and Dhanaraj, 2003). In the more extreme interpretations, which include assumptions about radical innovation-orientation, extensive lateral knowledge flows, and flexibility in organizational tasks and governance mechanisms, foreign subsidiaries are indeed ascribed critical strategic roles (Hedlund, 1986). This view has largely resulted in a shift towards understanding the MNC as a particularly adept knowledge-seeking (Cantwell and Narula, 2001; Cantwell and Mudambi, 2005; Mudambi, 2008) and knowledge-disseminating organization (Kogut and Zander, 1993).

Changing perceptions of the management of foreign subsidiaries have been part and parcel of this development. Over time, hierarchical organizational designs with foreign operations that are strictly controlled from headquarters have given way to designs whereby foreign units are allowed and even encouraged to act more independently. Within a broadened set of types of foreign subsidiaries, a growing number of geographically dispersed subsidiaries are expected to contribute significantly to the technological renewal and upgrading of the entire multinational group (Kuemmerle, 1997; Pearce and Papanastassiou, 1999; Cantwell and Mudambi, 2005; Kappen, 2011). The modern approach to the management of foreign subsidiaries, which is summarized in the 'new paradigm' of multinational management (Doz and Prahalad, 1991), suggests forms of coordination and control that embrace egalitarianism as well as extensive lateral flows of knowledge across dispersed subsidiaries of the multinational network.

2.1. Towards a people-centric perspective on technological renewal

Recent contributions to these streams of literature have added detail to the strategic and technological roles of foreign subsidiaries, while partly questioning extreme interpretations of their overall contribution and importance for the development of the multinational group. Blomkvist et al.'s (2010) study of technologically advanced foreign subsidiaries shows that, over extended periods of time, most subsidiaries make modest contributions to the MNC's entry into new technologies and that major contributions can be attributed to a handful of units identified as 'superstar subsidiaries'. Similarly, they find mixed support for the notion that extensive combinative capabilities in the multinational network contribute to the technological performance of individual subsidiaries, an observation also made by Phene and Almeida (2008). In a follow-up investigation into the determinants of superstar subsidiaries, Blomkvist et al. (2012) present preliminary evidence that suggests exceptional contributions by a limited number of star scientists or superstar inventors. This points to a scenario that may apply more generally across inventive subsidiaries of the MNC.

The existence of exceptional individuals who dominate their field of activity is nothing new (e.g., Rosen, 1981), and it has been argued that stardom exists where transactions require knowledge (Adler, 1985). Exceptional individuals who dominate a certain field will have some knowledge about each other and are drawn together to collaborate and exchange views, with the idea of maximizing the outcome for both parties (Mullins, 1968). Specifically, it is argued that the generation of knowledge is skewed and dominated by a few key insights that challenge the way people think about an idea and thus generate high interest and use (Brouthers et al., 2012). The phenomena of extreme right skewness has been found in many contexts, such as the citation distribution of scholarly articles (Brouthers et al., 2012), ticket sales distribution of movies (Wallis, 2005) and sales revenue distributions of books and music; for example, in 1994 more than 70 percent of the total fiction sales in the U.S. were accounted for by only five authors (Sorensen, 2007).

As for inventors, it is known that among companies in general small groups of inventors are responsible for a major part of all significant technological advancements and performance (Narin and Breitzman, 1995; Ernst et al., 2000). Almeida et al. (2011) emphasize the importance of informal individual scientific collaborations for the emergence of firm-level innovations. They show that, at the individual level, collaboration among scientists seldom corresponds to, or is driven by, strategic alliances formed by the firm. Instead, skilled scientists seem to find each other and exchange knowledge through more informal mechanisms. It has also been argued that knowledge in evolving social networks is localized because of the labour market (Zucker et al., 1998a; Almeida and Kogut, 1999). The idea is that individuals spread knowledge as they switch employers; however, since they seldom relocate in space, the knowledge becomes spatially bounded (Breschi and Lissoni, 2009). Yet, previous research also shows that the geographic reach of inventors who participate in scientific communities has become enlarged and that their knowledge base extends beyond their home region (Singh, 2008). Cosmopolitan teams are nevertheless less likely to publish papers that are subsequently cited in patents, i.e., their role in technological development that results in innovations is less compared to more regional teams of scientists (Gittelman, 2007).

Overall, these observations indicate that, apart from being localized, the technological contributions of advanced foreign subsidiaries of the MNC may be unevenly distributed, and that skewed contributions may also extend to the level of individual inventors within these units. If this is found to be true, it would have important implications for understanding the sources of competitive advantage of the MNC, how to manage foreign R&D operations to ensure maximum technological contributions, and for understanding the geographical sources of technological renewal of the MNC. As a first step by which to assess the relevance of these possibilities, the present study starts by documenting the uneven technological contributions across foreign subsidiaries of the MNC. It then sets out to explore in more detail the potential existence of generally skewed distributions of inventive activity at the level of individual inventors.

3. Data and method

This study uses patents as an indicator of technological activity, specifically granted US patent applications, in order to determine the technological contributions made by individual inventors in foreign subsidiaries. In line with previous research, the count of granted patents was used to determine innovative output at the subsidiary and inventor level (e.g., Bottazzi and Peri, 2003). Despite the fact that patents only represent a partial, codified dimension of a firm's overall technological portfolio, they offer systematic insights into individuals and groups of inventors who participate in the inventive process and serve as a source of information about patterns of innovation (Cantwell, 2000). Patents make it possible to collect detailed information about the domicile and nationality of inventors, which means they are frequently used as an indicator of the regional and national geography of invention and technological capabilities (e.g., Cantwell, 1995; Jaffe, 1986; Archibugi and Pianta, 1992; Almeida and Phene, 2004; Feinberg and Gupta, 2004; Singh, 2007).

Patenting has been shown to correlate strongly with alternative measures of technological activity and innovative performance, such as research and development expenditure and new product introductions (Pavitt et al., 1987).[3] In a study comprising a large number of companies in four high-tech industries, Hagedoorn and Cloodt (2003, pp. 1375, 1365) found 'no major systematic disparity amongst R&D inputs, patent counts, patent citations and new product announcements', and concluded that 'future research might also consider using any of these indicators to measure the innovative performance of companies in high-tech industries'. In other words, while the degree of correspondence is not absolute, it can be assumed that patents systematically capture the introduction of new products and services that generate revenues for the inventing company.

The completion of a US patent application includes the name(s) and the location(s) (the city and country) of the individual

[3] The advantages and limitations of patent data have been discussed extensively in the literature (e.g. Pavitt, 1999; Griliches, 1990; Kleinknecht and Reinders, 2012). Some of the common critiques regarding the difficulties in determining patent value are less relevant in the present study due to the longitudinal nature of the data. All patents must meet the minimal standards of novelty, originality, and potential use, and studies covering long time periods are likely to average out most of the problems originating from variations in patent value (Bottazzi and Peri, 2003).

inventor(s) and the assignee (typically a firm). Assuming that the domicile of the inventor in the majority of cases coincides with the geographical location of the invention, it is possible to determine where the research and development underlying the invention was carried out. Thus, for every US patent registered under the name of any of the sample firms and their subsidiaries, it can be determine whether the patent *originated* in, for example, Germany, the United Kingdom, the United States, or any other country. This is an important advantage because company-specific patenting policies (such as involving the registration of patents under the name of the parent company rather than the inventing subsidiary) could otherwise conceal the true geographical distribution of technological activity and invention. Furthermore, it in many cases makes it possible to identify and control for collaborations across states and country borders between individual inventors.

Patenting activity and behaviour is closely connected to the rules of patenting offices. From a methodological point of view, therefore, it is preferable to compare patents that have been granted from the same legal authority and that have been through a common legal and administrative framework of review. The present study relies exclusively on the patenting activity of Swedish firms in the United States. One advantage of using US patenting data is that the large market in that country encourages the patenting of inventions that are believed to be of relatively high quality and commercial value. In so doing, it reduces the chance of accidental or insignificant inventions contaminating the results. United States patents also offer a historically consistent record of inventive activity, as all technology classes (and all earlier patents) are re-categorized whenever new classes are introduced.[4] It has been found that patenting by Swedish firms in the United States does not differ significantly from patenting profiles in other large markets such as Germany or France (Archibugi and Pianta, 1992). From that perspective, the empirical results are likely to present a generally representative picture of the sample firms' technological activity.

3.1. Overall sample

In order to assess the distribution of technological contributions across foreign subsidiaries of the MNC, we started by examining the complete US patenting records among all of the advanced foreign subsidiaries from a sample of the most R&D-intensive Swedish firms throughout the period between 1893 and 2008.[5] The search extracted 21 firms and identified 368 foreign subsidiaries with registered patenting activity for the examined period (for further details about the sample, see Appendix A). These are all advanced foreign units in the sense that they have proven their ability to make significant contributions to the state of the art in various fields of technology (a prerequisite for patentability). Most of them can also be expected to display a comparatively high complexity of activities and technological work of competence-creating subsidiaries (Cantwell and Mudambi, 2005, 2011). The age of an advanced subsidiary, as measured from its first recorded US patent, ranged from one year to 100 years, with an average age of 19 years and a median of 13 years.

The foreign subsidiaries included a total of 237 greenfield subsidiaries and 131 subsidiaries that were added to the multinational groups through acquisitions. The first step of the analyses was to identify the general distribution of technological contributions

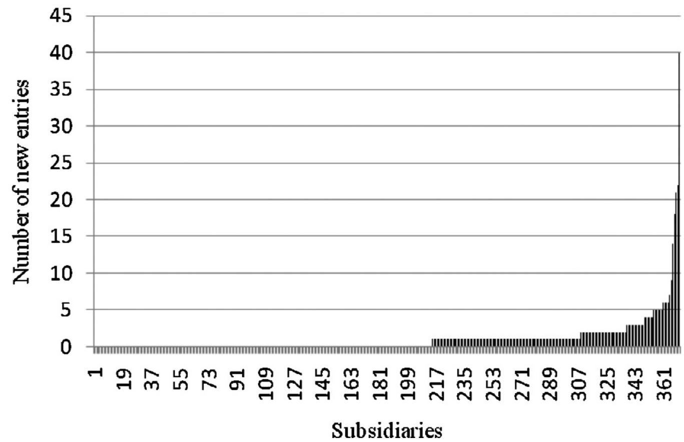

Fig. 1. Number of entries into classes of technology new to the entire multinational group – all subsidiaries.

across these units; this resulted in the identification of a smaller group of units that displayed exceptional inventive capabilities. The identification and selection of this narrower group of exceptionally inventive subsidiaries was followed by a detailed analysis of individual patents, with particular focus on identifying the inventors that had produced them.

3.2. Identification of exceptionally inventive foreign subsidiaries

To identify exceptionally inventive foreign subsidiaries, we used the classification of individual technologies applied by the US Patent Office to map out the extent to which individual foreign subsidiaries had produced entries into technologies that were new to the entire multinational group. At this level of aggregation, distinctions are made between, for example, metal working, powder metallurgical processes, chemistry carbon compounds, coating processes, and digital communication. In total, 158 of the examined subsidiaries had generated one or more entries into technologies that represented new additions to the MNC's technology portfolio; however, the distribution of absolute numbers of entry was found to be significantly skewed (Fig. 1).

The next step was to select exceptionally inventive subsidiaries for further analysis at the level of individual inventors. These subsidiaries included a number of units found at the extreme right of the distribution of Fig. 1 and, in a broad sense, correspond to the 'superstar subsidiaries' identified in prior work (Blomkvist et al., 2010). The extant literature does not offer a generally applicable methodology for identifying such exceptionally inventive subsidiaries (cf. Zucker and Darby, 2001; Almeida et al., 2011), although prior studies have indicated that the number of such subsidiaries is highly limited (Blomkvist et al., 2010). Any cut-off points should also take into account the fact that identified and selected subsidiaries should display the capacity to produce consistent and unusually large numbers of entries into technologies that are new to the multinational group.

The applied cut-off was that the selected subsidiaries should belong to the top 2.5 percent of all subsidiaries in terms of: (1) the absolute number of entries that represented significant new additions to the MNC's technological portfolio (according to the classes of technology defined by the US Patent Office), and (2) the number of such new entries on a yearly basis. Given that consistency in technological contribution is one of the characteristics of exceptionally inventive foreign subsidiaries, an additional selection criterion was that the units should have (3) been observable

[4] The European Patent Office (EPO) meets similar criteria as the US system with regard to historical updates. However, because the EPO did not start registering patents until the early 1980s, EPO patents are less suited to the analysis of historical trends and longitudinal patterns of inventive activity (Cantwell, 2006).

[5] Prior studies have shown that the sample firms account for a significant and representative number of inventions and R&D expenditure in Swedish industry (Wallmark and McQueen, 1986; Håkanson and Nobel, 1993).

as technologically advanced units over a minimum of ten years.[6] Applying these selection criteria, six exceptionally inventive subsidiaries were identified and selected for further and more detailed analysis.[7] These were the US subsidiary of dairy equipment producer Alfa Laval (a greenfield subsidiary), the US subsidiary of white goods manufacturer Electrolux (acquired), the US subsidiary of telecommunications equipment manufacturer Ericsson (greenfield), the German subsidiary of ball-bearing manufacturer SKF (greenfield), and the US and German subsidiaries of specialty metals producer Sandvik (greenfields).

3.3. Identification of inventive activity within selected subsidiaries

The identification of inventive activity within the selected subsidiaries covered the period from when they started as technologically advanced units until 2008 (in one of the cases, Alfa Laval's US subsidiary, the first available data at the individual level was from 1920 and merger activity truncated all observations in 1993). Patenting activity at the level of individual inventors was identified by searching the Thomson Innovation database for patents associated with a variety of names connected to the sample firms and subsidiaries. This search generated lists comprising more than 13,500 patents, which were subsequently separated from those patents that were found to be unrelated to the sample firms.

A total of 4174 patents remained for further analysis, ranging from 106 in the case of Sandvik's German subsidiary to 2528 in Ericsson's US subsidiary. Each patent was analyzed with regard to its inventors,[8] which ranged from one to 11 per patent. The order of inventors as they appeared on the patent was registered and co-inventors from locations other than those associated with the selected subsidiaries were recorded. In addition, each patent was compared to the complete patent portfolio of the MNC in order to distinguish which patents represented entries into classes of technology that were new to the entire multinational group (these entries into new technologies were the same as those used to derive the group of exceptionally inventive subsidiaries). This eventually enabled a formalized test that aimed to distinguish the role of individual inventors for the more significant broadening of the MNC's technological portfolio.

4. Results

As Fig. 1 shows, the contribution of foreign subsidiaries to the technological renewal of the MNC is significantly skewed. A large number of technologically advanced foreign subsidiaries with proven capacity to patent in the United States have never entered into technologies that are new to the entire multinational group. In contrast, the sample of exceptionally inventive foreign subsidiaries accounted for between nine (Sandvik, German subsidiary) and 40 (Alfa Laval, US subsidiary) new entries. Whatever the specification of cut-off points for the examination of the subsidiaries, for example, a reduction in the proportion of exceptionally inventive subsidiaries to only one or two percent of all units, the empirics suggest robust patterns and that modifications such as these would not significantly affect the overall findings.[9] However, one must consider the fact that four of the selected subsidiaries are located in the United States, which implies a particularly high propensity to patent in what would be their home market. This may have introduced a comparatively high proportion of less important patents and could also have biased the detection of new additions to the MNC's technology portfolio. Put somewhat differently, this may have resulted in the omission of otherwise highly inventive units in other geographical locations and units that, on account of different foci of sales efforts, may have patented only or mostly in geographical areas outside of the United States. Nevertheless, detailed information (through annual reports and company documents) about the historical development of two of the sample firms, SKF and Alfa Laval, supports the assumption that the selection procedure has indeed identified the most technologically active and important units (cf. Blomkvist et al., 2012).

Despite the variation in distribution of inventive activity across individual inventors of the sample subsidiaries, analysis at this level reveals that, in a similar way, the majority of all new technological contributions are attributable to a select number of highly productive inventors (Fig. 2). Skewed distributions are particularly pronounced in three subsidiaries: Alfa Laval's US subsidiary, Sandvik's German subsidiary, and SKF's German subsidiary. Out of 109 inventors at Alfa Laval's US subsidiary, the two most productive individuals were involved in 14 and 22 percent of all patents, respectively. The top three inventors in Sandvik's German subsidiary were involved in between 11 and 18 percent of all patents (out of a total of 76 inventors). Of the 300 inventors at SKF's German subsidiary, the top three were involved in between 20 and 32 percent of all patents.[10]

4.1. Distribution of inventive activity in other subsidiaries

While comparisons between exceptionally inventive and less productive foreign subsidiaries are not the main focus of this paper, we did also conduct a preliminary test of differences between these two groups in terms of the distribution of inventive activity across individual inventors. In order to make the comparison, six additional subsidiaries belonging to the original parent corporations were randomly sampled, as long as they were not among the original top 2.5 percent in terms of entry into new technologies and that had been operational as advanced units for at least 10 years. The resulting group of identified subsidiaries included Alfa Laval's German subsidiary (greenfield establishment, excluding the acquisition Bergedorfer Eisenwerk),

[6] This reduces the probability that units registered for new entries early on, which then prove only moderately productive, are inadvertently considered exceptionally inventive. For example, if a particular foreign subsidiary was observed for only one year, and during that year was registered for entry into one new technology, its long-term development may reveal that it was mistakenly considered more inventive than a unit producing 15 new entries over a 20-year period.

[7] Examining the top 2.5 percent foreign subsidiaries in terms of absolute numbers of entries into new technologies produced a list of nine units. In six out of nine cases, the corresponding ranking of subsidiaries in terms of entries per time period (year), limited to subsidiaries with a track record as an advanced unit over a period of 10 years or more, produced a list of units that overlapped with the first. These six cases were selected for further analysis at the level of individual inventors.

[8] In the consolidation process, inventor names were manually searched for any variations in spelling and were subsequently unified in order to avoid blurring the individuals' contributions.

[9] The resulting sample proved insensitive to extending the required period of observation from 10 to 15 years (retaining the other selection criteria), as the procedure of identifying the overlap between top subsidiaries, both in terms of absolute numbers of entries and entries per time period, generated the same six subsidiaries. When the required period of observation was reduced to five instead of 10 years, a number of recently acquired subsidiaries appeared on the ranking of subsidiaries according to entries per time period, which reduced the overlap to only two subsidiaries. As for most acquired subsidiaries, the first years of incorporation into the acquiring MNC would come with a 'honeymoon effect', as the addition of idiosyncratic technology portfolios tended to produce an unusually high number of new entries in the immediate post-acquisition period. As the long-term contributions of these acquired subsidiaries were uncertain, a period of observation longer than five years seemed preferable.

[10] The entire patent count assigns equal weight to patents obtained individually or as member of a group (Narin and Breitzman, 1995). In terms of the order of inventors as listed on the patents, the eight inventors appeared as first inventor on between 17 and 98 percent of their patents (average 66 percent).

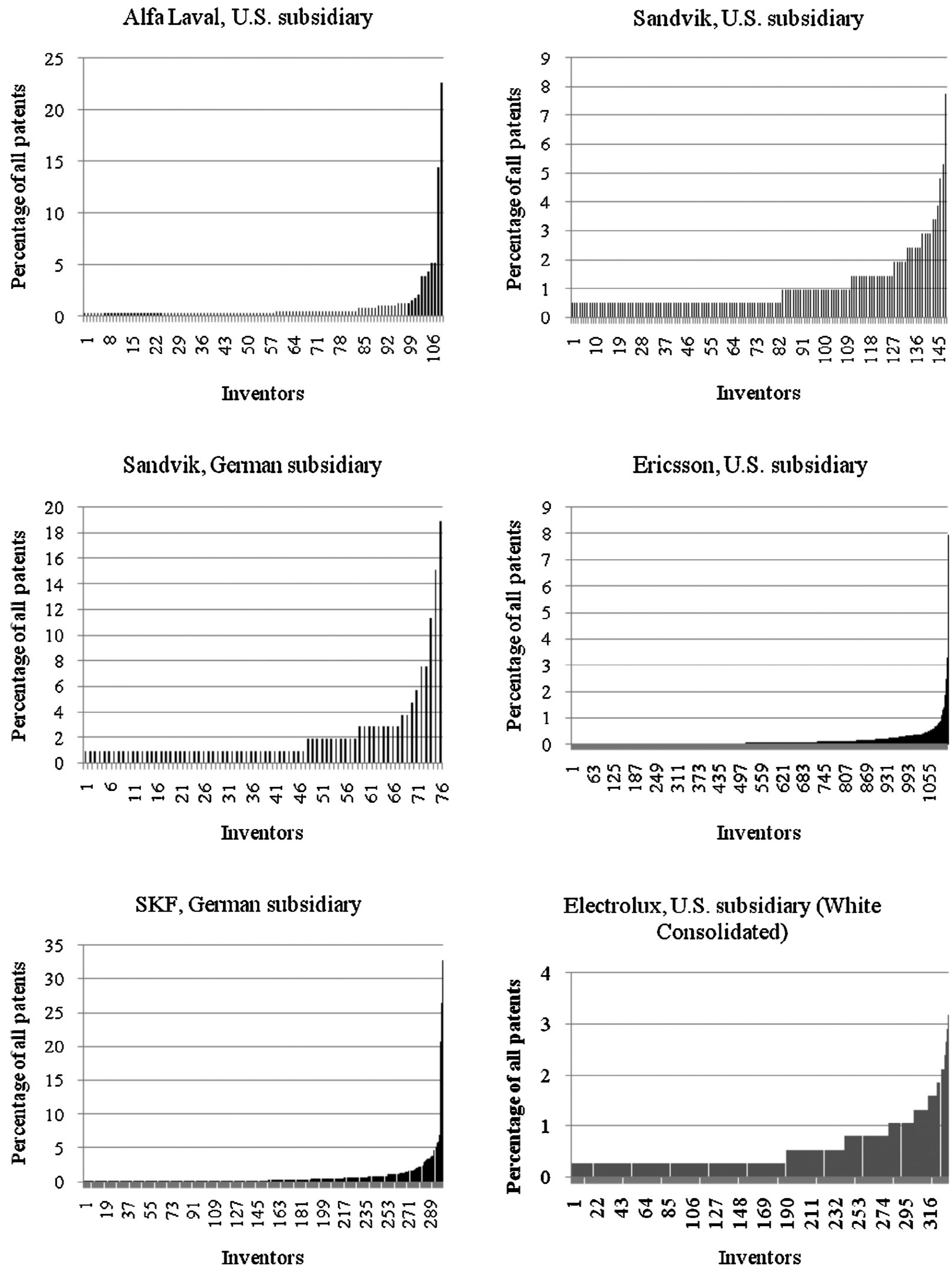

Fig. 2. Percentage of all patents represented by individual inventors. *Note*: cumulative percentages may exceed 100 percent, as patents may be represented by multiple inventors.

Electrolux's UK subsidiary (greenfield), Ericsson's Norwegian subsidiary (greenfield), Ericsson's acquisition of Raynet in the United States, Sandvik's acquisition of Osprey Metals in the United Kingdom, and SKF's acquisition RKS in France. Once sampled, the group went through the same analysis as before in terms of extracting patents and corresponding inventors.

While the number of patents was generally lower than among the exceptionally inventive subsidiaries (which in some cases also means that observed distributions of inventive activity are sensitive to relatively small variations in patenting activity across subsidiary inventors), the results indicate that the general pattern of skewed distributions and contributions at the level of individual inventors is repeated among the less productive subsidiaries (Fig. 3). This would suggest that a large proportion of the inventive activity at the subsidiary level is explained by the undertakings of a limited group of highly productive individuals, regardless of whether foreign units are in the high- or low-performing category.

4.2. *Superstar inventors and the geography of invention*

While a select group of exceptionally productive inventors accounts for a significant proportion of all patents in each of the subsidiaries, this does not necessarily say anything about the extent to which superstar inventors are also able to contribute to the more significant broadening of their MNCs' technology portfolios or the quality of invention in a more general sense. Exceptionally

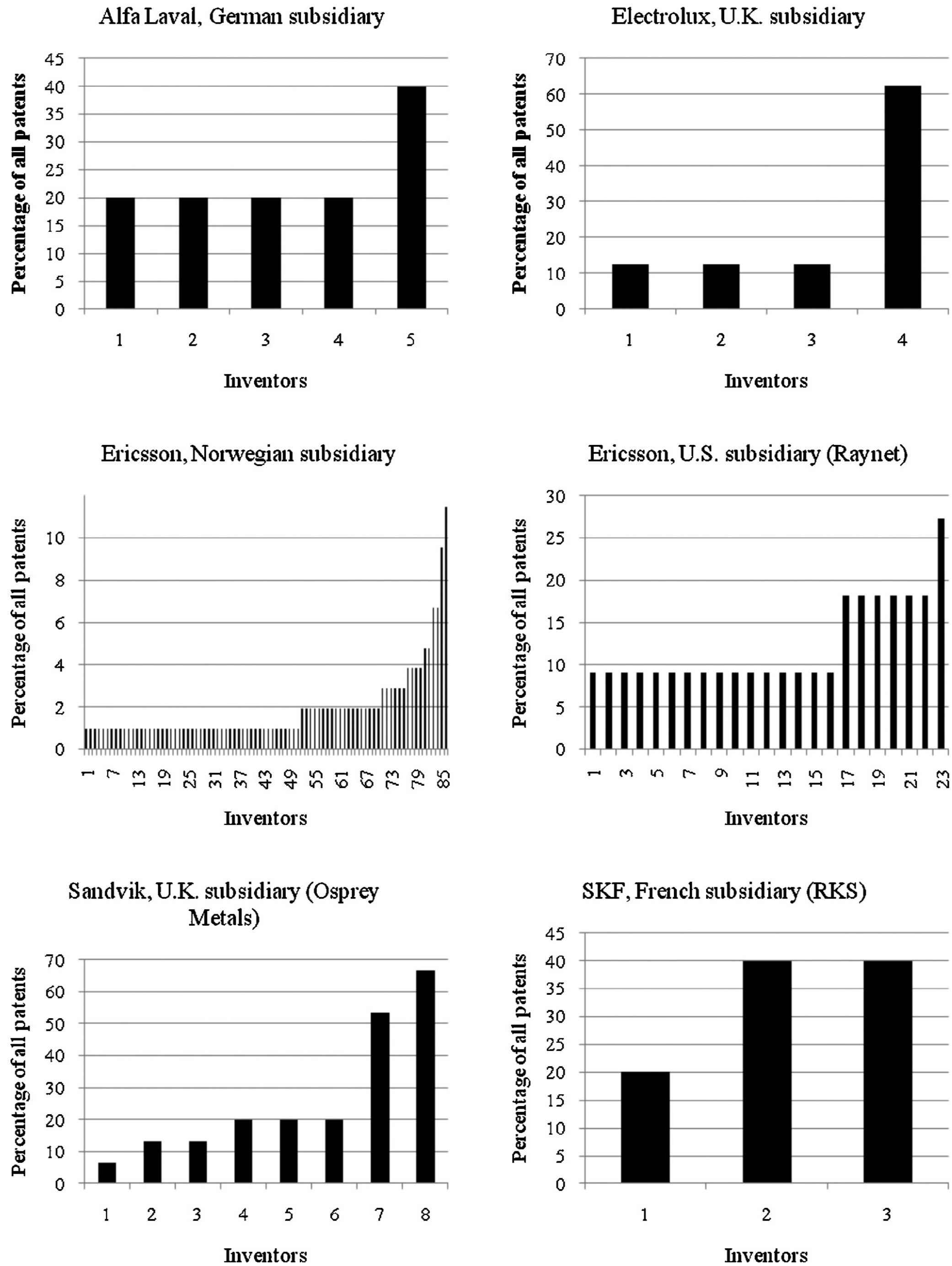

Fig. 3. Percentage of all patents represented by individual inventors, control group sample of subsidiaries.

productive inventors may well focus on incremental advancements within established technological fields, perhaps as the result of being over-embedded in specific collaborative teams, while more radical departures from the established technology portfolio of the MNC depend upon peripheral inventors making occasional but ground-breaking technological contributions (Regnér, 2003).

In order to explore this possibility, we devised a logistic regression to test whether the identified superstar inventors were over- or under-represented in those instances where individual patents also meant entry into classes of technology that were new to the respective multinational groups. In line with other studies that have attributed 'star' status to groups of individuals that represent between 0.65 and 1.78 percent of the total number of researchers or scientists (Zucker et al., 1998b; Rothaermel and Hess, 2007; Almeida et al., 2011), the present empirical investigation assigned markers of superstar status to the top 1 percent of all inventors in the respective subsidiaries.

For exploratory purposes, we also added variables that captured the extent to which patents were represented by single inventors or smaller or larger groups of inventors, the extent to which groups of inventors included inventors residing in different regional locations, and the extent to which the domicile of inventors signalled underlying collaboration across national boundaries (Singh, 2008). This set of variables captured the extent to which diversity in

Table 1
Estimates of the probability of entering into classes of technology new to the entire multinational group.

Estimating the probability of entering a new technological field
Regressand:
Binary variable:
New technological class = 1
Other technological class = 0

Regressor	Est	S.E	Est	S.E	Est	S.E
Number of inventors	−0.071	0.108	−0.024	0.12	−0.351	0.213
Superstar inventor	0.076	0.278	0.030	0.340	−0.128	0.517
Location context (GDP)	−0.262	0.425	−0.303	0.488	−2.013	1.365
International collaboration			−0.969	0.613		
Regional collaboration					−0.147	0.549
Firm dummies	Y		Y		Y	
−2 log likelihood	790.100		628.810		417.201	
Nagelkerke R^2	0.098		0.097		0.104	
N	4146		3793		3122	

Notes:
* Significant at 5% level.
Variable clarification: The regress and was measured as 1 if the patent was granted in a class previously not patented in by any unit of the MNC. The number of inventors is measured as the absolute number of involved inventors for each patent. Superstar inventor was coded 1 if a top 1% inventor was involved in the patent, otherwise 0. If the patent included international (regional) collaboration, this variable was coded 1, otherwise 0. GDP is measured as the log of total GDP (billion 1990 Geary-Khamis dollars).

Table 2
Estimates of year-normalized patent citations.

Estimating patent value
Dependent Variable:
Year-normalized patent citations

Regressor	Est	S.E	Est	S.E	Est	S.E
Number of inventors	0.148	0.128	0.192	0.136	0.300	0.195
Superstar inventor	0.351	0.373	0.386	0.381	0.453	0.430
Location context (GDP)	1.928	1.124	1.501	1.197	3.347	1.769
International collaboration			−0.700	0.646		
Regional collaboration					−0.298	0.605
Firm dummies	Y		Y		Y	
F-value	13.120		10.974		7.659	
R^2	0.178		0.172		0.136	
N	393		385		339	

Notes:
* Significant at 5% level.
Variable clarification: The dependent variable was measured as the year-normalized value of patent citations. The number of inventors is measured as the absolute number of involved inventors for each patent. Superstar inventor was coded 1 if a top 1% inventor was involved in the patent, otherwise 0. If the patent included international (regional) collaboration, this variable was coded 1, otherwise 0. GDP is measured as the log of total GDP (billion 1990 Geary-Khamis dollars).

personal and professional backgrounds may result in more creative technological solutions, thereby accounting for both specific locational and relational features (Beugelsdijk, 2007; Beugelsdijk et al., 2010). We also controlled for both firm and location contexts. A set of firm dummies was included to account for the fact that levels of entry into new technologies vary across the sampled firms. Last, the gross national product of the respective host economies at the time of invention was added to control for the location context, as larger economies may offer greater variation in terms of the scope of localized knowledge flows and new business opportunities.[11]

Logistic regressions with entry into new technologies as the dependent variable revealed no significant influences beyond the firm dummies (Table 1). This suggests that superstar inventors are neither over-represented nor under-represented in those cases where new patents also mean more significant departures from the MNC's established technology portfolio. In other words, superstar inventors are as important for more significant technological renewal of the MNC as they are for contributions within established fields of technology. The absence of significant effects for either cross-regional or cross-national collaborations suggests that the geographical heterogeneity of the inventors did not affect the scope of inventive activity (Phene and Almeida, 2008).

As a complement to exploring the likelihood of entering into new technologies, we also ran a linear regression to investigate qualitative differences in the patents of the identified superstar inventors (Singh, 2008). In this approach, the number of citations received by individual patents was taken as an indicator of the patents' commercial and scientific value (Trajtenberg, 1990; Albert et al., 1991; Harhoff et al., 1999). For the analysis, we created a sub-sample based on proportional random sampling of 400 patents produced by the company units presented in Fig. 2. Given the proportion of patents attributed to superstar versus non-superstar inventors, we extracted 101 patents by superstars and 299 for the control group. The linear regression using year-normalized, ex post

[11] Notably, in the present study all of the identified superstar subsidiaries are located in Germany or the United States, which implies limited degrees of variation in the location context. As an alternative measure of location context we also applied a country dummy, with no significant changes to the results.

Table 3
Extent of cross-regional and cross-country collaborations among inventors.

	Full sample	Superstar sample	Restricted sample[a]
Cross-national collaboration	0.089	0.16	0.064
Cross-regional collaboration	0.138	0.23	0.111

Values expressed in percentages of all patents.
[a] Full sample excluding superstar inventors.

citation counts as the dependent variable revealed no significant influences beyond the firm dummies (Table 2).[12,13] Thus, similar to the test of entry into new technologies, analyses of patent values as measured by citations suggest that superstar inventors are neither over- nor under-represented in terms of producing high-quality inventions. As in the case of entry into new technologies, the observed tendency is that superstars, if anything, generate a higher proportion of high-quality inventions, but in the current sample that effect is not found to be statistically significant (the estimate for superstar status narrowly fails significance at the 10 percent level).

Further examinations of the superstar inventors revealed interesting information about the sources of knowledge for invention. It is well known that the contribution of individual inventors varies depending upon their affiliation with epistemic communities and geographic proximity (Gittelman, 2007). Patenting groups that included a superstar inventor tended to be slightly larger (mean value 2.60) than groups without one (mean value 1.77). Table 3 shows that patents and technological discoveries that involve a superstar inventor are twice as likely to draw upon collaborations that include inventors from other regions or nationalities (significant z scores, $p < 0.05$). Apparently, however, this does not seem to have an effect on the likelihood of producing more radical departures from the respective MNCs' established technology portfolios.

5. Discussion

The observed skewed patterns of inventive activity among individual inventors of foreign subsidiaries of the MNC may appear intuitively obvious, but they have largely gone unnoticed in the extant literature. The simple observation of significantly skewed technological contributions, which mirrors what has been found in other contexts (Narin and Breitzman, 1995; Ernst et al., 2000; Almeida et al., 2011), opens up a new people-centric perspective in several areas of research, including the sources of sustained competitive advantage of the MNC, the management of geographically dispersed capabilities of the multinational network, and the geographical sources of technological renewal.

5.1. Implications for sustained competitive advantage of the MNC

The role and importance of technological advantages of the MNC has long been recognized in the literature, for example in the context of foreign expansion or potential advantages from internationally dispersed research and development (Hedlund, 1986). Despite this, most discussions and analyses have remained at the organizational level. In the extant literature, it is the MNC that possesses and develops a technological advantage and its further development depends on its ability to manage and leverage geographically dispersed networks of foreign subsidiaries. Similarly, analyses of firm performance and advantages from multinationality have traditionally remained at aggregate levels. Drivers of firm performance have been sought at the firm, industry, and country levels (e.g., Brouthers, 1998; Christmann et al., 1999; McGahan and Victer, 2010), with additional reference to the firm's ability to draw advantages from geographical scope and internationally integrated organizational structures (Doz, 1986; Goerzen and Beamish, 2003).

In contrast to these macro approaches to the competitive advantage of the MNC, the empirical observations presented here emphasize how an important part of the sources of sustained competitive advantage of the MNC are found at the micro level (Crane, 1972; Saxenian, 1991; Almeida and Kogut, 1999; Almeida et al., 2011; Tallman and Chacar, 2011). The data shows monotonically decreasing numbers of progressively more inventive individuals, which suggests that, like the firm size distribution (Axtell, 2001), a power law distribution is at hand. The resemblance in distributions across the examined subsidiaries suggests a common pattern of inventor activity within already exceptionally inventive units, and that distinctive nodes of activity at the micro level explain a significant proportion of all foreign technological renewal of the firm.

Individual inventors who can make significant contributions to the corporation's technological renewal are distinct micro-level assets that are valuable, rare, non-imitable, and largely non-substitutable (Barney, 1986; Peteraf, 1993). They also represent the dynamic capabilities that allow the firm to renew itself and sustain its superior performance over extended periods of time (Teece et al., 1991; Eisenhardt and Martin, 2000; Lacetera et al., 2004). Of course, there are many sources of competitive advantage and the capabilities of these individual inventors depend upon and interact with resources, processes, and routines at other organizational levels (Bell and Zaheer, 2007; Rothaermel and Hess, 2007; Hess and Rothaermel, 2011; Salvato and Rerup, 2011). Yet, in the context of the firm and its innovation performance, the findings of the present study suggest the conceptual and managerial fruitfulness of revaluing and re-examining a source of competitive advantage and dynamism that the extant literature has tended to downplay. Hence, there are good reasons to believe that a people-centric perspective should be emphasized and carry substantial weight in further research on MNC competitive advantage.

5.2. Implications for management of the MNC

The literature on MNC management has largely focused on coordination and control issues and headquarter–subsidiary relationships (Martinez and Jarillo, 1989). In terms of technological and strategic renewal, contributions have typically emphasized overall organizational designs and mechanisms for coordinating and controlling the activities of internationally dispersed company units (e.g., Hedlund, 1986; Meyer et al., 2011; Ebersberger and Herstad, 2012). To the extent that individuals at the subsidiary level are identified, they are typically seen as subsidiary heads or foreign subsidiary managers.

While these approaches capture an important facet at the organizational level of the geographically dispersed MNC, and a range of

[12] In order to reduce the risk that older patents are bound to have more citations than otherwise similar younger patents (Hall et al., 2001), we normalize the number of forward citations by the patent's age (granted year) to separate the effects of age and number of citations (cf. Marco, 2007).
[13] In this model specification, the application of firm dummies responds to the observation that different fields of technology have different patent citation patterns (Albert et al., 1991).

lateral flows of knowledge across units of the multinational corporation are important for both explorative and exploitative purposes, the identification of select numbers of highly productive inventors within individual foreign subsidiaries introduces managerial considerations that have remained largely unexplored. In contrast to the tacit and often inscrutable routines of the MNC, superstar inventors tend to be well-known among company employees and are easily identified by means of their inventive output (Ernst et al., 2000). It is relatively simple – on paper, at least – to create conditions and devise incentive systems to sustain these superstar inventors' inventive efforts and to retain them within the corporation (Fleming and Marx, 2006). One particular but often forgotten consideration is how overall organizational changes and adjustments, typically in response to efficiency and exploitative pressures, affect what happens to motivation and explorative activities at the lower levels of the organization. From a managerial point of view, it would further appear important to consider ways to attract new talent and smoothen the transitional periods when highly productive inventors end their careers and new generations take over.

A lot can be learned from other contexts and fields of research about the management of talent, and MNCs have most likely developed and experimented with successful and unsuccessful approaches in the past. In international business research, however, traditional macro approaches have prevented the penetration of such micro-level issues. Considering the observations of the present study, there may be good reasons to reverse this trend more forcefully in the future. With regard to the technological contributions made by exceptionally inventive individuals, the question would be how to 'make the most' of far-flung and diverse activities (Martinez and Jarillo, 1989) rather than to design coordination and control systems that avoid disorganization (cf. Boddewyn et al., 2004). In that undertaking, only part of the managerial responsibility would rest at the corporate level, whereas much of the practical work requires a shift towards the local insights and 'touch' of subsidiary heads and managers.

The findings of this paper thus emphasize the strategic importance of identifying, acquiring, keeping, and managing star inventors (Ernst et al., 2000; Coff and Kryscynski, 2011). It is not to be seen as a "quick fix", especially in terms of attracting star talent (cf. Groysberg et al., 2004, 2008), but when the inventive work of star researchers and scientists functions retaining them within the corporation should be high on management's list of priorities. A variation on this theme concerns asset-seeking foreign investments, where it would be crucial to understand not only the targeted business environment and technological portfolios of acquisition targets, but also to know about the star inventors within and behind them. Studies on motivation at the individual and organizational levels show that self-determination and teamwork are positively associated with innovation output (Mudambi et al., 2007). They also show that scientists "pay to be inventors", and that for individual scientists the work environment is more important that the pay-check (Stern, 2004). In view of this, unreflective measures to maximize short-term gains and re-structure innovation efforts in the expanding multinational network may quickly erode the inventive capacity and output of otherwise highly productive individuals.

5.3. Implications for studies of the geographical sources of invention

As the analytical focus shifts from the subsidiary to the individual inventors, so does the conceptualization of the geographical sources of invention. At the MNC and foreign subsidiary levels, where individual units are often referred to or conceptualized as country representatives of a particular MNC, it makes intuitive sense to search for geographical sources of invention at the regional or country level. At the individual level, however, and considering their often limited movements in geographical space (Robinson et al., 1972; Breschi and Lissoni, 2009), it appears that the geography of invention would be even more confined or fine-sliced. For a relatively large proportion of all new technological advancements at the foreign subsidiary level, the geographical sources of invention should be tightly connected to the movements and networks of specific individuals (Ingram and Roberts, 2000).

There are good reasons to assume that exceptionally inventive individuals spend most of their daily lives nearby their work places; from that perspective, regions may represent overly broad conceptualizations of the impulses behind a large proportion of the subsidiary's technological advancements. For example, (1998, p. 291) concluded that star biotechnology scientists are 'properly viewed as locationally (semi-) fixed', as they are typically unwilling to abandon university appointments and their laboratory teams and their commercial activities remain within easy commuting distance of home or university (Zucker et al., 1998a). Especially in the case of face-to-face interactions that are assumed to be critical for the exchange and development of tacit knowledge, the sources of invention may be found in distinctive associations with local universities (Zucker et al., 1998b) and highly localized interaction and knowledge exchange within specific teams of inventors (Tallman and Chacar, 2011).

This is not to suggest that individual inventors' exposure to distant or foreign locations is unimportant; the current data supports the assumption that exceptionally inventive individuals uphold and use a comparatively extensive network of contacts at the cross-regional and cross-national levels. There is also some evidence that although the absolute number of so-called skilled transients remains limited, they are becoming increasingly common in the international context (Findlay, 1995; OECD, 2002) and highly productive inventors could well be over-represented within this category. Temporary experiences outside the immediate local area, or contacts that are sustained by means of distant communication, may be particularly important for the development and integration of knowledge that boosts individual innovative performance (Bell and Zaheer, 2007). Notably, however, the present results raise questions about the extent to which such connections contribute to inventions that lead the corporation in new technological directions.

5.4. A speculative note on the significance of subsidiary embeddedness

Much remains to be found out about the connection between superstar inventors and their geographical networks of contacts and collaborations. Until now, research has focused on subsidiary embeddedness, creative milieux and regional innovation systems as a crucial element for acquiring and upgrading technological capabilities (Lundvall, 1992; Malmberg et al., 1996; Cantwell and Santangelo, 1999; Holm and Pedersen, 2000; Andersson et al., 2002; Verspagen and Schoenmakers, 2004). However, it is interesting to speculate that superstar inventors may operate independently of such general influences; if this is indeed the case, it presents a scenario of instances of spurious correlation in the prior literature on embeddedness. Supposing that superstar inventors are sealed off from many local influences, performing much of their work in the R&D department and drawing upon scientific advancements in academia and a dispersed community of engineering peers, observed levels of technological activity may not be the primary outcome of processes of subsidiary embeddedness. Instead, they may be driven primarily by the entry and professional development of individual and superstar inventors, thus suggesting the relevance and significant impact of individual inventor embeddedness.

Two of the individual cases discovered in the course of the present study may serve as an example. In SKF's German subsidiary, the first patenting by the superstar inventor Manfred Brandenstein occurred in 1973. This represented the start of a period of significant increases in the unit's patenting activity and contributions to the broadening of the group's technology portfolio. Between 1973 and 1980, Brandenstein appeared as first inventor in three out of a total of 57 patents. That share increased to 62 out of 126 patents between 1981 and 2008. The second-most productive inventor, Armin Olschewski, started patenting in 1975. Between 1975 and 1980, he was first inventor in eight out of 61 patents, compared to 62 out of 89 patents between 1981 and 2008 (Brandenstein and Olschewski cooperated on many inventions). The pattern that emerges could be one of brief apprenticeship followed by extended periods of significant contributions to the subsidiary's and ultimately the MNC's technology portfolio.

These figures are not exhaustive in terms of pinpointing the sources of invention. To the extent the two superstar inventors were able to learn from other subsidiary members and inventors with extensive networks of local contacts, the mechanisms of gradually increasing subsidiary embeddedness remain unchallenged. However, to the extent that inventive activities were largely based on fine-sliced local interactions, contacts and distant communication with peers (which appears to be particularly common among superstar inventors), as well as on development work carried out within the confines of research and development departments, observations of enhanced technological activity could be mistakenly attributed to the subsidiary embeddedness effect. In any event, it appears difficult to explain the rather dramatic numbers of inventions that are attributable to the two inventors of the SKF subsidiary simply by increasing levels of embeddedness at the subsidiary level.

6. Limitations and avenues for further research

There are clearly some important limitations to the current study. The cut-offs applied in the identification of exceptionally inventive foreign subsidiaries have no precedence in the extant literature; in this respect, they only offer an initial approach that can be refined in future work. Furthermore, the sample of exceptionally inventive subsidiaries was selected on the basis of number of entries into new classes of technology, as defined by the US Patent Office. While this level of aggregation would correspond to the types of technological contributions discussed in the literature on MNC renewal and foreign subsidiary management, finer levels of aggregation could have produced a different set of exceptionally inventive subsidiaries, perhaps characterized by other types of contributions to the technological development of the overall multinational group. However, the fact that the subsidiaries identified in the present study are located in large and strategically important markets probably means they would also prove highly active along any alternative dimensions of technological development.

Due to the unavailability of historical data on financial performance at the subsidiary level, the present study has not been able to directly address or estimate performance implications. Larger samples and systematic investigations of performance effects would require more extensive archival research and detailed scrutiny of how intra-corporate transfers and accounting practices may have affected financial results at the subsidiary level. Nevertheless, it would be interesting to explore whether the existence of highly active inventors coincides with the growth and decline of foreign subsidiaries. It would be reasonable to assume that inventive excellence yields organizational power and advantages in competition for resources in the multinational network (Mudambi and Navarra, 2004) and that it may trigger and sustain the virtuous cycles of subsidiary initiatives and development suggested by earlier work (Birkinshaw and Hood, 1998). In reverse, the voluntary or forced departure of key inventors may cause the onset of vicious cycles that lead to the demise of individual subsidiaries. One particularly interesting but still speculative observation concerns Alfa Laval's US subsidiary, which saw the start of what seems to have been a deliberate withdrawal or re-location of technological activity as the productivity of its by far most productive inventor, Howard Hapgood, declined markedly after the Second World War (cf. Zander and Zander, 1996).

Several of the issues raised in this paper remain open for further and more detailed scrutiny. This includes more detailed analyses of the extent to which exceptionally inventive individuals tend to work alone or assume central positions in several constellations of inventors (thus representing important boundary spanners and conduits for intra-firm knowledge transfer). While the role and effects of inventor networks have been examined in increasing detail (Balconi et al., 2004; Nerkar and Paruchuri, 2005), issues in the MNC context that remain to be explored include if superstar inventors tend to connect with other and perhaps geographically distant superstars, how, as indicated by the current results, their positions in relatively larger groups of researchers and as potential gatekeepers speed up knowledge transfer both within and across individual units of the multinational network (Fleming and Marx, 2006; Breschi and Catalini, 2010), and also how superstar status and network positions influence the likelihood of re-combination of knowledge into multi-technology inventions and products.

Another question of managerial importance concerns the emergence and development of superstar inventors, or, put somewhat differently, where superstar inventors come from. Presumably, it is not so much a question of inherent and original talent, as it appears unlikely that scientific and engineering skills are vastly different across the units and locations represented by the current sample firms. Part of the answer is likely to be found in the dynamics that explain the emergence of superstar subsidiaries (Blomkvist et al., 2012), which include an interrelated combination of market size, relative profitability, and organizational autonomy. Whenever these conditions are present, individual foreign subsidiaries can develop the resources, critical mass, and scope of innovation activities that allow individual inventors to fully leverage their inventive capabilities. Other potential influences may come from internal systems, processes, and organizational cultures that either promote or constrain inventor creativity. Yet, this does not fully explain why inventive contributions should be unevenly distributed across inventor within particularly favoured units, and the drivers and pathways that lead to superstar positions remain to be studied in greater detail. Factors that may come into play include how particularly successful units may be able to attract exceptional talent from other parts of the multinational network, or how over time path dependency in the formation of inventor networks may amplify the inventive output of individual inventors.

Although the results of this study indicate similar distributions of inventor activity across foreign subsidiaries, larger samples and citation data could reveal systematic differences in the structuring of inventive work among highly and less productive units. For example, some units may draw upon the input of a small and select number of highly inventive individuals, whereas others rely upon more evenly distributed and, therefore, perhaps more routinized and reproducible invention (Ernst et al., 2000). In this case, the overarching issue is the design of micro-level technological activity in the MNC and its implications for sustainable inventive and commercial performance. This is an area where taxonomical studies at finer levels of aggregation than have been used in the past hold great promise for the future.

7. Summary and conclusions

MNCs have come to be understood as large and networked entities. Consequently, it is easy to neglect individual members and how they can have a decisive influence on its technological, strategic, and organizational development. Perhaps the most significant contribution of this study is that it highlights the important role played by individuals and foreign superstar inventors in the development of the overall technological portfolio of the MNC. While traditional approaches to understanding the foreign operations of the MNC have primarily focused on the organizational or network levels, our results suggest that addressing and evaluating micro-level activities and their effects on the technological and strategic development of the multinational group represents a largely untapped potential for further research. In terms of sources of competitive advantage, MNC management, and the geographical drivers of technological renewal, the movement towards a people-centric approach to the dynamics of foreign subsidiaries (and beyond) would add a new and previously under-estimated piece to our understanding of the growth and evolution of the MNC.

As we have only been able to take an initial look at the role of individual inventors in the firm, several questions of both conceptual and practical importance remain to be answered. We hope that our simple yet persuasive empirical observations elicit some interest (cf. Davis, 1971), thereby setting the stage for further studies in a largely uncharted area of research. If firm routines and external influences at the firm level only account for part of the inventive productivity of individuals, an overarching question that remains to be addressed is what additional factors determine the inventive performance of individual subsidiary members. Knowing more about this specific issue would be particularly valuable from a managerial point of view. If the underlying characteristics and motivations of key inventors are known, it may become possible to devise recruitment and management practices that can secure the desired levels of inventive activity. Similar reasoning would apply to other key people at the subsidiary level as well. In this respect, the current study may serve as a general reminder about an important element in MNC development that current research has largely forgotten.

Acknowledgements

Financial support from the Bank of Sweden Tercentenary Foundation is gratefully acknowledged.

Appendix A.

The sample of consolidated Swedish MNCs that provided the basis for the sampling of superstar subsidiaries consisted of the following firms:

Firm[a]	Principal field of industrial activity	Number of greenfield/acquired subsidiaries
AGA (1904)[b]	Industrial gases	7/2
Alfa Laval (1878)	Separators, agricultural equipment	13/8
ASEA (1883)	Power generation and distribution equipment	14/3
Astra (1913)	Pharmaceuticals	19/1
Atlas Copco (1873)	Pneumatic and hydraulic equipment	14/9
Electrolux (1910)	White goods, home appliances	25/14
Ericsson (1876)	Telecommunication equipment	25/6
ESAB (1904)	Welding equipment	3/7
Fagersta (1873)	Metals, rock drills	1/0
MoDo (1873)	Pulp and paper	4/1
Perstorp (1880)	Chemicals, conglomerate	8/3
Pharmacia (1911)	Pharmaceuticals	13/0
PLM (1919)	Packaging material	3/1
Saab-Scania (1891)	Automotive products, aircraft	2/1
Sandvik (1862)	Specialty steel and metals, hard materials	20/34
SCA (1925)	Pulp and paper	14/14
SKF (1905)	Ball and roller bearings	23/11
Stora (1888)	Pulp and paper	1/7
Tetra Pak (1946)	Liquid packaging machinery	10/0
Trelleborg (1905)	Rubber products, conglomerate	8/5
Volvo (1915)	Automotive products, food	10/4

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

[b] AGA was acquired by Linde in 2000 and observations were 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 (1990, merged with Kabi Vitrum), PLM (1999, acquired by Rexam), Scania (1990, car division acquired by GM), Stora (1998, merged with Enso), Tetra Pak (1993, acquired Alfa Laval), and Volvo (1999, car division acquired by Ford).

A.1. Identification of technologically active foreign subsidiaries

In order to correctly identify the technological activity of the sample firms and their foreign subsidiaries, a detailed examination of each individual firm was performed to identify any name changes or potential changes in ownership through mergers and acquisitions. The data consolidates any US patenting associated with 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), *Who Owns Whom – Continental Europe*, and from 1991 onward, information in annual reports and corporate trees offered by the Thomson Innovation database. Complementary publications and information, such as publications on company histories and information about acquisitions and mergers extracted from the Internet, were also used in the consolidation process.

A.2. Additional considerations

A few additional points about the data collection process should be noted. It has not been possible to establish the extent to which some of the registered patents may have been purchased from external sources. Generally, however, and considering the historically low proportion of purchased technology among larger corporations (Sanders et al., 1959; Granstrand et al., 1992), this effect is estimated as being of marginal importance. In some locations, the sample firms appear to have carried out operations in several distinct locations. While patents may have been registered under the same legal entity, from an operational point of view it would be possible to talk about several rather than one subsidiary per location (in other cases, and as reflected in the current data, it was known that the sample firms maintained several operationally and legally distinct local units, which were then registered as separate subsidiaries sharing the same location). This suggests that distributions of inventive activity at the subsidiary level may conceal other and perhaps even more pronounced patterns at the level of local sub-units.

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