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SMEs INVENTIVE PERFORMANCE AND PROFITABILITY

IN THE MARKETS FOR TECHNOLOGY

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Abstract

This paper studies the inventive performance and profitability of small and medium sized firms (SMEs) that are "technology specialists" compared to the inventive performance and profitability of SMEs that are instead vertically-integrated. In this paper perspective, "technology specialists" are firms that specialize upstream in generating inventions and trade those inventions in disembodied form with other firms, usually through licensing agreements. Instead, vertically-integrated firms are those firms that both generate inventions and commercialize products incorporating those inventions. We argue that technology specialists achieve a higher inventive performance than vertically-integrated firms, since they can accumulate deeper and broader inventive experience, whilst keeping a more flexible organizational structure. These firms display a lower profitability though, due to the imperfections inherent in invention market transactions and the lower bargaining power caused by the lack of commercialization assets. The theoretical framework is tested through a cross-industry investigation on a sample of European SMEs. Implications for the viability of being a technology specialist as a strategy and for the development of markets for technology are discussed.

Keywords: Markets for technologies; vertical boundaries; firm inventive performance; firm profitability; Small Medium Enterprises.

1. INTRODUCTION

Recent studies have established the increasing importance of markets for technology (e.g., Arora et al., 2001; Krammer, 2014; Ritala and Hurmellinna-Laukkanen, 2009; Veer and Jell, 2012; Wang et al. 2012) – hereafter, MFT – that is, markets where inventions are traded as "free standing" entity, disembodied from individuals, organizations and products (e.g., Arora et al., 2001). In these markets firms can exchange their inventions for a price, usually through a licensing agreement, which is a contract where the owner of an invention allows another party the right to use or modify it in exchange of compensation (WIPO, 2014). Previous research on MFT has mainly taken a policy perspective on this phenomenon, arguing that the development of these markets allows for an efficient division of innovative labour among small and large firms according to their comparative advantage – which is, respectively, doing research and generating inventions for small firms, and producing and marketing the final products that embody new inventions for large firms (Arora et al., 2001; Arrow, 1983; Holmstrom, 1989). This type of configuration is socially desirable, in principle, since every type of firm focuses on the activity it performs better (Firth and Narayanan, 1996; Li and Tang, 2010); hence, a higher overall value might be generated compared to a situation where all firms internalize both the research and final product commercialization activities (e.g., Arora and Ceccagnoli, 2006; Arora et al., 2001; Conceicao et al., 2012).

However, the firm-level implications of MFT in terms of firm inventive performance (i.e. the extent to which a firm is capable of generating valuable inventions) and profitability have been largely neglected. It is not clear whether small firms are better off exploiting their comparative advantage in inventing by becoming "technology specialists" – that is, specializing upstream in the inventive activities and then sell their inventions in the MFT – or whether they should vertically integrate – that is, commercialize their own inventions to final customers. In particular, on the side of inventive performance, previous research on MFT has largely neglected how the interdependence between upstream invention and downstream product commercialization activities affects the firm's capacity to generate high quality inventions; consequently we still lack an understanding of whether the inventive performance of technology specialists overcomes that of vertically-integrated small firms. At the same time, on the side of profitability, the literature on MFT has largely neglected to consider the ability of technology specialists to appropriate the economic returns of their inventions. Indeed, becoming a technology specialist and selling inventions to other firms requires firms to incur the private costs related to search and negotiation in the MFT (e.g. Fosfuri, 2006). In addition, being a technology specialist also implies that a firm lacks downstream, complementary assets that have been demonstrated to be a relevant source of bargaining power (e.g., McGahan and Silverman, 2006; Teece, 1986). Accordingly, we still do not know the extent to which – at the firm level – the economic benefits of being a technology specialist overcome the costs.

This study fills in these gaps by investigating the following research question: how does the choice of being a technology specialist (as opposed to being a vertically-integrated firm) affect an SME's inventive performance and profitability? Addressing these issues is important because it allows for an understanding as to what extent being a technology specialist is a viable strategy for an SME. The rest of the paper is organized as follows. In section 2 we present our theory and hypotheses and in section 3 we describe the method that we used to test the hypotheses developed. In section 4 we present the empirical results, while in section 5 we discuss their implications to practice and theory. Finally, in section 6, we present the conclusions from the study.

2. TECHNOLOGY SPECIALISTS VS. VERTICALLY-INTEGRATED SMES: IMPLICATIONS ON INVENTIVE PERFORMANCE AND PROFITABILITY

Building on the principles of specialization and division of labour (Smith, 1776; Stigler, 1951; Young, 1928), literature on MFT has argued that small and large firms are naturally endowed with different capabilities in inventing and commercializing; hence, they can benefit from specializing in the activity in which they are relatively more efficient (e.g., Arora et al. 2001; Ceccagnoli and Jiang, 2013). In particular, we can represent the innovation value chain as the chain of activities from upstream research activities – i.e., research and inventions generation – to downstream activities – i.e., large-scale development of those inventions into products, manufacturing and marketing to the final customers. Large, established firms, due to their highly bureaucratic structure, have a comparative advantage in performing downstream activities, which typically involve a high degree of routinization and standardization (Allarakhia and Walsh, 2011; Holmstrom 1989; Mangematin et al. 2011). Small firms, instead, have a comparative advantage in performing upstream research activities because, due to the low organizational distance between managers and researchers (e.g. Arrow, 1983; Marion et al., 2012), they are more likely to pursue risky but potentially extremely valuable technological trajectories (Arrow, 1983; Arora et al. 2001).

These arguments suggest that, at the system level, the division of value chain activities among firms on the basis of their comparative advantage leads to the generation of a higher value compared to a situation where every firm performs all these activities (i.e. invention, development and commercialization to final customers) internally. Hence, based on this argument, it would appear preferable – from a social welfare perspective – if SMEs specialized in upstream research activities, i.e. if they became "technology specialists" (Arora et al 2001). However, existing research in this area provides only limited insight on whether operating as a technology specialist also brings a "private" advantage to SMEs, that is, whether technology specialists have a better performance compared to the vertically-integrated SMEs, i.e. those SMEs that internalize all value chain activities. More precisely, existing research on MFT has provided only limited consideration to the interdependence between upstream invention generation and downstream commercialization activities. Consequently, existing research has not investigated the extent to which this interdependence affects the inventive performance of small firms that are technology specialists, and only focus on the generation of inventions, vs. vertically-integrated small firms, which internalize both activities.

In addition, existing research on MFT has not investigated the extent to which SMEs' profitability is affected by the choice between upstream specialization vs. vertical integration. Becoming a technology specialist implies undertaking search and negotiation activities in the MFT; hence, it might require incurring additional costs that might reduce SME's profitability (e.g. Leiblein and Madsen, 2009). The extent to which these costs overcome the benefits of being a technology specialist has been overlooked by extant literature. Furthermore, a technology specialist lacks downstream complementary assets that a vertically-integrated firm instead possesses, with possible implications on its bargaining power and consequently on its profitability compared to a vertically-integrated SME (e.g. Fosfuri, 2006; Leiblein and Madsen, 2009). However, these implications have been neglected by extant studies. The goal of this paper is to fill this gap and compare the implications for an SME of being a technology specialist vs. being vertically-integrated, in terms of both their inventive performance and profitability. In doing so this paper contributes to improving our understanding on the performance of SMEs (Hoffman et al. 1998).

We argue that being a technology specialist (as opposed to being a vertically-integrated firm) has a positive impact on a small firm inventive performance for two reasons. The first reason relates to the deeper and broader inventive experience that technology specialists can accumulate (Leiblein and Madsen, 2009). Technology specialists devote all their efforts and resources to their inventive activity (Arora et al., 2001). This makes them more likely to enjoy faster accumulation of inventive experience in their technological fields compared to vertically-integrated small firms – which instead spread their resources and attention across upstream (i.e., invention) and downstream (i.e., commercialization) activities. While this argument holds for any firm (regardless of its size), it is even more salient for small firms, whose resource endowments are typically scarcer compared to those of larger firms (Teece, 1986). This implies that technology specialist SMEs tend to acquire a “deeper” inventive experience than vertically-integrated SMEs (Diez-Vial, 2009; Yelle, 1979).

At the same time, because technology specialists have the ultimate goal to sell or license their technologies to other firms (Bianchi et al., 2011; Veer and Jell, 2012), they have the incentive to generate inventions that target a greater variety of business applications and customer needs compared to vertically-integrated firms, whose research activity mainly serves in-house needs (Arora et al. 2001; Grant, 2002; Hicks and Hegde, 2005). This argument holds a fortiori for smaller vertically-integrated firms, which, due to their resource constraints, usually operate in a limited set of market niches. This implies that technology specialists tend to acquire a “broader” inventive experience than vertically-integrated firms and this effect is even stronger in the case of SMEs (Hicks and Hegde, 2005). Both a depth and breadth of inventive experience enables lessons learned from experience to accrue more steadily, thus generating better inventions (Katila and Ahuja, 2002).

The second reason why being a technology specialist (as opposed to being a vertically-integrated firm) has a positive impact on a small firm’s inventive performance is related to the organizational structure typically characterising technology specialists vs. vertically-integrated firms, which makes the former better positioned to generate valuable inventions. A vertically-integrated firm is likely to display tight interdependences between upstream organizational units – focused on research and on the generation of valuable inventions – and downstream units – commercializing those inventions embodied into products for final customers (Taylor and Helfat, 2009). These interdependences are likely to inhibit the generation of path-breaking inventions and rather favour path dependence at the expense of novelty (Powell, 1992; Taylor and Helfat, 2009). A very clear illustration for this mechanism is presented by Fosfuri and Roende (2009). Vertically-integrated companies are companies where an upstream R&D unit and a downstream manufacturing unit coexist. In principle the

R&D unit may select the research trajectory to be pursued between multiple alternatives, which vary in their value and novelty. For instance, the R&D unit might choose between research trajectories likely to deliver radical and extremely valuable inventions, and other trajectories probably resulting in incremental inventions. Choosing a research trajectory oriented to the generation of radical inventions is likely to require the creation of new sets of manufacturing routines and expertise – and so, huge adaptation costs in the production units (e.g. Linton and Walsh, 2013). This implies that these more radical trajectories naturally meet a strong internal resistance (Henderson, 1993; Henderson and Clark, 1990) in vertically-integrated firms. To avoid a costly internal conflict, the R&D units of vertically-integrated firms are likely to lean towards incremental (though probably less valuable) research trajectories.

A large bulk of empirical evidence supports the idea that vertically-integrated firms present systemic resistance to generating radical inventions that alter the relationships among different stages of the production process (Glasmeier, 1991; Mariotti and Cainarca, 1986; O'Connor and DeMartino, 2006; Tripsas, 1997). In contrast, technology specialists can take advantage of a higher degree of freedom in their decision making, which stems from the absence of the typical organizational and coordinative constraints that characterize vertically-integrated firms. Given that experimentation and risk taking are crucial in the discovery of valuable technological solutions (e.g., Ahuja and Lampert, 2001; Gupta et al., 2006), we suggest that the greater opportunity of technology specialists compared to vertically-integrated firms to undertake radical research paths is likely to result in a greater ability to generate valuable inventions.

All these arguments lead us to predict:

Hypothesis 1: Technology specialist SMEs have higher inventive performance than vertically-integrated SMEs.

While being a technology specialist may positively affect SMEs' inventive performance, at the same time it may also hamper their profitability for two reasons related respectively to: a) the imperfections that plague the MFT functioning (e.g. Cockburn, 2007; Gans et al., 2008) and b) the lower bargaining power of technology specialists in negotiations due to their lack of downstream (i.e. commercialization) assets (McGahan and Silverman, 2006; Teece, 1986).

Consider first the imperfections that obstruct the functioning of MFT. Existing research has emphasized how the actual volume of technology transactions occurring in MFT is much lower than it could be due to several imperfections in the functioning of these markets (Gans et al.2008; Giuri et al., 2007). This clearly hampers the technology specialists' possibility to make profits through invention trading. For instance, it is usually quite complicated for a company that has generated a new invention to identify the right buyer, since this involves scanning multiple market niches and identifying technological problems to which the invention could constitute a solution (Ceccagnoli and Jiang, 2013; Cockburn, 2007). This generates very high search costs and, consequently, a reduction in the profits that technology specialists can generate by selling their technologies in MFT.

Moreover, even once a potential buyer has been found, uncertainty about the market value of an invention might obstruct the transaction (Gambardella, 2013). Having generated the invention the seller, compared to the buyer, usually has more information regarding its true value (Gans et al., 2008). This information asymmetry leads to a classic adverse selection problem (Beggs, 1992; Sakakibara, 2010) because the buyers are not always capable of selecting between good and bad inventions and they make offers that take into consideration the possibility that the acquired invention might be a low quality one (Cockburn, 2007). As a result, sellers of good inventions end up receiving offers that are lower than what they know would be fair, which reduces the likelihood of an agreement with the buyer. A similar dynamic also occurs in the circumstance in which the inventing firm itself is uncertain about the true value of its inventions – such as in the case of very novel and path-breaking inventions. In this situation inventing firms tend to be overoptimistic about the quality of their own inventions (Dushnitsky, 2010; Giuri et al. 2007). This reduces the chance to agree with the buyer on a price, because even fair offers tend to be perceived by the inventor as too low. Overall, the difficulties in reaching an agreement about the value of the invention with any potential buyers hamper the possibility that technology specialists will generate profits from their inventions. Consistently with these arguments, previous research has found that divergences over the financial terms of licensing agreements – which is the usual way an invention is sold in MFT – are some of the major reasons why negotiations break down (Cockburn, 2007).

Finally, the trading of inventions is plagued by possible opportunistic behaviours by the transaction counterparts, especially in the absence of "appropriate intellectual property rules, procedures, and protection" (Gouvea et al. 2012, p. 563). Such moral hazard issues are likely to induce prospective buyers to consider with caution the option of buying an invention on the market (Dechenaux et al. 2011; Dushnitsky, 2010). This is due to the fact that the knowledge underlying the inventions often displays tacit components in addition to codified components (Arora, 1996; Winter, 1987). The effective transfer of such knowledge, therefore, requires a certain amount of complementary effort from the inventing firm side to assist the buyer in the complete understanding and integration of the invention in its products (Leone and Reichstein, 2012). However, inventing firms might display opportunistic behaviours and try to skimp on the full effort required to transfer knowledge to the buyer (Arora, 1996). This issue is further complicated by the fact that transactions of inventions often require highly specialized complementary investments from the buyers, who are consequently exposed to the risk of "hold up" (Shane, 2002). The risk of moral hazard and hold up reduces potential buyers' propensity to acquire external inventions. From the point of view of a technology specialist, this results in a further obstacle to profit from invention trading.

Besides MFT imperfections, the second reason why technology specialists tend to be less profitable than vertically-integrated small firms is that a vertically-integrated firm – by definition provided with downstream assets – can sell its inventions embodied into final products, without having to negotiate with a counterpart; by contrast, a technology specialist has to engage in a negotiation with a firm provided with downstream assets to sell its inventions. In this type of negotiation, the margins accruing to the technology specialist tend to be squeezed due to the stronger bargaining position of the buyer that originates from the possession of downstream (commercialization) vis-a-vis upstream (research) assets (Chiu et al. 2008). Hence, since the possession of downstream assets represents a critical determinant of the ability to appropriate the economic returns of an invention (e.g. Teece, 1986), vertically-integrated firms are better able to profit from their inventions compared to technology specialists.

Previous empirical evidence supports our line of reasoning. For instance, Arora and Nandkumar (2012), examining the software security industry, found that MFT raise the value of marketing capabilities in ensuring firm survival, and simultaneously decrease the value of technological capabilities. In the same vein, but using a much broader dataset on all publicly traded U.S. firms, McGahan and Silverman (2006) show that the stock market value of firms controlling downstream assets in a focal industry increases when outsider players generate inventions that could be fruitfully commercialized within the industry. This happens because outsiders usually don’t possess the relevant downstream assets to operate in the industry. As a result, insiders tend to enjoy a higher bargaining power in negotiations and eventually appropriate a greater portion of the value generated through the transaction of inventions, reducing the profits accruing to firms who do not possess downstream assets (i.e. technology specialists).

To summarize, the imperfections of MFT and the limited bargaining power of technology specialists determined by their lack of downstream assets exert a negative effect on the ability of technology specialists to profit from their inventions in MFT. Accordingly, we hypothesize that:

Hypothesis 2: Technology specialist SMEs have lower profitability than vertically-integrated SMEs.

3. METHOD

The empirical investigation of this study was accomplished on a population of European-based SMEs, across all industries, within the timeframe 1996-2001. Coverage across all industries provides the advantage of permitting a systematic investigation of the study's predictions. Geographic restriction to Europe is motivated by the fact that huge institutional differences characterize markets for technology across different regions throughout the world, a circumstance that may have an impact on the performance of the firms under investigation in this study (Ginarte and Park, 1997). As a consequence, focusing on a specific and relatively homogenous geographical area may guarantee that many of these features remain constant across this study sample, enabling a more robust test of the hypotheses. However, as the appropriability regime may still be expected to vary from country to country even within the European area, a control for the strength of patent protection was included in the statistical analyses (Ginarte and Park, 1997).

While the 1990s were characterized by the steady increase in the volume of market transactions of inventions and by the increase in variance across firms in terms of their vertical boundaries and invention-commercialization choices, the greatest changes in this direction occurred – at least in Europe – in the second half of the 1990s, that is the temporal window on which this study is focused.

3.1 Sample and data

We used a cross-sectional dataset of Europe-based SMEs across all industries in the timeframe 1996-2001 to test our hypotheses. The choice of employing a cross-sectional dataset instead of a panel dataset is motivated by the concern for the reliability of yearly data on invention commercialization strategies, provided that our sample is composed by SMEs. Indeed, forming a panel dataset would require the collection of yearly data on firms' invention commercialization strategies (i.e. yearly data on whether each firm had sold or licensed its inventions to other firms or had embodied its inventions into products). Having conducted an accurate and extensive pilot search on multiple data sources (including Business & Industry, Factiva, Zephyr and Securities Data Corporation databases as well as company web sites and specialized websites) we discovered that collecting yearly data for small private companies was problematic since these firms do not receive systematic media coverage. Therefore it is not possible to find each licensing agreement or each product launched by each of these companies in each single year reported on public sources.

However, our pilot search supported the idea that expanding our cross-sectional analysis to a time window of six years would lead to a reliable assessment of firms' strategies. In fact, we found that if a company engages in a strategy of exclusively using licensing agreements to commercialize its inventions, the likelihood that in a period of six years at least one of its licensing agreements will be announced on a website or in a corporate report is quite high. Similarly, if a company has launched products based on its inventions, this information is likely to appear at least once on the materials we collected on the company in the six years window of reference.

Furthermore, the invention commercialization strategies of firms in our sample seem quite stable in the temporal window under investigation of our study. Hence, a cross-sectional perspective seems not only a way to bypass the reliability problem that a panel approach would cause, but also a more appropriate approach from the standpoint of yearly data variability. The choice of using a cross-sectional dataset is in fact in line with other studies in the field such as Arora and Gambardella (1990); Fosfuri (2006) and Gans et al. (2002).

Firms that had at least one EPO-granted patent that had been applied for within the time frame 1996-2001 were included in the sample. Using the patent application date and not the grant date enables us to control for differences in delays that may occur in granting patents after the application is filed (e.g Trajtenberg, 1990). Furthermore, the protection of patent, once granted, is retroactive and also covers the application period. Two motivations underlie the decision to include in the sample firms with at least one patented invention. First, patents represent an externally validated measure of inventive activity (Belenzon and Patacconi, 2013; Griliches, 1990). Second, patent protection reduces several frictions that typically characterize the trading of inventions and has a huge effect on the likelihood of selling or licensing an invention to other firms (e.g., Arora and Ceccagnoli, 2006; Gans et al., 2008). Hence including firms with at least one patented invention allows a reliable identification of the firms “at risk” of engaging in invention trading activities.

Company names identified from the patent database have been matched with company names from the Amadeus database (Bureau van Dijk); hence both listed and non-listed companies were included in our sample. Checks for misspelling of company names were made and corrected. Subsidiaries at the parent level were then tracked on Amadeus, in order to exclude from the sample all firms that proved to be subsidiaries of large firms or joint ventures. Amadeus was then employed to discriminate between large and small-medium firms. As this study is concerned with SMEs, firms were retained in the sample only if they showed no more than 250 employees in at least one year within the timeframe 1996-2001 covered by this study. As indicated by the European Commission, 250 employees is the standard cut-off point to identify SMEs in the European context (Recommendation 2003/361/EC).

These sample construction rules provided the master list that was employed to collect the data that we used in this study. Data on firms' vertical integration and invention trade were collected and triangulated through an extensive search of press releases, including Business & Industry, Factiva, Zephyr and the Securities Data Corporation (SDC) databases as well as from company web sites. In cases where this information was not available from current companies' websites, or if the companies' websites were no longer active, the Internet Archive's Wayback Machine was used to visit the past websites (Yadav et al., 2007). Data on firms' inventive portfolios was collected using PatStat. Data on firms' age were obtained from company websites and Internet archives. Amadeus was employed to collect data on firms' profitability and size across the whole timeframe covered by this study. Finally, to obtain data on the strength of the appropriability regime across the different European countries included in this study sample, this paper referred to publications by Park (2008) and Ginarte and Park (1997).

The final sample included 551 firms, of which 20 were technology specialists. Basic characteristics of industry affiliation and country of origins of the firms included in our sample are displayed in Tables 1 and 2.

TABLE 1. Industry Affiliation: Overall Sample and Technology Specialists

		All firms in the sample			Technology Specialists		
Description	**US SIC**	**Num**	**%**	**Cum %**	**Num**	**%**	**Cum %**
Industrial And Commercial Machinery And Computer Equipment	35	173	31.40%	31.40%			
Fabricated Metal Products, Except Machinery And Transportation Equipment	34	66	11.98%	43.38%	2	10.00%	10.00%
Engineering, Accounting, Research, Management, And Related Services	87	50	9.07%	52.45%	13	65.00%	75.00%
Electronic And Other Electrical Equipment And Components, Except Computer Equipment	36	43	7.80%	60.25%			
Chemicals And Allied Products	28	42	7.62%	67.88%	3	15.00%	90.00%
Measuring, Analyzing, And Controlling Instruments; Photographic, Medical And Optical Goods; Watches And Clocks	38	29	5.26%	73.14%			
Rubber And Miscellaneous Plastics Products	30	24	4.36%	77.50%			
Miscellaneous Manufacturing Industries	39	21	3.81%	81.31%			
Business Services	73	12	2.18%	83.48%			
Primary Metal Industries	33	10	1.81%	85.30%			
Furniture And Fixtures	25	10	1.81%	87.11%			
Transportation Equipment	37	9	1.63%	88.75%			
Paper And Allied Products	26	7	1.27%	90.02%			
Lumber And Wood Products, Except Furniture	24	7	1.27%	91.29%			

Stone, Clay, Glass, And Concrete Products	32	6	1.09%	92.38%			
Apparel And Other Finished Products Made From Fabrics And Similar Materials	23	5	0.91%	93.28%			
Agricultural Production	01	4	0.73%	94.01%			
Heavy Construction Other Than Building Construction Contractors	16	4	0.73%	94.74%			
Textile Mill Products	22	4	0.73%	95.46%			
Food And Kindred Products	20	3	0.54%	96.01%			
Printing, Publishing, And Allied Industries	27	3	0.54%	96.55%	1	5.00%	95.00%
Building Construction General Contractors And Operative Builders	15	3	0.54%	97.10%			
Electric, Gas, And Sanitary Services	49	3	0.54%	97.64%			
Leather And Leather Products	31	2	0.36%	98.00%			
Oil And Gas Extraction	13	2	0.36%	98.37%	1	5.00%	100.0%
Building Materials, Hardware, Garden Supply, And Mobile Home Dealers	52	2	0.36%	98.73%			
Mining And Quarrying Of Nonmetallic Minerals, Except Fuels	14	1	0.18%	98.91%			
Construction Special Trade Contractors	17	1	0.18%	99.09%			
Petroleum Refining And Related Industries	29	1	0.18%	99.27%			
Transportation By Air	45	1	0.18%	99.46%			
Transportation Services	47	1	0.18%	99.64%			
Apparel And Accessory Stores	56	1	0.18%	99.82%			
Personal Services	72	1	0.18%	100.0%			
TOTAL		**551**			**20**		

TABLE 2. Country of Origin: Overall Sample and Technology Specialists

	All sample			Technology Specialists		
Country	**Number**	**%**	**Cum %**	**Number**	**%**	**Cum %**
Italy	300	54.45%	54.45%			
France	73	13.25%	67.70%	1	5.00%	5.00%
Finland	38	6.90%	74.60%	3	15.00%	20.00%
Great Britain	37	6.72%	81.32%	8	40.00%	60.00%
Netherlands	29	5.26%	86.58%			
Spain	25	4.54%	91.12%	1	5.00%	65.00%
Norway	19	3.45%	94.57%	3	15.00%	80.00%
Germany	16	2.90%	97.47%	1	5.00%	85.00%
Denmark	14	2.54%	100.00%	3	15.00%	100.00%
TOTAL	**551**			**20**		

Table 1 reports the industry affiliation for all firms in the sample on the basis of US SIC codes. The table is organized to allow for an immediate comparison between the distribution across industries of the overall sample and the distribution across industries of the technology specialists. Table 1 shows that the overall sample of our European innovative SMEs tends to be distributed across high and low tech industries, though a relatively larger majority of them actually belongs to high tech sectors. In fact, the most represented industries where European innovative SMEs are active are SIC 35 (31.4%, Industrial and Commercial Machinery and Computer Equipment), SIC 34 (11.98%, Fabricated Metal Products, Except Machinery and Transportation Equipment); SIC 87 (9.07%, Engineering, Accounting, Research, Management and Related Services); SIC 36 (7.80%, Electronic, Other Electrical Equipment and Components); SIC 28 (7.62%, Chemicals and Allied Products); SIC 38 (5.26%, Measuring, Analyzing and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks) and SIC 30 (4.36% Rubber and Miscellaneous Plastics Products). Overall, firms in these sectors constitute more than 75% of the sample, and these sectors represent predominantly – though not exclusively – high tech business activities. Firms in the remaining sectors are fragmented across a high number of industries, where high tech business activities are much less represented.

By replicating the same analysis for technology specialists, we observe that technology specialists are relatively more concentrated in high tech industries compared to the overall sample. In particular, we find that the great majority of technology specialists belong to SIC 87 (65%, Engineering, Accounting, Research, Management and Related Services). Other SIC represented include SIC 28 (15% Chemicals and Allied Products); SIC 34 (10%, Fabricated Metal Products, Except Machinery and Transportation Equipment); SIC 27 (5%, Building Construction General Contractors and Operative Builders) and SIC 13 (5%, Oil and Gas Extraction). In order to understand in more detail the activity of technology specialists, which constitute the focus of our investigation, we closely investigated the inventive profile of the companies that became technology specialists. Concerning the technological area of activity of technology specialists, we find that among the 20 technology specialists, 55% (11 companies) are in the biotech technological field. Among the remaining companies, 2 focus on the generation of mechanical technologies for the aeronautic and automotive sectors; 2 are in IT/electronics (generating magnetic tagging technologies and technologies for switchboards); 3 companies generate chemical technologies (generating respectively thermoplastic elastomer technologies, composting technologies and chemical active ingredients), 1 company generates toys and 1 company generates technologies for oil and gas offshoring.

Overall, technology specialists in our sample appear to be concentrated in high tech sectors characterized by strong appropriability regimes. Moreover the majority of technology specialists are in the biotech sector. This is in line with extant studies on MFT indicating biotechnology as one of the fields where invention trade has developed more in the last decades (Arora et al. 2001; Bianchi et al., 2011). Indeed, research in this area indicates that – beginning in the 1970s, several small R&D intensive biotech companies, mostly US-based, entered the industry. Through time the sector in the US consolidated towards a structure of small upstream technology specialists (Arora et al. 2001), trading their inventions to downstream companies. The analysis of the characteristics of our sample indicates that also in Europe, small biotechnologies firms tend to represent a high portion of the firms operating in MFT.

In Table 2 we report the distribution of our sample across countries. We note that 54.45% of the sample is composed by Italian companies, 13.25 % by French companies, 6.90% by Finnish companies, 6.72% by British companies and 5.26% by Dutch companies. The remaining 13.43% is composed by Spanish, Norwegian, German and Danish companies. We did not impose any geographic restriction in our sample, which included all European firms available in the Amadeus database having been granted at least 1 patent that had been applied at the EPO office in 1996-2001, and having no more than 250 employees in the same period. Therefore the distribution of our sample is to some extent also informative of the geographical distribution of the population of these types of firms. The predominance of Italian firms in our sample is consistent with the evidence that the Italian economy is essentially based on small and medium enterprises. For instance, in 1991, 24.2% of manufacturing firms in Italy had less than 10 employees, compared to 13.3% in the UK and 7.8% in Germany (OECD, 1997).

It is also interesting to note that when we move to the sub-sample of technology specialists, the distribution indicates that 40% of the sample is composed by British companies; another 45% is equally distributed amongst Danish, Finnish and Norwegian companies and finally, France, Spain and Germany constitute 5% of the sample each. Britain, Denmark and Norway are the countries where the ratio specialists versus non-specialists is the highest (specialists constitute, respectively, 22%, 21% and 16% of the companies from those countries in the sample) compared to the other European countries included in our sample.

3.2 Variables

3.2.1 Dependent Variables

This study employs two dependent variables corresponding to two distinct dimensions of firm performance: inventive performance and profitability. As already specified, in order to investigate firm inventive performance, we refer to patent data. However, patents substantially vary in their economic and technological value (Griliches, 1984; Sreekumaran Nair et al., 2011; Trajtenberg, 1990). Thus, patent citations are a better indicator of the importance or value of patents than simple patent counts (Frietsch et al. 2014; Galasso and Simcoe, 2011; Hall et al. 2005; Hess and Rothaermel, 2011; Kelley et al., 2011; Trajtenberg, 1990). Following extant literature in this area, we measure firm inventive performance using a citations-based index, i.e. weighting each patent i of the firm by the actual number of citations (Ci) that it subsequently received (Trajtenberg, 1990). In particular, for each firm in the sample, the INVENTIVE PERFORMANCE variable was computed as $\sum_{i=1}^{n}(1 + C_i)$, where n is the count of the EPO-granted patents that had been applied for by the focal firm within the timeframe 1996-2001 and Ci is the number of citations subsequently received by each patent. Existing research suggests that the use of a citation-based measure of inventive activities effectively captures the value of the inventions developed by the firm (e.g. Galasso and Simcoe, 2011; Hess and Rothaermel, 2011; Trajtenberg, 1990), hence the use of this indicator is consistent with the theory developed in this paper.

In calculating this variable two important issues were taken into account. First, citation counts are inherently truncated (Hall et al. 2005; Rosenzweig and Mazursky, 2013). Patents continue to receive citations for long periods of time, while we observe only citations up to a certain point in time. Moreover, citations to patents applied for in earlier time periods (that had a longer time window to be cited) cannot be aggregated and compared with citations to patents applied for more recently. In order to address this concern, for each patent of each firm in our sample, we counted the number of citations received in the first three years after patent grant.

Second, inventors are likely to patent their inventions in multiple patent offices. In these cases the same invention receives a different patent number, although the two patents are "equivalent" from an invention standpoint. In particular extant literature suggests that unlike US patents, a large share of EPO patents are cited indirectly through their non-EPO equivalent (Hall et al. 2007). A proper count of forward citations should therefore also include citations received by patent equivalents (Harhoff et al., 2006). In order to address this issue we used the Patstat dataset to reconstruct patent families and track all citations received by each patent of each firm in the sample, including those to the patents non-EPO equivalent. This variable construction provided the measure of invention performance employed in this study.

To assess firm PROFITABILITY, we calculated for each firm in the sample the average of the company's Return on Assets (ROA) obtained within the timeframe 1996-2001.

3.2.2 Independent Variable

Our independent variable indicates whether or not a firm had been a technology specialist within the timeframe under investigation in this study. Consistently with our theory we use the expression technology specialist to indicate a firm that commercializes its inventions exclusively as free standing entities as opposed to integrating these inventions into products. To identify firms that have traded their inventions we refer to firms who have engaged in invention licensing activities, following a large body of prior research in this area (e.g. Arora et al. 2001; Fosfuri, 2006; Somaya et al.,2011; Leone and Reichstein, 2012). Accordingly, for each firm a dichotomous variable, TECHNOLOGY SPECIALIST, was constructed and valued 1 if we found evidence that, in the period 1996-2001, (1) the firm engaged in licensing activities and (2) had not embodied its inventions into products, 0 otherwise. For each of the companies in our sample, we extensively searched different sources available (including Business & Industry, Factiva, Zephyr and the Securities Data Corporation (SDC) databases as well as company websites and specialized websites) to identify announcements and reports mentioning the name of the firm. We used the Internet Archive's Wayback Machine to visit the version of the websites published in the period 1996-2001 (Yadav et al., 2007). We read the full text of all announcements. To assess whether the company had engaged in licensing activity we referred to the content of the announcement. For instance, we identified as technology licensing agreements those cases in which the announcement: a) mentioned the transfers of inventions from the focal firm to other firms; b) included words such as 'license' or 'licensing'; or c) mentioned that the focal firm received a payment for the transfer of its invention (e.g., referring to some specific licensing terms such as 'royalties' or 'fees'). We also reviewed these sources to assess whether the firm, in the six years of interest, had not embodied the invention into products. To assess this, we referred to the same sources mentioned above. In many cases, companies explicitly specified their strategy on their website or in their reports. When this information was not available, we searched the company website to check whether any products were advertised. We also searched news and specialized press to identify any announcements regarding product launches. Finally, in some cases we used the presence of manufacturing facilities to assess whether the company was active in the product market.

3.2.3 Control Variables

There is a recognized – although controversial – relationship between a firm's size and its inventive performance (e.g., Berends et al, 2014; Cohen and Klepper, 1991; Feldman, 1997; Koen, 1992; Freeman and Soete, 1997; Revilla and Fernandez, 2012; Rothwell and Zegveld, 1982; Rubenstein and Ettlie, 1983; Shefer and Frenkel, 2005). The size of a firm may also affect its profitability in different ways (e.g. Bercovitz and Mitchell, 2007; Mas-Ruiz and Ruiz-Moreno, 2011). Indeed, compared to large firms, small firms may be less able to exploit economies of scale and scope, or be more financially constrained (e.g., Teece, 1986) which may cause a negative effect on the cost of capital (e.g. Apitado and Millington, 1992; Beedles, 1992). Although this study sample is formed by SMEs, a variance across the size of the firms in the sample is present and may affect the result of the statistical analysis. To control for these effects, we calculated the variable SIZE for each firm as the minimum number of employees between 1996 and 2001.

This study also controlled for firms' age. On the one hand, age may affect the ability of a firm to build a reputation as a competent, reliable and trustworthy inventing firm, and consequently may have a positive impact on the chance to have its inventions accepted by the market and profit (Danneels, 2002; Dowling and Helm, 2006; Katila, 2002). On the other hand, age may create organizational inertia and so negatively affect the firm inventive performance (Katila, 2002; Sorensen and Stuart, 2000). To control for all these effects, this study employed an AGE variable that was constructed for each firm as a count of the years elapsed from the firm's foundation year to 2001.

Characteristics of the firms' inventive portfolio may also have an impact on firm performance. One of the more critical characteristics in this regard is the generality of a firm's inventive portfolio, i.e. the attitude of a firm to generate inventions more broadly applicable to a wide range of markets (Bresnahan and Trajtenberg, 1995; Gambardella and Giarratana, 2013; Hall et al., 2000; Valentini, 2012). By allowing access to a wider array of markets, a more general inventive portfolio may provide the firms with bigger market size, with positive effects on profitability. To control for these effects, we measured the generality of the inventions according to the procedure employed by Trajtenberg et al. (1997). This measure accounts for the extent to which citations received by a patent are spread across different technological classes. Specifically, for each patent i granted to the firms in our sample and applied in 1996-2001, the patent generality measure was calculated for each patent i, as follows: Patent Generality$_i$ = $1 - \sum_{j=1}^{n} s_{ij}^2$ where s_{ij} indicates the share of citations received by patent i from patents belonging to patent class j, out of n patent classes. To account for any forward citations truncation issues (Hall et al., 2005; Rosenzweig and Mazursky, 2013) we calculated the measure by using the citations received by each patent in the first three years after patent grant. The patent generality measure was then averaged at the firm level to obtain a FIRM INVENTION GENERALITY variable.

We also control for the strength of the appropriability regime, which might exert an important impact not only in determining the strategy chosen by a firm to commercialize its inventions (Teece's, 1986) but also on the firm propensity to engage in invention activities in the first place (Dosi et al., 2006; Laursen and Salter, 2014; Teece, 1986). Hence, we controlled for the differences in the strength of patent rights across the European countries represented in this study sample by constructing a PATENT STRENGTH control variable on the basis of the index of patent protection developed by Park (2008). This study was an update to 2005 and an extension to 122 countries of a previously developed patent protection index by Ginarte and Park (1997) covering 110 countries and referring to a time span from 1960 to 1990. In both studies, the index of patent protection was constructed, per country per quinquennium – within the timeframe 1960-1990 (Ginarte and Park, 1997) and the timeframe 1995-2005 (Park, 2008) – on the basis of five categories of patent laws: 1) extent of coverage; 2) membership in international patent agreements; 3) provisions for loss of protection; 4) enforcement mechanisms; 5) duration. For each country and for each period, they then scored each of these categories a value ranging from 0 to 1 and then summed up to constitute an overall value of patent index (per country per period) ranging from 0 to 5. To construct our measure of PATENT STRENGTH, per each European country included in this study sample, we took the average of the 1995 and 2000 patent protection index values. These results were then normalized so that the strongest possible level of patent protection is equal to 1.

Finally, we included a set of INDUSTRY DUMMIES in order to control for industry (defined at the level of one digit SIC code) specific effects. Descriptive statistics and correlations are displayed in Table 3.

TABLE 3 Descriptive Statistics and Pairwise Correlation[a]

Descriptive Statistics and Pairwise Correlation

Variables	Description	Obs	Mean	SD	Min	Max	1	2	3	4	5	6	7
1. INVENTIVE PERFORMANCE	$\sum_{i=1}^{n}(1+C_i)$, where n is the count of the EPO-granted patents that had been applied for within the timeframe 1996-2001 and Ci is the number of citations subsequently received by each patent	551	3.492	7.447	1.000	106.000	1						
2. PROFITABILITY	Mean of the company's Return on Assets (ROA) obtained within the timeframe 1996-2001	551	5.230	15.050	-81.043	57.600	-0.133***	1					
3. TECHNOLOGY SPECIALIST	Dummy variable taking value 1 is the firm engaged in licensing activity and did not sell products in the period 1996-2001	551	0.036	0.187	0.000	1.000	0.067	-0.333***	1				
4. SIZE	The minimum number of employees of the firm between 1996 and 2001	551	55.595	54.877	1.000	248.000	0.107**	0.110**	-0.132***	1			
5. AGE	Count of the years elapsed from the firm's foundation year to 2001	551	37.031	34.305	1.000	394.000	-0.056	0.107**	-0.152***	0.343***	1		
6.FIRM INVENTION GENERALITY	Firm level mean of Patent Generality$_i$. Patent Generality$_i$ = 1–$\sum_{j=1}^{n} s_{ij}^2$ where s_{ij} indicates the share of citations received by patent i from patents belonging to patent class j, out of n patent classes	551	0.365	0.167	0.000	0.775	-0.024	0.013	-0.033	-0.03	-0.093**	1	
7. PATENT STRENGTH	For each European country included in this study sample, average of the 1995 and 2000 patent protection indices obtained by Park's (2008) study (normalized)	551	0.898	0.026	0.788	0.921	0.025	0.082*	-0.089**	-0.067	-0.042	-0.051	1

a. * p< 0.1; ** p< 0.05;   *** p< 0.0

4. RESULTS

We first estimated the impact of being a technology specialist through an OLS regression (Table 4). Model 4.1 estimates the inventive performance of the firm as a function of its choice to become a technology specialist and a set of controls and tests Hypothesis 1 that technology specialist SMEs display a higher inventive performance than vertically integrated SMEs – against the null hypothesis that the inventive performance of technology specialist SMEs is not statistically significantly different from the inventive performance of vertically integrated SMEs. Results of model 4.1 show that the coefficient of the variable TECHNOLOGY SPECIALIST equals to 0.386, which means technology specialists display an inventive performance about 47 per cent greater than the inventive performance of vertically integrated firms (p value <0.10). Model 4.2 estimates instead the profitability of the firm as a function of its choice to become a technology specialist and a set of controls, and tests Hypothesis 2 that technology specialist SMEs display a lower profitability than vertically integrated SMEs – against the null hypothesis that the profitability of technology specialist SMEs is not statistically significantly different from the profitability of vertically integrated SMEs. Results of model 4.2 show that the coefficient of interest equals to -0.490, which implies technology specialist are about 39 per cent less profitable than vertically integrated SMEs (p value <0.01).

Table 4. OLS regression estimation[a, b]

	Model 4.1	Model 4.2
	Inventive Performance (Log)	**Profitability (Log)**
TECHNOLOGY SPECIALIST	0.386*	-0.490***
	(0.206)	(0.124)
SIZE (Log)	0.147***	0.006
	(0.034)	(0.020)
AGE (Log)	-0.109**	0.072***
	(0.045)	(0.027)
FIRM INVENTION GENERALITY (Log)	-0.001	-0.031
	(0.057)	(0.034)
PATENT STRENGTH (Log)	0.129	-0.096
	(1.197)	(0.719)
Industry dummies	Included	Included
Constant	0.671*	4.182***

	(0.352)	(0.211)
N. Observations	551	551
R squared	0.073	0.099

[a]* p< 0.1; ** p< 0.05; *** p< 0.01
b Since the minimum of the variable FIRM INVENTION GENERALITY is 0, we added 0.01 to the variable before taking the logarithm; since the minimum of the variable PROFITABILITY is -81.043, we added 81.053 (|min|+0.01) to the variable before taking the logarithm.

To account for the possibility that firms' choice to become a technology specialist is endogenous to their performance, we employed a two stage least square model (2SLS) (Wooldridge, 2002). In implementing this model, we have used the variable TECHNOLOGY SPECIALIST as the dependent variable of the first equation, and INVENTIVE PERFORMANCE and PROFITABILITY, respectively, as the dependent variables of the second stage. We selected the average proportion of technology specialists in the same country and similar size of the focal firm as an instrument for the variable TECHNOLOGY SPECIALIST. The rationale behind this choice is related to the fact that some exogenous characteristics of the country's institutional environment (for instance, the Intellectual Property Right (IPR) protection or the extent of local competition) may affect a SMEs' decision to become technology specialists, and this influence varies according to the firm category size. Hence, in calculating this variable we have grouped SMEs in two groups: firms with less than 38 employees and firms with over 38 employees, where 38 employees is the median number of employees of firms in our sample.

In Table 5a and 5b we report the results from the 2SLS. Model 5.1 estimates the first stage equation, which shows how the average proportion of technology specialists in the same country and similar size of the focal firm is positively correlated with the likelihood of the focal firm being a technology specialist. Model 5.2 estimates the inventive performance of the firm as a function of its choice to become a technology specialist and a set of controls. Model 5.3 estimates the firm profitability as a function of the firm choice to become a technology specialist and a set of controls. Results from both Model 5.2 and Model 5.3 largely confirm the results of the OLS model and show that being a technology specialist has a positive impact on the inventive performance of a firm and a negative impact on firm profitability, consistent respectively with our Hypotheses 1 and 2.

TABLE 5a Two Stage Least Square Regression Estimation: First Stage[a, b]

	Model 5.1
	Technology Specialist
INSTRUMENTAL VARIABLE	1.446***
	(0.177)
SIZE (Log)	0.000
	(0.007)
AGE (Log)	-0.025***
	(0.009)
FIRM INVENTION GENERALITY (Log)	-0.010
	(0.011)
PATENT STRENGTH (Log)	0.240
	(0.249)
Industry dummies	Included
Constant	0.101
	(0.069)
N. Observations	551

TABLE 5b Two Stage Least Square Regression Estimation: Second Stage[a, b]

	Model 5.2	Model 5.3
	Inventive Performance (Log)	**Profitability (Log)**
TECHNOLOGY SPECIALIST	2.765***	-2.249***
	(0.694)	(0.437)
SIZE (Log)	0.167***	-0.008
	(0.038)	(0.024)
AGE (Log)	-0.014	0.003
	(0.057)	(0.036)
FIRM INVENTION GENERALITY (Log)	0.015	-0.044
	(0.064)	(0.040)
PATENT STRENGTH (Log)	1.077	-0.797
	(1.363)	(0.859)
Industry dummies	Included	Included
Constant	0.237	4.078***
	(0.514)	(0.324)
N. Observations	551	551

a * p< 0.1; ** p< 0.05; *** p< 0.01

b Since the minimum of the variable FIRM INVENTION GENERALITY is 0, we added 0.01 to the variable before taking the logarithm; since the minimum of the variable PROFITABILITY is -81.043, we added 81.053 (|min|+0.01) to the variable before taking the logarithm.

A possible concern regards the small number of technology specialists in our sample (20 over 551). To increase comparability among technology specialists and vertically integrated SMEs (and also to further address any endogeneity issue) we replicated the analysis on a subsample which included technology specialists and a control group constituted by an equal number of similar non-technology specialists. In particular, we used a propensity score matching method to select the group of vertically integrated firms, similar to the technology specialist firms along several important dimensions which could determine the firm choice to become a technology specialist (Dehejia and Wahba, 2002; Hasan et al., 2011; Rosenbaum and Rubin, 1983), including firm age, size, firm invention generality, industry affiliation and appropriability at the country level. For each technology specialist, the closest matching company among the vertically integrated firms was chosen. We replicated the OLS regression analysis using this subsample of 40 companies. Results are reported in Table 6. Model 6.1 estimates the inventive performance of the firm as a function of its choice to become a technology specialist and the set of controls, while Model 6.2 estimates instead the profitability of the firm as a function of its choice to become a technology specialist and the set of controls. The results support both Hypotheses 1 and 2.

Table 6. OLS regression estimation (after matching)[a, b]

	Model 6.1	Model 6.2
	Inventive Performance (Log)	**Profitability (Log)**
TECHNOLOGY SPECIALIST	0.732**	-0.738*
	(0.329)	(0.366)
SIZE (Log)	-0.128	-0.103
	(0.151)	(0.168)
AGE (Log)	-0.110	0.319
	(0.204)	(0.227)
FIRM INVENTION GENERALITY (Log)	0.074	-0.105
	(0.222)	(0.247)
PATENT STRENGTH (Log)	-0.382	-2.489
	(3.833)	(4.260)
Industry dummies	Included	Included
Constant	0.720	4.140**
	(1.606)	(1.785)
N. Observations	40	40
R squared	0.240	0.212

[a] * p< 0.1; ** p< 0.05; *** p< 0.01

b Since the minimum of the variable FIRM INVENTION GENERALITY is 0, we added 0.01 to the variable before taking the logarithm; since the minimum of the variable PROFITABILITY is -81.043, we added 81.053 (|min|+0.01) to the variable before taking the logarithm.

We also used a quantile regression to estimate the relationship between the choice of being a technology specialist and the firm's inventive performance and profitability. In fact, the distributions of the two dependent variables (INVENTIVE PERFORMANCE and PROFITABILITY) are characterized by heavy tails. Other studies, whose dependent variables were characterized by heavy tails, have employed a quantile regression (Coad and Rao, 2008; Koenker and Basset, 1978). Results (available upon request) are again consistent with our theory.

5. DISCUSSION

These results have important implications for practitioners and researchers.

5.1 Implications to practice

The results from this paper enhance our understanding of the viable strategies a small firm can choose for profiting from its inventions. Our findings suggest that, because of the imperfections that plague technology markets and of the low bargaining power of firms lacking downstream assets (i.e., technology specialists), the choice of simply selling inventions disembodied from products in the MFT (as opposed to directly commercializing them to final customers) might not be the best option for SMEs. To be sure, these results reflect what happens on average across all industries in all European countries. However, our research might suggest that the viability of a technology specialist strategy would increase in those industries and/or countries where the strength of the IPR regime or the tendency to engage in trust-based behaviours limits the imperfections that hamper the well-functioning of MFT. In this respect, future research might better elaborate on the role of environmental and firm contingencies that make technology specialist SMEs more profitable than vertically-integrated SMEs.

The results from this paper also raise implications for policy makers. A key conclusion of past literature of MFT is that the diffusion of technology specialists – and the consequent development of MFT – is socially desirable because it facilitates the division of innovative labour amongst small and large firms, which tend to have a comparative advantage, respectively, in generating inventions and commercializing them (e.g., Arora, 2001; Teece, 1986). However, our study shows that while technology specialist SMEs have better inventive performance compared to vertically-integrated SMEs, they also display worse profitability, an outcome that over time might reduce the overall number of firms that choose this strategy. Hence, our findings have relevant policy implications, because they might imply that the number of SMEs deciding to become technology specialists might be lower than optimal.

For policy-makers, this emphasizes the importance of designing mechanisms that reduce the high transaction costs that plague MFT, in order to increase technology specialists' profitability. For instance, policy makers could favour the emergence of specialized intermediaries – that is, firms providing services such as patent evaluation, patent monetization and patent management, which might contribute to solve some of the imperfections affecting MFT (e.g., information asymmetries between buyers and sellers). The investigation of the role of intermediaries on the liquidity, transparency and efficiency of the MFT may constitute a promising new line of inquiry for future research.

5.2 Implications to theory

This paper also has implications to theory. First of all, this study better specifies the idea, developed by previous contributions on MFT (e.g., Arora et al. 2001), that the division of innovative labour amongst small and large firms is optimal for the overall economy. Indeed, our study shows that small firms that specialize in upstream activities, as opposed to spreading their limited resources among research and commercialization activities, generate more valuable inventions. However, since technology specialists are relatively less profitable than vertically-integrated firms, only a few SMEs may decide to specialize upstream. Thus, the potential social benefits associated with the generation of better inventions by technology specialists might not be fully realized.

Second, this paper also has implications for research on firm survival. Recent studies have demonstrated the role of inventive performance on firms' survival (e.g., Cefis and Marsili, 2006). By emphasizing that technology specialists achieve a superior inventive performance but that these firms experience worse profitability, this study calls for the need to improve our understanding of the relationship between inventive performance and firm survival. For instance, future research could analyse whether the positive relationship between a firm's inventive performance and survival only holds for those firms that have acquired the downstream assets needed to commercialize their inventions to the final customers.

Finally, the results from this paper might also have implications for research on Venture Capital (VC). It is well established that Venture Capital (VC) is crucial for small and young firms performance (Bottazzi and Da Rin, 2002; Samila and Sorenson, 2011). The results of this study would suggest that the VC role could be particularly important when MFT are not well functioning, and so vertical integration is a better option for small firms in order to profit from their inventions. Indeed, VC might provide financially-constrained small firms not only with the necessary resources to invest in the acquisition of downstream assets (e.g., Stucki, 2014), but also with the managerial expertise required to commercialize their products to the final customers (e.g., Robson and Bennett, 2000). Hence, an interesting avenue for future research could be the exploration of the role played by VC as a potential substitute for MFT.

5.3 Limitations

This study has some limitations. First, we only considered SMEs inventive performance and profitability, but other performance dimensions could be evaluated. For instance, future studies could investigate whether the decrease in profitability experienced by technology specialists is actually traded off with superior growth outcomes in terms of company size, or if the choice of being a technology specialist is more appropriate to foster firms' adaptability in the face of a changing environment. In this respect, it could be interesting to replicate this study across different time windows in order to see how firms using different strategies react to environmental and macroeconomic shocks.

Second, our sample of technology specialists is quite limited. Two issues might be considered in this respect, i.e. whether (1) the data are representative of the overall populations of technology specialists in Europe in the time period considered; (2) the results obtained are reliable. With regard to the first point, it should be noted that very limited data are available publicly on the population of SMEs who are technology specialists. Hence, we believe that the selected sample is valuable because it allows us to provide an analysis on the behavior of a relevant type of firms that otherwise could not be investigated.

Regarding the second point, when the independent variable does not display relevant variation, there is a high risk of the results not being statistically significant (e.g., Wooldridge, 2002). Nevertheless, our results are significant. Hence we could argue that what we presented was a conservative estimate of the real effect and that our results could be even stronger if we had more variation in our main independent variable, that is, if we had a larger number of technology specialists.

Third, this study only focuses on small and medium firms. However, the choice between selling an invention in the MFT and embedding it into a product to be sold to final customers might in principle also regard other players, like large firms or users. Future research should therefore investigate to what extent and under what contingencies these players sell their ideas to other firms rather than selling their products to final customers. In addition, we employ a cross sectional perspective in our analysis. The investigation of the same issue in a longitudinal perspective could potentially lead to insightful results, and also offer the possibility to control for firm time-invariant heterogeneity. However, we acknowledge that the panel data on technology commercialization strategies of small private firms represents a challenging task since this data are not available on public or commercial dataset. Future research may consider the possibility of using a survey approach in order to obtain some insight using a longitudinal dataset.

Finally, this paper refers to the use of licensing agreements as evidence of the fact that a firm pursued a “technology specialist” strategy, i.e. it profited from its inventions by licensing them in disembodied form to other firms as opposed to incorporating them into products, and investigates the implications related to the use of this strategy on firm profitability and inventive performance. It would be very interesting for future research to also investigate the antecedents of (i.e. the reasons behind) the firm’s choice to use licensing agreements. In addition to a monetary reason, there might be other strategic reasons that led firms to license their inventions such as entering a foreign market or setting an industry standard. In this respect, whilst the use of secondary data allows conducting such investigation only to a very limited extent, the use of surveys or in-depth case studies could provide new relevant insights in this area.

6. CONCLUSION

This study investigates the effects of being a technology specialist on firm inventive performance and profitability. In particular, the results from this paper show that technology specialist SMEs are better performers than vertically-integrated small firms in terms of inventiveness, but worse performers in terms of profitability. Focusing their attention on inventive activities allows technology specialists to learn how to generate higher quality inventions faster than vertically-integrated firms, due to the deeper and broader inventive experience technology specialists have the chance to accumulate (Arora et al. 2001; Katila and Ahuja, 2002; Yelle, 1979); and to their flexible organization structure (Henderson and Clark, 1990; Fosfuri and Roende, 2009). However, the imperfections that plague the functioning of MFT (Cockburn, 2007), and the higher bargaining power of firms possessing commercialization assets vis-a-vis research assets (e.g. Arora and Nandkumar, 2012; Teece, 1986), lead technology specialists to experience a significantly lower profitability than vertically-integrated firms.

This study has a number of practical and theoretical implications, as already discussed in the previous section. One of the most interesting contributions is probably that it emphasizes the existence of a conundrum between what would be socially optimal – that is, the division of innovative labour amongst large firms, specializing in downstream commercialization, and small firms, specializing in inventing – and what would be privately optimal for small firms, which instead have the incentive to integrate downstream to better capture the economic returns from their inventions. Hence, this study calls for the need to design and implement institutional mechanisms aimed at addressing this conundrum and reconciling private with social benefits in the context of firms' inventive activity.

REFERENCES

Ahuja, G., Morris Lampert, C., 2001. Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. Strategic Management Journal 22(6-7), 521-543.

Allarakhia, M., Walsh, S., 2011. Managing knowledge assets under conditions of radical change: the case of the pharmaceutical industry. Technovation 31(2/3), 105–117.

Apitado, V. P., Millington, J. K., 1992. Restrictive loan covenants and risk adjustment in small business lending. Journal of Small Business Management 30(1), 38-48.

Arora, A., 1996. Contracting for tacit knowledge: The provision of technical services in technology licensing contracts. Journal of Development Economics 50(2), 233–256.

Arora, A., Ceccagnoli, M., 2006. Patent protection, complementary assets and firms' incentives for technology licensing. Management Science 52(2), 292–308.

Arora, A., Fosfuri, A., Gambardella, A., 2001. Markets for Technology: The Economics of Innovation and Corporate Strategy. MIT Press, Cambridge MA.

Arora, A., Gambardella, A., 1990. Complementarity and external linkages: The strategies of the large firms in biotechnology. Journal of Industrial Economics 38, 361–379.

Arora, A., Nandkumar, A., 2012. Insecure advantage? Markets for technology and the value of resources for entrepreneurial ventures. Strategic Management Journal 33(3), 221–251.

Arrow, K. J., 1983. Innovation in large and small firm, in: J. Ronen (Ed.), Entrepreneurship. Lexington Books, Lexington, pp. 15-28.

Beedles, W. L., 1992. Small firm equity cost: evidence from Australia. Journal of Small Business Management 30(3), 57-65.

Beggs, A. W., 1992. The licensing of patents under asymmetric information. International Journal of Industrial Organization 10, 171-191.

Belenzon, S., Patacconi, A., 2013. Innovation and firm value: An investigation of the changing role of patents, 1985–2007. Research Policy 42(8), 1496-1510.

Bercovitz, J., Mitchell, W., 2007. When is more better? The impact of business scale and scope on long-term business survival, while controlling for probitability. Strategic Management Journal 28, 61-79.

Berends, H., Jelinek, M., Reymen, I., Stultiëns, R., 2014. Product Innovation Processes in Small Firms: Combining Entrepreneurial Effectuation and Managerial Causation. Journal of Product Innovation Management 31(3), 616-635.

Bianchi, M., Cavaliere, A., Chiaroni, D., Frattini, F., Chiesa, V., 2011. Organisational modes for Open Innovation in the bio-pharmaceutical industry: An exploratory analysis. Technovation 31, 22-33.

Bottazzi, L., Da Rin, M., 2002. Venture capital in Europe and the financing of innovative companies. Economic Policy 17, 229-270.

Bresnahan, T. F., Trajtenberg, M., 1995. General purpose technologies “Engines of Growth”? Journal of Econometrics 65, 83-108.

Ceccagnoli, M., Jiang, L., 2013. The cost of integrating external technologies: supply and demand drivers of value creation in the markets for technology. Strategic Management Journal 34, 404-425.

Cefis, E., Marsili, O., 2006. Survivor: the role of innovation in firms’ survival. Research Policy 35(5), 626-641.

Chiu, Y. C., Lai, H. C., Lee, T. Y., Liaw, Y. C. 2008. Technological diversification, complementary assets, and performance. Technological Forecasting and Social Change 75(6), 875-892.

Coad, A., 2007. A Closer Look at Serial Growth Rate Correlation. Review of Industrial Organization 31(1), 69-82.

Coad, A., Rao, R., 2008. Innovation and firm growth in high-tech sectors: A quantile regression approach. Research Policy 37 (4), 633-648.

Cockburn I, 2007. Is the market for technology working well? Obstacles to licensing and ways to overcome them. Conference on Economics of Technology Policy, Monte Verità, Switzerland.

Cohen, W. M., Klepper, S., 1991. The tradeoff between firm size and diversity in the pursuit of technological progress. Small Business Economics 4, 1-14.

Conceicao, O., Fontes, M., Calapez, T., 2012. The commercialization decisions of research-based spin-off: targeting the market for technologies. Technovation 32, 43-56.

Danneels, E., 2002. The dynamics of product innovation and firm competences. Strategic Management Journal 23(12), 1095-1121.

Dechenaux, E., Thursby, J., Thursby, M., 2011. Inventor moral hazard in university licensing: The role of contracts. Research Policy 40(1), 94-104.

Dehejia, R. H., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. Review of Economics and Statistics 84(1), 151–161.

Díez-Vial, I., 2009. Firm Size Effects on Vertical Boundaries. Journal of Small Business Management 47(2), 137-153.

Dosi, G., Marengo, L., Pasquali, C., 2006. How much should society fuel the greed of innovators? On the relations between appropriability, opportunities and rates of innovation. Research Policy 35, 1110-1121.

Dowling, M., Helm, R., 2006. Product development success through cooperation: A study of entrepreneurial firms. Technovation 26, 483-488.

Dushnitsky, G., 2010. Entrepreneurial optimism in the market for technological inventions. Organization Science 21(1), 150-167.

Feldman, M., 1997. Small Firm Innovative Success: External Resources and Barriers, Maryann Feldman and Associates, Baltimore MD.

Firth, R. W., Narayanan, W. K., 1996. New Product Strategies of Large, Dominant Product Manufacturing Firms: An Exploratory Analysis. Journal of Product Innovation Management 13, 334-347.

Fosfuri, A., Roende, T., 2009. Leveraging resistance to change and the skunk works model of innovation. Journal of Economic Behaviour and Organization 72(1): 274-289.

Fosfuri, A., 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. Strategic Management Journal 27(12), 1141–1158.

Freeman, C., Soete, L., 1997. The Economics of Industrial Innovation, Pinter, London.

Frietsch, R., Neuhäusler, P., Jung, T., Van Looy, B., 2014. Patent indicators for macroeconomic growth—the value of patents estimated by export volume. Technovation 34, 546-558.

Galasso, A., Simcoe, T., 2011. CEO Overconfidence and Innovation. Management Science 57, 1469-1484.

Gambardella, A., Giarratana, M., 2013. General Technological Capabilities, Product Market Fragmentation, and Markets for Technology. Research Policy 42, 315-325.

Gambardella, A., 2013. The economic value of patented inventions: Thoughts and some open questions. International Journal of Industrial Organization 31 (5), 626-633.

Gans, J. S., Hsu, D. H., Stern, S., 2002. When does start-up innovation spur the gale of creative destruction? RAND Journal of Economics 33(4), 571-586.

Gans, J. S., Hsu, D. H., Stern, S., 2008. The impact of uncertain intellectual property rights on the market for ideas: evidence from patent grant delays. Management Science 54, 982-997.

Ginarte, J. C., Park, W. G., 1997. Determinants of patent rights: a cross-national study. Research Policy 26, 283-301.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Hoisl, K., Le Bas, C., Luzzi, A., Magazzini, L., Nesta, L., Nomaler, Ö., Palomeras, N., Patel, P., Romanelli, M., Verspagen, B., 2007. Inventors and invention processes in Europe: results from the PatVal-EU Survey. Research Policy 36(8), 1107-1127.

Glasmeier, A. K., 1991. Technological discontinuities and flexible production networks. The case of Switzerland and the world watch industry. Research Policy 21, 469-485.

Gouvea, R., Linton, J. D., Montoya, M., Walsh, S. T., 2012. Emerging technologies and ethics: A race-to-the-bottom or the top?. Journal of Business Ethics 109(4), 553-567.

Grant, R., 2002. Contemporary Strategy Analysis, Blackwell Publishing, Malden MA.

Griliches, Z., 1984. R&D, Patents and Productivity, University of Chicago Press, Chicago.

Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 27, 1661-1707.

Gupta, A. K., Smith, K. G., Shalley, C. E., 2006. The interplay between exploration and exploitation. Academy of Management Journal 49(4), 693-706.

Hall, B., Jaffe, A., Trajtenberg, M., 2000. Market value and patent citations: a first look. NBER Working Paper No.7741, National Bureau of Economic Research, Inc, Cambridge, MA.

Hall, B. H., Jaffe, A., Trajtenberg, M., 2005. Market value and patent citations. RAND Journal of Economics 36(1), 16-38.

Hall, H. B., Thoma, G., Torrisi, S., 2007. The market value of patents and R&D: Evidence from European firms. Working paper 13426, National Bureau of Economic Research, Cambridge, Mass.

Harhoff, D., Hoisl, K., Webb, C., 2006. European patent citations – How to count and how to interpret them? University of Munich and CEPR (London), University of Munich, and OECD.

Hasan, I., Kobeissi, N., Wang, H., 2011. Global equity offerings, corporate valuation, and subsequent international diversification. Strategic Management Journal 32(7), 787-796.

Henderson, R., 1993. Underinvestment and incompetence as responses to radical innovation. evidence from the photolithographic industry. Rand Journal of Economics 24(2), 248-270.

Henderson, R., Clark, K. B., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly 35(1), 9-30.

Hess, A. M., Rothaermel, F. T., 2011. When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry. Strategic Management Journal 32, 895-909.

Hicks, D., Hegde, D., 2005. Highly innovative small firms in the markets for technology. Research Policy 34(5), 703-716.

Hoffman, K., Parejo, M., Bessant, J., Perren, L., 1998. Small firms, R&D, technology and innovation in the UK: a literature review. Technovation 18(1), 39-55.

Holmstrom, B., 1989. Agency costs and innovation. Journal of Economic Behavior & Organization 12(3), 305-327.

Katila, R., 2002. New Product Search Over Time: Past Ideas in their Prime? Academy of Management Journal 45(5), 995-1010.

Katila, R., Ahuja, G., 2002. Something old, something new: a longitudinal study on search behaviour and new product introduction. Academy of Management Journal 45(6), 1183-1194.

Kelley, D. J., Ali, A., Zahra, S. A., 2013. Where Do Breakthroughs Come From? Characteristics of High-Potential Inventions. Journal of Product Innovation Management 30(6), 1212-1226.

Koen, M. S., 1992. Business Intellectual Property Prediction. MOSCI Corporation, Rolla MO.

Koenker, R., Bassett, G, 1978. Regression quantiles. Econometrica 46(1), 33–50.

Krammer, M. S. S., 2014. Assessing the relative importance of multiple channels for embodied and disembodied technological spillovers. Technological Forecasting & Social Change 81, 272-286.

Laursen, K., Salter, A., 2014. The Paradox of Openness: Appropriability, External Search and Collaboration. Research Policy 43(5), 867-878. 5

Leiblein, M. J., Madsen, T. L., 2009. Unbundling competitive heterogeneity: incentive structures and capability influences on technological innovation. Strategic Management Journal 30, 711-735.

Leone, M. I., Reichstein, T., 2012. Licensing-in fosters rapid invention! the effect of the grant-back clause and technological unfamiliarity. Strategic Management Journal 33(8), 965-985.

Leuven, E., Sianesi, B., 2003. PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. http://ideas.repec.org/c/boc/bocode/s432001.html

Li, H., Tang, M., 2010. Vertical integration and innovative performance: The effects of external knowledge sourcing modes. Technovation 30, 401-410.

Linton, J., Walsh, S., 2013. The effect of technology on learning during the acquisition and development of competencies in technology-intensive small firms. International Journal of Entrepreneurial Behaviour & Research 19(2), 3-3.

Mangematin, V., Errabi, K., Gauthier, C., 2011. Large players in the nanogame: dedicated nanotech subsidiaries or distributed nanotech capabilities? The Journal of Technology Transfer 36(6), 640–664.

Marion, T. J., Friar, J. H., Simpson, T. W., 2012. New Product Development Practices and Early-Stage Firms: Two In-Depth Case Studies. Journal of Product Innovation Management 29, 639-654.

Mariotti, S., Cainarca, G. C., 1986. The evolution of transaction governance in the textile clothing industry. Journal of Economic Behaviour and Organization 7, 351-374.

Mas-Ruiz, F., Ruiz-Moreno, F., 2011. Rivalry within strategic groups and consequences for performance: the firm-size effects. Strategic Management Journal 32, 1286-1308.

McGahan, A. M., Silverman, B. S., 2006. Profiting from technological innovation by others: The effect of competitor patenting on firm value. Research Policy 35(8), 1222–1242.

O'Connor, G. C., DeMartino, R., 2006. Organizing for Radical Innovation: An Exploratory Study of the Structural Aspects of RI Management Systems in Large Established Firms. Journal of Product Innovation Management 23, 475-497.

OECD, 1997, Small Business, Job Creation and Growth: Facts, Obstacles and Best Practices, available at www.oecd.org/cfe/smes/2090740.pdf.

Park, W. G., 2008. International patent protection: 1960-2005. Research Policy 37, 761-766.

Powell, T. C., 1992. Strategic Planning as Competitive Advantage. Strategic Management Journal 13(7), 551-558.

Revilla, A. J., Fernandez, Z., 2012. The relation between firm size and R&D productivity in different technological regimes. Technovation 32, 609-623.

Ritala, P., Hurmelinna-Laukkanen, P., 2009. What's in it for me? Creating and appropriating value in innovation-related coopetition. Technovation 29, 819-828.

Robson, P. J. A., Bennett, R. J., 2000. SME growth: The relationship with business advice and external collaboration. Small Business Economics 15, 193-208.

Rosenbaum, P. R., Rubin, D. B., 1983. The central role of the propensity score in observational studies for causal effects. Biometrika 70(1): 41–55.

Rosenzweig, S., Mazursky, D., 2013. Constraints of Internally and Externally Derived Knowledge and the Innovativeness of Technological Output: The Case of the United States. Journal of Product Innovation Management 31(2), 231-246

Rothwell, R., Zegveld, W., 1982. Innovation and the Small and Medium-Sized Firm, Pinter, London.

Rubenstein, A. H., Ettlie, J. E., 1983. Radical Technology, Organization Science, Structure and Context in the Innovation Process, Applied Science and Technology Association, Evanston IL.

Sakakibara, M., 2010. An empirical analysis of pricing in patent licensing contracts. Industrial and Corporate Change 19(3), 927-945.

Samila, S., Sorenson, O., 2011. Venture capital, entrepreneurship, and economic growth. The Review of Economics and Statistics 93, 338-349.

Shane, S., 2002. Selling university technology: Patterns from MIT. Management Science 48(1), 122–138.

Shefer, D., Frenkel, A., 2005. R&D, firm size and innovation: an empirical analysis. Technovation 25, 25-32.

Smith, A., 1776 [1983]. The Wealth of Nations, Penguin Papers, Harmondsworth, UK.

Somaya, D., Kim, Y., Vonortas, N. S., 2010. Exclusivity in licensing alliances: using hostages to support technology commercialization. Strategic Management Journal 32, 159-186.

Sørensen, J. B., Stuart, T., E., 2000. Aging, obsolescence, and organizational innovation. Administrative Science Quarterly 45(1), 81-112.

Sreekumaran, S. N., Mathew, N., Nag, D. 2011. Dynamics between patent latent variables and patent price. Technovation 31, 648-654.

Stigler, G., 1951. The division of labour is limited by the extent of the market. Journal of Political Economy 59, 185-193.

Stucki, T., 2014. Success of start-up firms. The role of financial constraints. Industrial and Corporate Change 23(1), 25-64.

Taylor, A., Helfat, C. E., 2009. Organizational Linkages for Surviving Technological Change: Complementary Assets, Middle Management, and Ambidexterity. Organization Science 20(4), 718-739.

Teece, D. J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15, 285–305.

Trajtenberg, M., 1990. A penny for your quotes: Patent citations and the value of innovations. RAND Journal of Economics 21(1), 172-187.

Trajtenberg, M., Henderson, R., Jaffe, A., 1997. University vs. corporate patents: a window on the basicness of invention. Economics of Innovation and New Technology 5(1), 19-50.

Tripsas, M., 1997. Unraveling the process of creative destruction: complementary assets and incumbent survival in the typesetter industry. Strategic Management Journal 18 (Summer Special Issue), 119–142.

Valentini, G., 2012. Measuring the Effect of M&A on Patenting Quantity and Quality. Strategic Management Journal 33, 336-346.

Veer, T., Jell, F., 2012. Contributing to markets for technology? A comparison of patent filing motives of individual inventors, small companies and universities. Technovation 32, 513-522.

Wang, Y., Vanhaverbeke, W., Roijakkers, N., 2012. Exploring the impact of open innovation on national systems of innovation - A theoretical analysis. Technological Forecasting & Social Change 79, 419-428.

Winter, S. G., 1987. Knowledge and competence as strategic assets, in: Teece, D. J. (Ed.), The competitive challenge: Strategies for Industrial Innovation and Renewal, Ballinger, Cambridge, MA, pp. 159-184.

WIPO, 2014. http://www.wipo.int/export/sites/www/freepublications/en/licensing/903/wipo_pub_903.pdf.

Wooldridge, J. M., 2002. Econometric analysis of cross-section and panel data, The MIT Press, Cambridge, Massachussets.

Yadav, M. S., Prabhu, J. C., Chandy, R. K., 2007. Managing the future: CEO attention and innovation outcomes. Journal of Marketing, 71 (4), 84-101.

Yelle, L. E., 1979. The learning curve. Historical review and comprehensive survey. Decision Science 10, 302-328.

Young, A., 1928. Increasing returns and economic progress. Economic Journal 38, 527-542.