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EFFECTS OF FIRM-SPECIFIC FACTORS ON TECHNOLOGY COMMERCIALISATION STRATEGIES: FINDINGS FROM ITALIAN NTBFs

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Abstract

The following study analyses the implication of new technology-based firms' (NTBFs) peculiar characteristics on the commercialization strategy of technology and innovations. The proposed synthetic framework extends previous literature that identified macroeconomic determinants as key drivers in shaping the technology exploitation approach, arguing that firm-specific factors also matter. The availability of financial resources and the type of human competencies may influence the way a firm translates promising "ideas" into a stream of revenues. Funding gap, likely to affect high-tech start-ups, may make difficult for a firm to pursue the heavy investments required to enter the product market. Moreover, the homogeneity within NTBFs' founding teams, notably rich of technical competencies but lacking of academic and work experience in commercial areas, may represent a further difficulty in pursuing downward integration. I argue that both factors influence the firm's technology exploitation strategy driving NTBFs to opt for external rather than internal exploitation.

Further analysis are conducted to understand whether firms pursuing a market for technology's (MFT) oriented strategy at foundation, as time rolls by, switch in favour of a market for product strategy. I argue that only in few exceptions MFT may represent a long-term strategy. By contrast, I suggest that the lowering of financial constraints alongside with the easier access to external competencies push the majority of firms to shift from external to internal technology exploitation and competes into the product market few years after their foundation .

The previous hypotheses are tested on a recent dataset composed of more than 200 Italian NTBFs operating in different high-tech industries. Empirical results confirm the relationship between the founding team's human capital competencies and the strategy put in place at foundation, while give neither significant support nor contradicting indications on the effect of funding gap on the firm's pursued strategy at foundation. Moreover, empirical models suggest a negative relationship between the firm's experience and its propensity towards MFT.

Abstract (Italian)

Il seguente studio analizza le implicazioni delle peculiari caratteristiche tipiche delle new technology based firms (NTBFs) sulla loro strategia di commercializzazione della tecnologia e delle innovazioni. Il framework proposto estende la precedente letteratura, che pone l'attenzione principalmente sui fattori macroeconomici che assumono un ruolo chiave nel determinare lo sfruttamento della tecnologia, sostenendo l'importanza rivestita da fattori firm-specific. Infatti, la disponibilità di risorse finanziarie e di competenze umane può influenzare il modo in cui l'impresa riesce a trasformare promettenti idee in risultati concreti. Un funding gap, che verosimilmente colpisce start-ups operative in settori a alta tecnologia, può rendere difficile l'investimento di ingenti somme necessarie per lo sviluppo degli assets necessari a competere nel market for product. Inoltre, l'omogeneità all'interno del team fondatore delle NTBFs, notoriamente ricco di competenze tecniche ma scarso di esperienza economico-commerciale, può rendere più difficile l'ingresso nel market for product. Entrambi i fattori possono accrescere la propensione delle NTBFs nei confronti del market for technology (MFT).

Ulteriori analisi sono condotte per meglio comprendere se un'impresa attiva nel MFT alla fondazione prediliga, nel lungo termine, il passaggio a una strategia basata sul market for product. Io suggerisco che solo in rari casi il MFT possa rappresentare una strategia di lungo termine, poiché la riduzione delle difficoltà di accesso ai finanziamenti e al mercato del lavoro, può indurre l'impresa a riconsiderare la sua strategia.

Le precedenti ipotesi sono testate su un dataset composto da circa 200 NTBFs italiane operanti in diversi settori ad alta tecnologia. I risultati empirici confermano la relazione tra il capitale umano del team fondatore e la strategia messa in atto dall'impresa, mentre non forniscono né supporto né indicazioni contrarie riguardo al ruolo rivestito dal funding gap. Per concludere, i modelli empirici mostrano una significativa e negativa relazione tra l'esperienza maturata dall'azienda e la sua propensione verso il MFT.

Summary

The following study has the objective to analyse under a different perspective factors which influence firms' propensity, and in particular that of high-technology start-ups, towards market for technology. In fact, in addition to the analysis of macro factors, this study shows that firm-specific factors, such as competencies of the founding team, have a significant impact on the firm's strategy at foundation, and remarks the existence of a relevant knowledge gap. Moreover, the conducted analyses, though underlining the existence of a pronounced funding gap at foundation, do not highlight a significant relationship between the difficulties in accessing debt financing and the firm's propensity towards market for technology (hereafter MFT). To conclude, the study provide empirical support to the evolutionary model of high-tech start-ups from a "soft company" business model to a "hard model" business model, in contrast with theories which support the validity of MFT commercialisation strategy in the long term.

The thesis is organised according to the following structure: chapter one introduces the notion of division of innovative labour and of market for technology, summarizing briefly its development through the years. Chapter two provides a literature review of the factors that influence the firm's propensity towards market for technology. Chapters three and four provide respectively a descriptive analysis of the sample in use and an analysis of the econometric models utilised. The thesis ends with the comment of the econometric results and the conclusions. Hereafter, I propose a brief summary of the thesis.

Chapter one introduces the notion of MFT, its origins and its effects on the model of innovation. After having depicted the growing importance assumed by knowledge in the contemporary society, the thesis reviews the theoretical contribute of several authors that have underlined that the peculiar characteristics of knowledge, such as being a non-rival good and overall difficult to transfer, pose a serious limit to the development of the division of innovative labour (Teece 1988, Winter 1987, von Hippel 1990, 1994). A greater division of labour in the innovation process would lead to a number of advantages such as a higher and superior use of the already developed knowledge and a better exploitation of the comparative advantage between small and large firms in the production of innovative technologies. Despite the nineteenth century has been marked by the development, made by large companies, of extensive laboratories devoted to the research and development of new technologies, a consistent share of innovations of last century originated in small laboratories that subsequently sold their innovations to larger firms, better equipped for commercialisation. The chapter is concluded by an analysis of the evolution of MFT in the last two centuries. Lamoreaux and Sokoloff (1996, 1998) document the existence of a vibrant "market for ideas" in the US in the eighteen century. However, a number of factors led to its dimming in favour of the affirmation of large R&D laboratories of larger firms at the beginning of the

nineteenth century. The nineties represented a turning point. “The changing technology of technological change” (Arora and Gambardella 1994, p. 528) gave new boost to the development of the market for technology, triggering its definitive affirmation worldwide.

Chapter two provides a wide literature review of the factor influencing a firm’s propensity towards MFT. First, I shed light on the concepts of MFT proposed by several authors, and provide the definition in use in this study. Subsequently, building on Lichtenthaler (2008), I analyse the multiple objectives achievable through the commercial exploitation of knowledge through the MFT, these grouped into strategic, monetary and “compulsory” objectives. The thesis developed taking into consideration how macro factors, such as the appropriability regime, the necessity and availability of complementary assets, competition faced in the market for product, transaction costs and uncertainty influence both the firm’s ability to extract rents form innovations and the strategy put in place. In addition to macro factors, this study analyses how the strategy of new technology based firms (hereafter NTBFs), i.e. small firms operating in high technology sectors, can be influenced by firm-specific factors such as the existence of difficulties in accessing debt financing and the presence of a founding team’s knowledge gap in economic areas. This study hypothesizes that credit constraints faced at foundation may lead NTBFs to opt for a technology commercialisation strategy through the MFT. Similarly, I argue that the high level of academic attainment and work experience gained in technical fields, the shortage of competencies gained in socio-economic areas, the limited managerial experience and the difficulty in recruiting skilled personnel increase the firm’s propensity towards a MFT commercialisation strategy instead of the entrance into the market for product. To conclude, this study analyses whether a MFT oriented strategy can be maintained in the long term or firms, thanks to better financial conditions and higher accessibility to human capital in the labour market, tend to opt in favour of the entrance into the product market. In fact, the better financial conditions, due to the retained earnings deriving from the exploitation of previous innovations, and the firm reputation build since foundation, provide NTBFs a better access to financing facilities and thus a better access to complementary assets. Similarly, a better access to the labour market, gives the firm the opportunity to recruit skilled personnel in key areas and thus expand its perimeter downward. Overall, I hypothesize that in the long term, firms, due to the gained experience, tend to switch form a “soft company” business model, characterised by the sale of knowledge under the form of intangible products, to a “hard company” business model where the firm is active in the market for product.

The third chapter provides a number of descriptive statistics of the sample utilised for the econometric tests. The sample is composed of 201 Italian NTBFs operating in the chemical-pharmaceutical, manufacturing ICT and robotic sectors. The descriptive analysis shows both the high level of educational attainment of NTBFs’ founders and the typically technical nature of such education. Founding teams suffer from a pronounced knowledge gap in socio-economic areas. Moreover, the analysis documents both the relevant role played by banks as financing facility in Italy and the pronounced funding gap suffered by high-tech start-ups. To conclude, the analysis of the propensity towards the MFT both at foundation and in 2007 shows that about a third of the NTBFs born pursuing a MFT's oriented strategy, as time rolls by, switch in favour of a commercialisation of technology through the market for product.

The fourth chapter offers the description of the econometric models in use (two-limit tobit and probit), the estimations methods, the variable used and the analytical model proposed.

Chapter five analyses the econometric results. In accordance with what hypothesized, human capital competencies of the founding team have a significant impact on the type of strategy put in place at foundation by the NTBF. The econometric analyses highlight that each year of educational and working experience gained in technical areas increases the firm's propensity towards a MFT commercialisation strategy, while each year spent to accumulate experience in socio-economic areas increases the likelihood of technology exploitation through the market for product. Similarly, founding teams with a previous managerial experience are more likely to pursue a product market commercialisation strategy. Moreover, taking into consideration the level of heterogeneity among the founding team, firms founded by homogeneous teams, likely to be rich of technical competencies, show a greater propensity towards MFT. The analysis do not provide empirical support, nor contradicting indications, to the impact of the firm's funding gap on the strategy put in place. To conclude, sample selection models show a significant relationship of the firm's gained experience on the pursued strategy. Thus, this models offer empirical support to the evolutionary model of NTBFs from "soft company" to "hard company".

To conclude, this thesis offers both theoretical and empirical support to the effect of firm-specific factors on the firm's strategy put in place at foundation, distinguishing between MFT and product market oriented strategy. Moreover, this study offers significant support to the validity of the evolutionary model from "soft company" to "hard company".

Sommario

Il seguente studio ha l'obiettivo di analizzare sotto una nuova prospettiva i fattori che influenzano la propensione delle imprese, e in particolare delle start-ups a elevato contenuto tecnologico, nei confronti del market for technology. Infatti, in aggiunta all'analisi dei fattori macro, lo studio suggerisce un'elevata incidenza dei fattori firm-specific, quali le competenze accumulate dal team fondatore, sulla strategia perseguita dall'impresa alla fondazione, rimarcando quindi l'esistenza di un pronunciato knowledge gap. Inoltre, le analisi condotte, pur sottolineando un pronunciato funding gap per le start-ups alla fondazione, non evidenziano invece una relazione significativa tra le difficoltà di finanziamento e la propensione dell'azienda verso il market for technology. Infine, lo studio supporta empiricamente la validità del modello di evoluzione delle imprese da "soft companies" a "hard companies", a scapito delle teorie che indicano la strategia MFT oriented come opportunità di lungo periodo.

La tesi è organizzata secondo la struttura seguente: il capitolo primo introduce la nozione di divisione di lavoro innovativo e di market for technology, riassumendone brevemente lo sviluppo fino ai giorni nostri. Il capitolo secondo propone una rassegna della letteratura economica che analizza fattori che determinano la propensione di un'impresa verso il market for technology. I capitoli tre e quattro propongono rispettivamente un'analisi descrittiva del campione in uso e un'analisi dei modelli econometrici utilizzati. Lo studio si conclude con il commento dei risultati empirici e le conclusioni. Di seguito, propongo una breve sintesi della tesi, seguendone la suddivisione in capitoli.

Il capitolo primo introduce la nozione di market for technology (in seguito MFT), le origini e gli effetti sul processo innovativo. Dopo aver posto l'accento sulla crescente importanza rappresentata dalla conoscenza nella società contemporanea, si analizzano i contributi di alcuni ricercatori che hanno sottolineato come le peculiari caratteristiche della conoscenza, quali l'essere un bene non-rivale e generalmente difficile da trasmettere, pongano un serio limite allo sviluppo della divisione del lavoro innovativo (Teece 1988, Winter 1987, von Hippel 1990, 1994). Una maggiore divisione del lavoro nell'ambito dell'innovazione porterebbe una serie di vantaggi quali una maggiore e migliore utilizzazione della conoscenza prodotta e un migliore sfruttamento del vantaggio comparato tra piccole e grandi imprese nella produzione di tecnologie innovative. Infatti, nonostante il novecento sia stato caratterizzato dalla nascita e sviluppo di grandi centri di ricerca e sviluppo di proprietà di imprese di grandi dimensioni, una quota consistente delle innovazioni dello scorso secolo ha avuto origine all'interno di piccoli laboratori che hanno successivamente "venduto" la conoscenza a imprese più adatte alla sua commercializzazione. Il capitolo si conclude con un'analisi dell'evoluzione del MFT negli scorsi due secoli. Lamoreaux and Sokoloff (1996, 1998) documentano la presenza di un attivo "mercato della conoscenza" negli US già a metà dell'ottocento, ma una serie di fattori portano al suo offuscamento e all'affermazione dei grandi centri di R&D al servizio delle imprese. I recenti anni novanta, tuttavia, rappresentano una sorta di svolta. "The changing technology of technological change" (Arora and Gambardella 1994, p. 528), ha dato nuova linfa allo sviluppo del market for technology, innescandone un vero e proprio boom.

Il secondo capito, propone una rassegna della letteratura dei fattori che influenzano la propensione di un'impresa a operare nel mercato della tecnologia. Innanzitutto, viene proposta un'analisi del concetto di MFT proposto da vari autori e si propone la definizione usata nella tesi. Successivamente, in linea con gli studi di Lichtenthaler (2008), vengono analizzati i molteplici obiettivi che lo sfruttamento della conoscenza tramite il mercato della tecnologia permette di raggiungere, raggruppabili in obiettivi strategici, monetari e "forzati". In seguito, la tesi pone l'attenzione su come fattori "macro", quali il regime di appropriabilità, la necessità di accedere a assets complementari, la competizione fronteggiata nel mercato del prodotto, i costi di "transazione" e l'incertezza, possano influenzare sia l'abilità dell'impresa di estrarre una rendita dalla tecnologia e sia la strategia messa in atto. In aggiunta ai fattori macro, lo studio si pone l'obiettivo di analizzare come la strategia delle new technology based firms (NTBFs), ovvero piccole imprese operanti in settori a elevato contenuto tecnologico, possa essere influenzata da fattori micro quali la presenza di limitazione nell'accesso al credito e di un pronunciato knowledge gap del team fondatore in aree socio-economiche. Lo studio sostiene che la scarsità di finanziamenti ottenibili da istituti di credito alla fondazione spinga le NTBFs a optare per una strategia di sfruttamento della tecnologia attraverso il MFT. In maniera simile, l'elevato grado di istruzione e le esperienze lavorative ottenute in campi tecnici, la scarsa conoscenza in aree socio-economiche, le limitate capacità manageriali e la difficoltà a reclutare capitale umano qualificato, potrebbero rendere più favorevole, alla fondazione, una commercializzazione della tecnologia attraverso il MFT rispetto all'entrata nel mercato del prodotto. In conclusione, lo studio analizza se una strategia orientata al MFT possa essere mantenuta nel lungo termine o se le imprese tentano di colmare il funding gap e il knowledge gap subito alla fondazione, per optare per l'entrata nel mercato del prodotto. Infatti, il miglioramento delle condizioni finanziarie, grazie agli introiti derivanti dalle innovazioni vendute o date in uso, e la reputazione costruita durante gli anni che permette un migliore accesso ai finanziamenti, permette alle imprese il migliore accesso agli assets complementari. In maniera simile, il miglior accesso al mercato del lavoro permette all'impresa di reclutare le competenze necessarie per l'espansione nelle aree di produzione e commercializzazione del prodotto. Nel complesso, si sostiene il passaggio nel lungo termine da un "soft company" business model, caratterizzato dalla vendita di conoscenza sotto forma di intangibles, a un "hard company" business model dove l'impresa opera prevalentemente nel mercato del prodotto.

Il terzo capitolo offre una panoramica delle statistiche descrittive del campione in uso per i test econometrici. Il campione è composto da 201 NTBFs italiane operanti nei settori chimico-farmaceutico, dell'ICT manifatturiero e della robotica. L'analisi descrittiva mostra sia l'elevato livello di educazione accademica dei fondatori sia la tipologia prettamente tecnica si suddetta educazione. I team fondatori sono relativamente scarsi di educazione e esperienza lavorativa maturata in ambiti socio-economici. L'analisi documenta inoltre sia la rilevante importanza della banca in qualità di finanziatore in Italia, sia l'esistenza di un pronunciato funding gap per le start-ups. Infine, l'analisi alla fondazione e al 2007 della propensione delle imprese verso il MTF, indica che un terzo delle NTBFs che nate perseguendo una strategia orientata al MFT, ha poi virato verso una commercializzazione attraverso il mercato del prodotto.

Il quarto capitolo offre una panoramica dei modelli econometrici utilizzati (two-limit tobit e probit), le modalità di stima, le variabili utilizzate e i modelli analitici proposti.

Il capitolo quinto propone un'analisi dei risultati econometrici ottenuti. In linea con quanto ipotizzato, il capitale umano del team fondatore significativamente influenza il tipo di strategia messa in atto alla fondazione. Le analisi econometriche evidenziano come ciascun anno di educazione accademica e esperienza lavorativa ottenuta in aree tecniche incrementa la propensione verso una strategia orientata al MFT, mentre gli anni spesi ad accumulare competenze socio-economiche aumentano la probabilità che l'impresa si orienti verso il mercato del prodotto. Similmente, team fondatori che posso contare su una precedente esperienza manageriale, sono più inclini a perseguire una strategia basata sullo sviluppo e sulla commercializzazione di un prodotto "fisico". Inoltre, l'analisi dell'eterogeneità dei team di fondatori, mostra che team molto omogenei, e molto probabilmente ricchi di competenze tecniche, optano in favore di una strategia orientata al MFT. I modelli econometrici non rilevano invece, a livello significativo, nessun impatto del funding gap sulla strategia scelta alla fondazione. Per concludere, i modelli di sample selection mostrano un chiaro e significatività impatto dell'esperienza maturata dall'impresa sulla strategia seguita. Questi ultimi modelli confermano quindi la validità del modello di evoluzione delle imprese da "soft company" a "hard company", a scapito delle teorie che indicano la strategia MFT oriented come opportunità di lungo periodo.

In conclusione, la tesi evidenzia teoricamente e empiricamente l'effetto di fattori firm-specific sulla propensione a intraprendere strategie che prevedono lo sfruttamento della tecnologia sviluppata tramite il MFT o il market for product. Inoltre, lo studio porta evidenze empiriche a supporto del modello di evoluzione delle start-ups che prevede la transizione da "soft company" alla fondazione a "hard company" negli anni successivi.

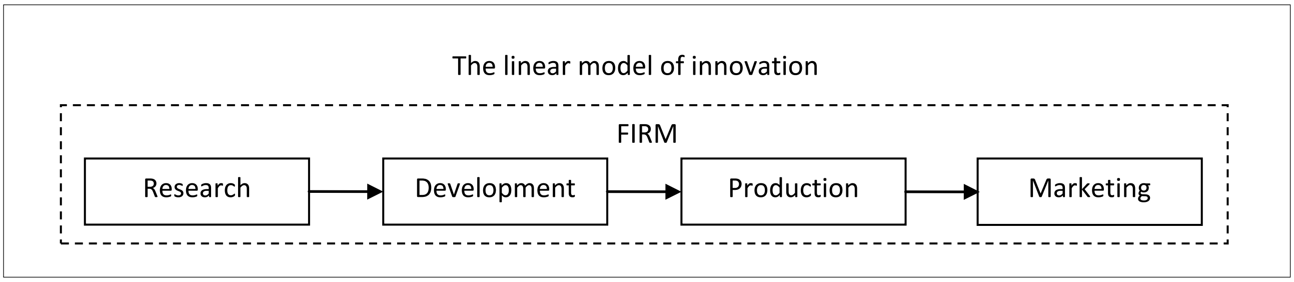
1. Introducing Markets for Technology

1.1. Introduction

As argued by a number of scholars, contemporary society has been increasingly marked by knowledge and information production and dissemination. The rise of science-based industries and the centrality that theoretical knowledge assumed as source of innovation led to the affirmation of the so-called "knowledge-based economy" (Bell 1976). Generally, a knowledge economy can be defined as "production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence" (Powell and Snellman 2004, p. 201). Physical inputs and natural resources lost their key role in favour of the growing importance of intellectual resources. Knowledge differs significantly from other inputs as it is non-rival and further fuel innovation (Romer 1990).

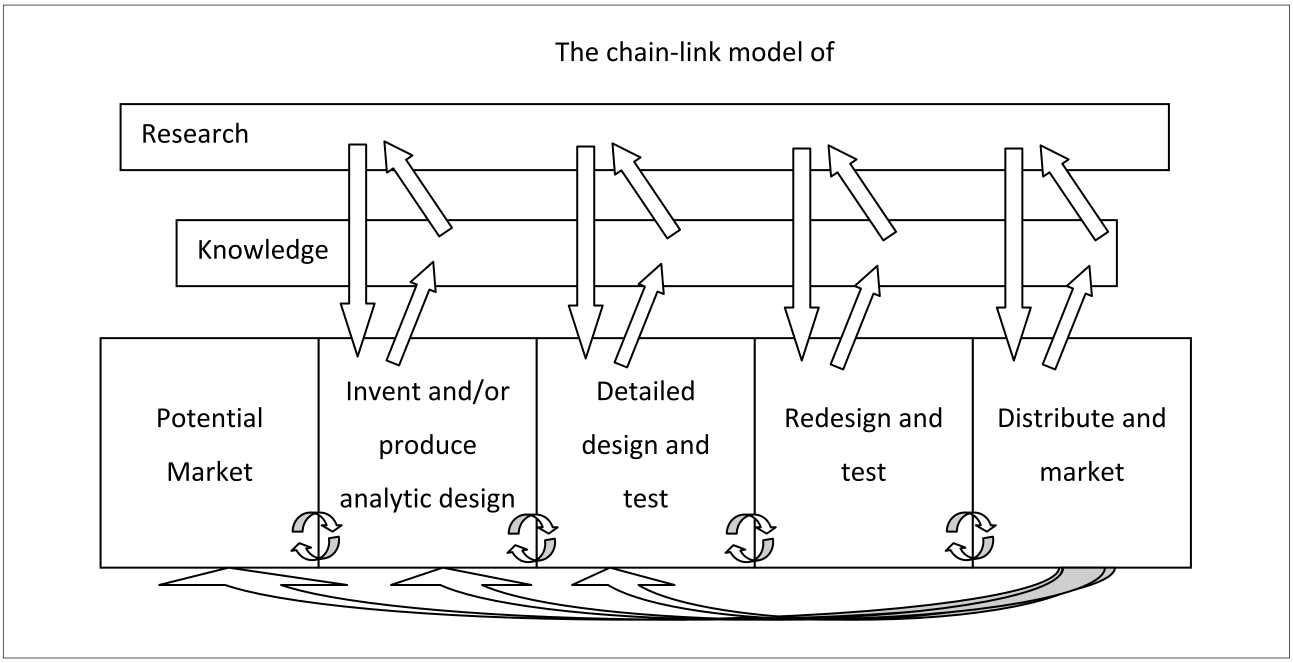
Despite the growing importance of knowledge is widely accepted and observed, more difficult has been to measure the extent to which society has become dependent on knowledge production. Various methods have been used to document the change. A first focus has been on the knowledge stock, intended as human, organisational and intellectual capital. Another line of research has paid attention to the effort put in the knowledge production activities, as R&D, investment in information and communication technology, education and training. Patent-based measures, as a mean to take into consideration both R&D effort and knowledge stock, have been the most common indicator of intellectual capital (Grindley and Teece 1997) and economically valuable knowledge (Griliches 1998). Several analysis and studies, based mainly on the data of the U.S. Patent and Trademark Office (USPTO), clearly documented the growing importance of knowledge in the economy. More globally, an OECD report on the importance of knowledge-base activities in the 90s estimated that more than 50 per cent of Gross Domestic Product in the major OECD economies was already knowledge-based (OECD 1996).

The growing importance of knowledge on economic activities has important repercussions on the process of creation and exploitation of knowledge as well. In the traditional model of innovation, in place for most of the 20th century, the innovative activity evolves linearly through several subsequent stages (see Picture 1). In this view, innovation starts from new scientific discoveries made in the firm's R&D laboratories, progress sequentially through development of the idea, creation of the concept, manufacturing and marketing, and terminates successfully with the sale of the product or service. The overall process takes place within the same firm, as interaction among the actors of the innovation chain and tacit knowledge are determinant to the success of the final output.



Picture 1: The linear model of innovation
Source: Klein, S.J. and N. Rosenberg (1986), "An Overview of Innovation", in R. Landau and N. Rosenberg (eds.), The Positive Sum Strategy: Harnessing Technology for Economic Growth, National Academy Press, Washington, DC.

However, recently, technology development under new technology dynamics "has led to wholly new pattern of specialisation both by firm and by industry" (Rosenberg 1982, p.71). The innovation production process has seen the breakdown of its activity among different actors and, in parallel, it has undergone an increasing process of specialisation (see Picture 2). It is now recognised that innovation can steam from several sources from inside and outside the firm. The process is not linear, as it requires considerable communication and feedbacks among all the actors of the system, from the science based firm or laboratory to the final client. In this model, firms actively search and promote inter-firm linkage and build network fundamental to gain access to new research results, acquire technological competencies. Moreover, this helps to spread costs and reduce risks associated with innovation.



Picture 2: The chain-link model of innovation
Source: Klein, S.J. and N. Rosenberg (1986), "An Overview of Innovation", in R. Landau and N. Rosenberg (eds.), The Positive Sum Strategy: Harnessing Technology for Economic Growth, National Academy Press, Washington, DC.

The network characteristic of the knowledge-based economy leads to the rise of specialised intermediaries, that is, firms adept and specialised in one stage of the innovation process. Concerning the very early steps of the process of knowledge production, I saw the rise of many high technology-based firms engaged mainly in the discovery and production of knowledge.

As suggested by Autio (1997, 1994), small firms active in high-technology sectors are a unique bundle of knowledge and human resources, motivated to maintain their technological leadership more than to achieve growth. Instead of following the common life cycle, those firms play a different role in the industry, “saddling” themselves with the burden of give new inputs to innovation process. According to this new perspective, small and large firms, instead of being considered mutually exclusive forces of innovation, are seen as complementary producers of new technology, with the former acting as a supplier of innovative technology input and the latter more focused on development and commercial exploitation of the market for product (Acs and Audretsch 1990).

Despite the justified emphasis on the production of knowledge, knowledge based economy cannot function without efficient knowledge transmission to economic actors with the role of exploiting such knowledge. Central to the development of this new industry structure are markets for technology. Without entering now the controversial point of giving a complete and specific definition, markets for technology, hereafter MFT, can be considered “places where transaction for scientific and intangible technological assets occurs” (Guilhon 2001). Only the existence of effective marketplaces for knowledge allows firms specialised in the production of new technologies to sell their ideas and appropriate of rent from innovation. Moreover, MFT would further enhance the division of labour in innovation and increase specialisation in the production of technology with a higher allocation of resources.

1.2. The division of innovate labour and its limits

Though the virtues of markets have sometimes been overemphasized, it is undeniable the role they play in facilitating trade across agents in modern economy. The existence of a market generally leads to a number of advantages mainly enhancing allocative efficiency. Markets play an important role in many industrial sectors as a great number of different goods is traded, ranging from raw materials to property rights. Similarly to all the other markets, the division of labour among different actors of the process stand at basis of MFT.

In *The Wealth of Nations,* Adam Smith (1776) proposes the idea that the breaking down of a productive activity in different sub-tasks lead to an increase of productivity. Economies of learning and larger scale, in addition to superior allocation of resources based on comparative advantage, give specialized upstream suppliers a substantial advantage over the individual upward integrated company. A more efficient production lowers the unit cost of goods and leads to a greater demand. In turn, this increases the market size and further enhances the division of labour. As for many other activities, production of technology and knowledge is characterised by increasing returns. However, despite specialisation and trade characterised several economic activities, the division of labour has not widely marked the production of technology. In the early sixties Stigler (1951) argued in favour of a sure affirmation of the division of labour in innovation activities and predicted the rise of stand-alone R&D laboratories selling their technology to downstream firms. However, for most of the last century "it seemed as if autarky in production of innovation was the natural order of things" (Arora and Gambardella 2010, p. 775). Almost all the 20th century has seen the rise of large research and development departments, specifically built to provide companies innovative technology to embody into their products or services. Thus, until recently, vertical integration instead of MFT has been mainly used by large corporation to acquire new technological inputs.

Previous research has provided multiple justifications for this pattern. Nelson and Winter's (1982) evolutionary theory considers production of technology a cumulative process based on tacit skills and organisational routines developed internally and hardly impossible to transfer. Creation of new technology requires extensive and numerous interactions among the individuals working at the project, and the belonging to the same organisation gives a substantial advantage. From research to design, to manufacturing and, at the end, commercialisation, experts specialised in different areas have to share tacit knowledge in order to translate the idea into a successful product.

Teece (1988) addressed the issue arguing that the division of innovative labour is severely limited by transaction costs. The peculiar nature of knowledge, alongside with high uncertainty typical of R&D, makes difficult to draw specific contracts for intangible research outputs at the outset of the innovation process. The difficulty in providing detailed specifications and writing complete and enforceable contracts leaves the door open to opportunistic behaviours and leads to significant appropriability problems. Moreover, sunk investments, originating from tight interactions with one technology supplier and the necessity of common investments, may generate lock-in problems.

Grossman and Hart (1986) and later Hart and Moore (1990) proposed two models that analyse the influence of transaction costs on the level of vertical integration of activities of the firms. Consistently with Teece's idea, vertical integration helps to solve opportunistic behaviour problems arising from incompleteness of contracts.

Drawing on Simons (1962), who analysed the organisational design issue behind the decomposition of a complex problem, von Hippel (1990, 1994, 1998) made important contribution on the reasons and economics behind problem-solving partitioning. Given that the core function of many innovation projects is problem solving, he argues that a greater efficiency can be achieved by dividing the overall effort into smaller tasks. Efficiency should drive the partitioning process in order to obtain tasks characterised by smaller interactions across them and thus reduce inefficiencies generated by extensive coordination and information flows. Von Hippel (1990) also argues that the extent to which an innovation activity is task-partitioned has strong implication for the division of labour determining the extent to which the process is integrated within the firm instead of being divided among different specialists. An effective task partitioning could lead to both reduction of information exchange costs and economies of specialization. In subsequent work, von Hippel (1994) took into consideration the role of tacit knowledge. Similarly to Nelson and Winter (1982), he argues that the innovation process highly relies on "sticky" information, that is, information that requires a great economic effort to be transferred. Even in the presence of efficient task-partitioning, significant transaction costs may arise because of the great deal of "sticky" information to be transferred, the high transfer cost per unit of "sticky" knowledge and the number of interactions among the parties.

However, "stickyness", tacitness and codification are not inherent properties of knowledge (Winter 1987). Winter (1987) proposes a taxonomy of knowledge, distinguishing among eight pair of attributes: articulable vs. tacit, teachable vs. unteachable, articulated vs. non articulated, observable vs. nonobservable, simple vs. complicated, context-independent vs. context- dependent, system-independent vs. system-dependent and monodisciplinary vs. transdisciplinary. The taxonomy, besides laying the foundation to the definition of knowledge as "economic commodity", suggests that knowledge can indeed be articulated and therefore made easier to transfer. Drawing on Winter, Arora and Gambardella (1994) argue that economic decisions drive the extent to which knowledge can be made more or less articulated and therefore tradable. Consistently, von Hippel argues that firms should invest in making information less "sticky", for example "converting critical form of technical expertise from tacit knowledge to the more explicit and easily transferable form of a software expert system" (von Hippel 1994, 436).

To conclude, the tacit and idiosyncratic nature of knowledge and the peculiar characteristics of the innovation process have posed serious limits to the development of the division of innovative labour and therefore to MFT. As I will explain later, division of labour in innovation has benefits and potentiality but costs deriving from the transfer of knowledge in addition to problems of opportunistic behaviours have to be overcome. An effective decomposition of the innovation process, which reduces the frequency with which the actors of the process have to exchange information, in parallel with a greater use of articulated and abstract knowledge would lower transaction costs and make division of innovative labour more feasible and economically beneficial.

1.3.Advantages of the division of innovative labour

Besides previously highlighted problems encountered by the division of innovative labour (Nelson and Winter 1982, Teece 1988), the innovation process based on markets for technology presents a number of advantages compared to the one characterised by R&D integration.

Primarily the transformation of tacit and unarticulated knowledge into a commodity, condition necessary to the exchange, makes knowledge "infinitely expansible" (Dasgupta and David 1994, Romer 1990). Articulated and tradable knowledge is a "non rival" good, thus it can be possessed and used jointly by many without loss of its intrinsic qualities. Moreover, it is characterised by low appropriability, which forces regulators to introduce mechanism to guarantee rent from innovation, and high transferability (Arrow 1962). Moreover, the more general-purpose the technology is the higher the gains can be, as the same knowledge can be exploited in several industries and be embedded in completely different products (Arora, Fosfuri and Gambardella 2001).

Second, in absence of effective division of innovative labour and MFT, technology and knowledge tend to be under-utilized (Arora and Gambardella 1999). Vertically integrated R&D laboratories make and, to a lesser degree, patent new discoveries which may not fit into their core business but which may be applicable in other sectors. Instead of being exploited commercially, not core technologies tend to be put apart and converge on the bulk of so-called "orphan technologies", that is, technologies that would have commercial value if they were licensed or sold. In support of this view, a British Technology Group's survey (British Technology Group 1998) conducted in North America, Europe and Japan, found that the companies interviewed neither exploit nor license more than 35% of their patented technologies simply because they are out of their core business. Consistently, Giuri et al. (2006), from the analysis of the Patval-EU survey across Germany, France, Spain, Italy, Netherland and UK, report that approximately 36% of firms' patent portfolio is unexploited. Half of the unused patents are kept unexploited for strategic purpose as blocking competitors. However, not negligible is the percentage of "sleeping" patents, i.e. those not exploited, not licensed and not kept for strategic reasons, reaching the 22% in chemicals and pharmaceuticals. The survey also points outs that large firms have the higher percentage of "orphan technologies", while small firms are show a lower percentage of "sleeping" patents and a higher percentage of licensed ones. Estimates restricted to the U.S. indicated in $115 billion of technology assets not exploited by companies. Even if the figures reported by BTG may be overestimated, they suggest the existence of a bulk of "orphan technologies" worldwide. Previous literature has considered transaction cost to represents a major obstacle to commercialisation of technology (Teece 1988). However, it is surprising that, according to BTG survey, the main reason why companies do not sell or license unused technology is that they do not take the opportunity into consideration. Even acknowledging transaction cost to play a role, it is generally accepted that the cost of transferring technology represents only a small fraction of the cost of developing it in the first place. Thus, an efficient MFT may boost gain from innovation mainly through gain from trade. Moreover, trade of discovered and patented technology may lead to decrease in the research of technology already developed elsewhere and, thus, to a better efficiency in innovation. The phenomenon is not irrelevant as documented by European Patent Office. In 1998 estimates point to a $20 billion spent to develop technology already discovered and patented elsewhere (European Patent Office 1998).

A third advantage originates from comparative advantage. Ideas may be developed by firms or singular inventors lacking the commercialization capabilities necessary to successfully exploit it. Moreover, engaging in commercialisation, and therefore, building effective manufacturing and commercial capabilities, may even retard innovation (Arora and Gambardella 2010). The firm may be forced to shift its attention from further developing innovation to manufacturing and marketing activities, or may have to change the nature of the organisation. Previous literature in the "knowledge transaction field" agrees that licensing to another firm, with a comparative advantage in downstream activities leads to a more efficient use of resources and yields gains to both parties (Teece 2000). Similarly, Katz and Shapiro's (1986) model shows that inventor-founded start-ups are often second best because of the lacking of entrepreneurial skills. Further theoretical and empirical evidences are going to be detailed in the next chapter.

Forth, in part consequence of the previous, the division of innovative labour and the existence of MFT may lead to an increase of the rate of technological innovation. Small firms and innovators, even if lacking of commercialization assets maintain a strong incentive to invest in innovation, being able to appropriate of the innovation rent through licensing. Conversely, in a world characterised by vertical integration, those firms may abandon R&D activities.

In the past, disadvantages mainly deriving from difficulties in handling and exchanging tacit knowledge have exceed the not negligible advantages given by an effective division of labour in innovation. However, the wider use of codified knowledge and information in the economy has undoubtedly reduced these difficulties allowing the society to take profit from the highlighted advantages.

1.4.The division of innovative labour between small and large firms

Despite the high level of integration of R&D laboratories into large companies in the 1900, first Jewkes at al. (1959), argue that a significant number of well know inventions originated outside the firm that finally commercialized them. Some consistent evidence come from Mueller's (1962) study on Du Pont, cited in the fifties as the leading and most successful chemical innovation company. The detailed analysis of the firm's inventions shows that Du Pont major product innovations had been based upon technology originated outside. Therefore, Mueller (1962) suggests that the firm has been more successful in acquiring, developing and improving existing innovation rather than discovering new technology.

Whether small or large firms are more innovative and the factors that underpin such idea have long been debated. On one side, supporter of the classical and neoclassical doctrine suggest that the spur of competition drives small firm to be more incline toward technological progress. On the other side, Schumpeter (1950) argues that large and well-established firms are better endowed to develop and exploit technology innovation.

In favour of the innovative advantage of large firms, literature has identified the ability to finance the high fixed cost of R&D and to tolerate the risky nature of the investment in research. Moreover, economies of scales in marketing and distribution, in addition to the ability to find economic application to a higher variety of technologies, lead large firms to enjoy higher potential profitability from innovations (for a detailed review see Cohen W. M., 2010). Behind most of previous factors stand the availability and access to financial capital. Coherently, as tested by Acs and Audretsch (1988), capital intensity tends to play an important role in innovation, giving an important advantage to large firms over small ones.

By contrast, Arrow (1983) argues that flexibility and lower distance among internal business units give small firms a significant advantage over large firms in pursuing innovative projects. Thus, small start-ups, provided that they can effectively access and obtain the necessary funds, have greater incentive and are better organised to develop novel and risky innovation project, while large firms have greater comparative advantage in production and commercialisation. Consistently, Levinthal and March (1993) argues that large and well-established firms are better suited for exploitation of technology than for exploration. Similarly, Arora et al. (2001) suggest that start-ups are better suited for making new discoveries, in particular radical breakthroughs, while large firms gain full benefits from development of incremental innovation and commercialisation.

Given the difficulty of unambiguously define and measure innovation, over the last fifty years empirical research on the relationship between firm size and “innovativeness” has provided a great number of robust but mixed results (see Cohen W. M., 2010 for an extensive literature review).

In sum, other not negligible factors affect the relationship between firm size and its capacity to innovate, but as argued by Arora and Gambardella (1994) the technological revolution, at the base of the enhancement of the division of innovative labour and of the expansion of MFT, may lower barriers and create incentives to promote the innovative activity of small high-tech start-ups.

1.5.The birth and rise of the market for technology

Despite being a phenomenon that has boomed only recently and has received the appropriate attention by researchers only since the 1990s, the market for technology developed almost two hundred years ago. In the early nineteen century, the institution of the U.S. patent system represented a turning point for the rise of market for technology (Lamoreaux and Sokoloff 1996). The U.S. system, specifically designed to enhance investments in innovative activity, provided a functional framework to protect inventors' discoveries for a fixed period of time. U.S. law widely reach its objective through two particular characteristics: a low cost of obtaining patent, lower than in other countries, and the exceptional ability to reserve for the first and true inventor the right to patent an invention (Machlup 1958).

The first factor widely increased the number of innovations deserving being patented, while the second one lets inventors be less protective of their discoveries. Expropriation problem was less severe in U.S. than elsewhere, leaving the opportunity to disclose critical technological information without incurring in opportunistic behaviour of the counterparts. Data from the Annual Report of the Commissioner of Patents elaborated by Lamoreaux and Sokoloff (1996) points out a steep increase of patenting activity in U.S in the years between 1840 and 1911. Although the annual number of patents per resident varied across regions, altogether it saw an average rise from 27.5 patents per million residents in 1849 to 334.2 in 1911.

In addition to fostering the participation in the patent system, the U.S patent system law had also been designed to promote the diffusion of technological knowledge. The Patent Office required all patentees to provide detailed specifications of their inventions, becoming an open and free to consult storehouse of information. Moreover, the high protection provided by property rights encouraged inventors to promote their innovations as much as possible, in order to take out the most of their ideas, either through commercialisation of products or trade of technology. This period saw also the rise of a number of published sources of information about patented technologies, both public, as the annual list of patents issued printed by the Patent Office, and private, as Scientific American, which kept producers informed about last development in technology and patents. This and other minor institutional changes lower transaction costs increasing significantly the volume of trade in patented technology. Patents assigned to third parties rose from 18.5 to 30.5 percent, more than doubling in some areas of the country (Lamoreaux and Sokoloff 1996). Such a vibrant market gave boost to the division of labour in innovation. Patentees increasingly focused their attention and resources on the pursuit of innovative activity, being able to extract valued from technological innovations through the market for ideas.

Although previous evidence, even if restricted to U.S, state the existence of an organised market for technology in the nineteen century, toward the end of the century the market for patents started losing pace. The proportion of arm's-length transactions after patent issue sharply declined in favour of assignments made at issue by patentees who shared some formal connections with the assignees (Lamoreaux and Sokoloff 1998). This evidences may be justified by the increasingly spread practise of innovators to assign licenses to their firms, in order to perform commercial exploitation. By the beginning of the 20th century market for ideas was eclipsed by the growth of large corporation, which focused mainly on internal R&D instead of acquiring technology from other sources. Consistently, Mowery (1983) reports that scientific personnel employed in independent research organisations declined in the first half of twentieth century.

Previous literature has identified high transaction cost associated with the exchange of increasingly complex technology and the inability to exploit tacit knowledge gained from interaction among individuals operating in different areas as the factors that induced the decline of market for technology in favour of in-house R&D (Teece 1988, Nelson and Winter 1982, Zeckhauser 1996). However, Lamoreaux and Sokoloff (1998, 2005) suggest that others factors than difficulties in contracting for technological knowledge were the cause at the base of the change. In this period, the development of more complex innovations required greater amounts of financial resources. Besides, the cost of financial and human capital rose putting at risk the innovative activity. These obstacles convinced innovators to accept employment relationship in R&D laboratories of fast growing large firms. Therefore, according to Lamoreaux and Sokoloff, increasing problems encountered in the capital market as the inability to fund risky inventive activity and contracting problems were among the main causes of market for technology decline. In support to this view, Aghion and Tirole's (1994) model shows that vertical integration is the more likely outcome when capital inputs play a substantial role in research. Conversely, when intellectual inputs dominate, as in software and biotechnology research, R&D specialists emerge. Thus, financial constraint may limit the development of MFT.

1.6.The nineties: a turning point

As widely acknowledged and documented by a number of indicators (see e.g. picture 3 and 4), the nineties have represented a sort of turning point, seeing the resurgence of MFT. However, the reasons behind the boom are still disputed.

Arora and Gambardella (1994) argue that the grounding of new technology in science, the progress made by ICT and further development of intellectual property protection have greatly contribute to extending the division of innovative labour and facilitated a new interpretation of technology under the form of "economic commodity". Greater and cheaper computational capabilities and new communication channels led to a sort of revolution in research activities. New research and testing methods, e.g. computer simulation, enjoyed a number of advantage, most evident rapidity and effectiveness, and replaced older theory testing procedures in many fields. However, the capacity and value of new testing methods highly depends on advances in theoretical understanding and in the ability to conceptualise problems in abstract forms. To exploit computational capabilities knowledge must undergo a formalisation process and engineers have to translate problems into abstract knowledge and theoretical models, and later into mathematical language. Example of the complementarity can be found in biotechnology, chemicals and nanotechnology (Arora and Gambardella 1994). As a greater fraction of information becomes intelligible and concrete, it become less context dependent and more easily can be codified to be meaningful and useful for other firms. Furthermore, developments in communication technologies contributed in reducing cost of inter-firms communication and encouraged the diffusion of frameworks for organising and representing abstract information. The "changing technology of technical change" (Arora and Gambardella 1994, p. 528) significantly lowered transaction costs identified by Teece as the main limits to MFT, and made the division of innovative labour more feasible. Similarly, Greenwood and Yorukoglut (1997) suggest that the rise in patenting and technology trade was due to a burgeoning technological revolution.

Conversely, Rosenbloom and Spencer (1996) argue that changes in the management of R&D facilities enhanced technology opportunity, as large corporations redirected toward more applied problems and small military technology focused laboratories converted to research in other than defence-driven fields.

Overall, previous sources agree that rise in patenting activity and the resurgence of MFT reflects the widening of technological opportunity of the mid-1880s and can be grouped into the so-called "fertile technology hypothesis" introduced by Kortum and Lerner (1999).

However, the same authors analysed also the validity of the "regulatory capture hypothesis", that is, weather accommodating public policies and changes in law developed to increase patent protection, gave new boost to innovation and patenting activity. Similarly to what happened in the early 1800, increased intellectual property protection may have lead to a sharp increase of patent applications and encouraged technology disclosure and trade.

In addition to previous theories, I believe not negligible has been the role of the significant growth in scope and sophistications of capital markets, which invested in young technology based firms and mitigate entrepreneurial challenges. Conversely to what documented by Lamoreaux and Sokoloff (1996, 1998) in the early 1900, the late 1970s and the early 1980s saw a great increase of venture capital industry that in few years more that decupled the amount of fund raised (Kortum and Lerner 2000).

Consistently with this view, nowadays in areas like Silicon Valley and Israel, characterised by high presence of institution for financing risky innovation projects (e.g. business angels, venture capital firms etc.), I observe the highest density of start-ups and technology spin-offs.

1.7.The market nowadays

Despite the recognised economic importance of MFT, to date, a worldwide systematic assessment of the size of this phenomenon has not been completed yet. Evidence and figures are rather fragmented among different sources and derive from a number of analyses.

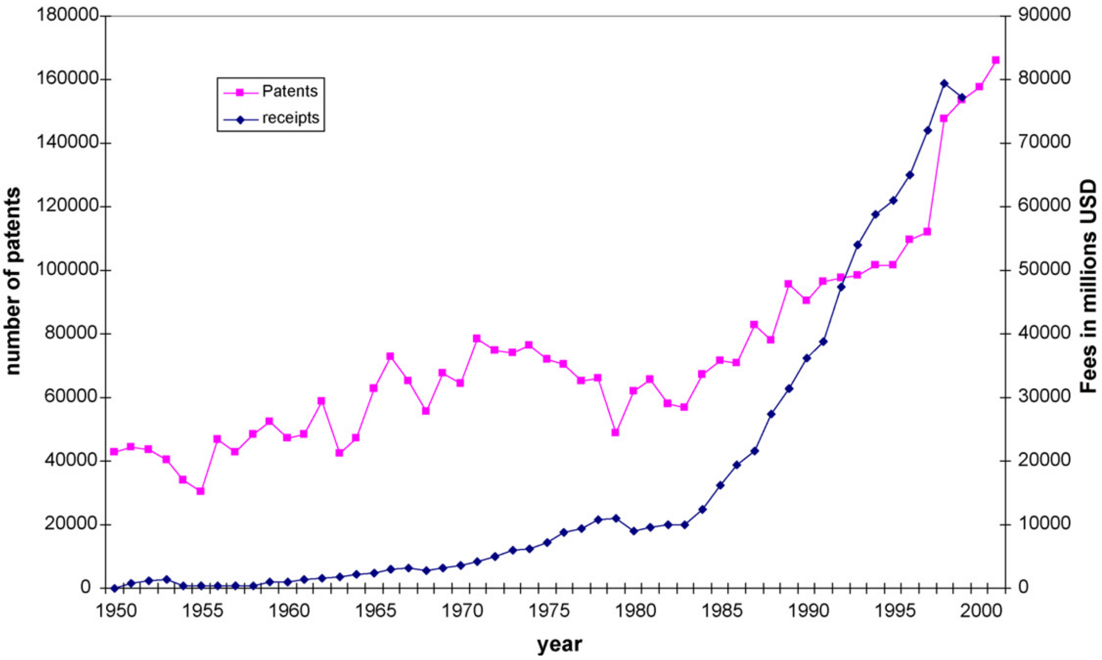
Some first evidence comes from a survey developed by the British Technology Group, based on interviews with 133 companies and 11 universities located in Europe, North America and Japan (British Technology Group 1998). The analysis is performed only on R&D-intensive companies or research universities. Despite the smallness and the low representativeness of the sample, findings are nonetheless indicative. The survey shows a higher licensing propensity in Japan, where 82% of the respondent had licensed from others and 67% had licensed to others, followed by North America, 80% and 72% respectively, and Europe, 71% and 53%. However, expenditures on technology licenses represents only 12%, 5% and 10% of the total R&D budget in North America, Europe and Japan respectively.

Arora et al. (2001), reviewing several studies, come to a first estimate of the size of MFT. Despite different methods and sources used, the estimates lead to remarkably similar results. They concluded that in the mid 1990s MFT was worth about $25-35 billions in US, $6.6 billion in Europe and $8.3 billion in Japan. These estimates implied a total of $35-50 billions in the world. These first findings show a great underdevelopment of technology commercialisation in Europe compared to Japan and even more to US.

Beside geographic differences, Arora et al. (2001), reviewing data from the Security Data Company database, pointed out that intensity of technology commercialisation practises shows a greater degree of heterogeneity also among different industrial sectors. So far, MFT appears to be especially relevant only in a small fraction of industrial sectors: biotechnology, chemicals, pharmaceuticals, software and semiconductors (Fosfuri 2006).

After estimates of the actual size of the market, some studies tried to document the relevance of MFT over time. Recently, Athreye and Cantwell (2007) reported the growth of worldwide royalty and license revenues in the period between 1950 and 2000. For the period up to 1970 data comes from the IMF Balance of Payments Yearbook, while for the 1970-2003 period the World Development Indicator database was used. These estimates tend to be a little higher than those reported by Arora at al. (2001) but the size of is still comparable and discrepancies are likely due to different utilized indicators. For example, Athreye and Cantwell estimate a world market for technology size of $55-60 billions in the mid-1990s. For 2000, the figure rise to the value of $80-90 billions.

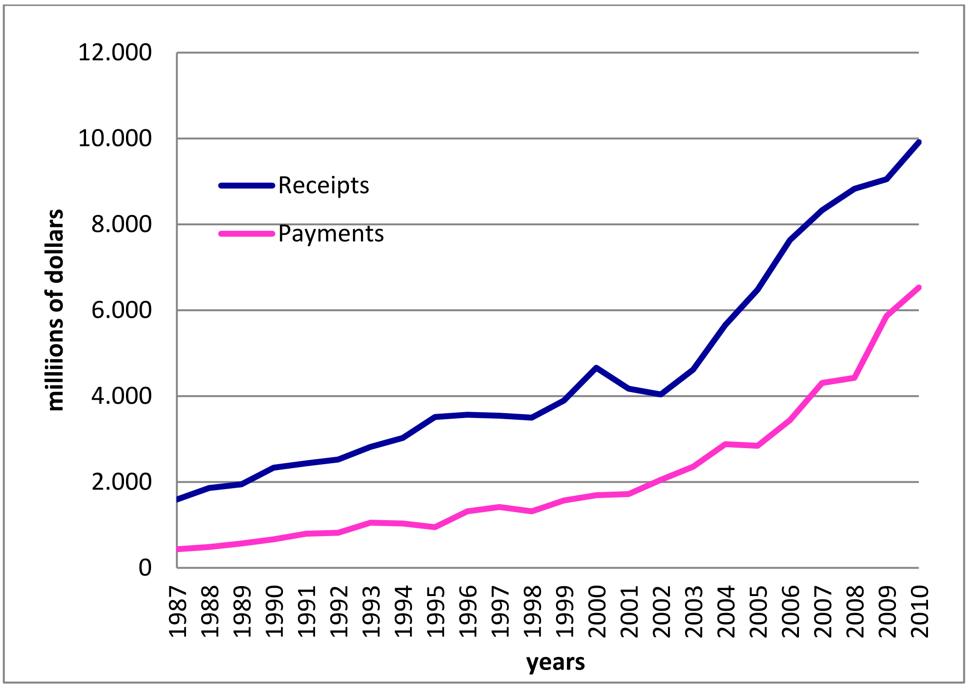
As shown by Picture 3, the trend rises dramatically after 1985. In the late 1990s, the market was surely affected by the rising of the dot-com bubble and its burst in the new millennium may explain the unexpected stop registered in 2000. Anyway, literature believes that MFT has still great margin of development and the undergoing ICT revolution is likely to sustain the trend in future years.



Picture 3: Growth in non-US held patents and worldwide royalty and license revenues
Source: Athreye and Cantwell, 2007

Arora and Gambardella (2010) pointed out two possible offsetting effects may affect the figures. First, transaction may have taken place between affiliated entities rather than on the market. For example, in 2007, data from the US show that only 21% of total receipts from royalties and licensing fees for industrial processes come from unaffiliated entities. This suggests that intra-firm transactions amount for less than the $90 billion estimated by Athreye and Cantwell (2007). Second, data form Athreye and Cantwell include payments for industrial processes and products, which correspond closely to MFT, and payments for software, trademarks and copyrights that may not have been included in other studies. Moreover, licensing and royalties receipts for industrial processes and products have grown far more slowly than those for software, trademarks and copyrights.

However, data relative to US payments and receipts for international licensing royalties for industrial processes shows as cross-border transaction involving the exchange of technology between unaffiliated parties has grown steadily up to 2010. Both figures has been affected by the burst of the dot-com bubble at the beginning of new millennium, while so far the recent financial crisis seem not have had any impacts.



Picture 4: International licensing royalties for industrial processes, unaffiliated transactions only, United States 1987-2010
Source: Table 4a and 4b, Royalties and License Fees, 2010, available at www.bea.gov/international/international_services.htm

Other recent and highly authoritative estimates of MFT, only for the United States, are provided by Robbin's (2006) study, based on confidential tax data. Putting together information from three US Federal data sources, the Bureau of Economic Analysis (BEA), Internal Revenue Service (IRS) and the Census Bureau, she produces order-of-magnitude estimates of $27.4 billion for 1995, $29,4 for 1996 and $31,8 billion for 1997 for US corporate supply of IP-licensing of industrial processes. These figures are remarkably similar to those provided by Arora et al. (2001) using different data sources.

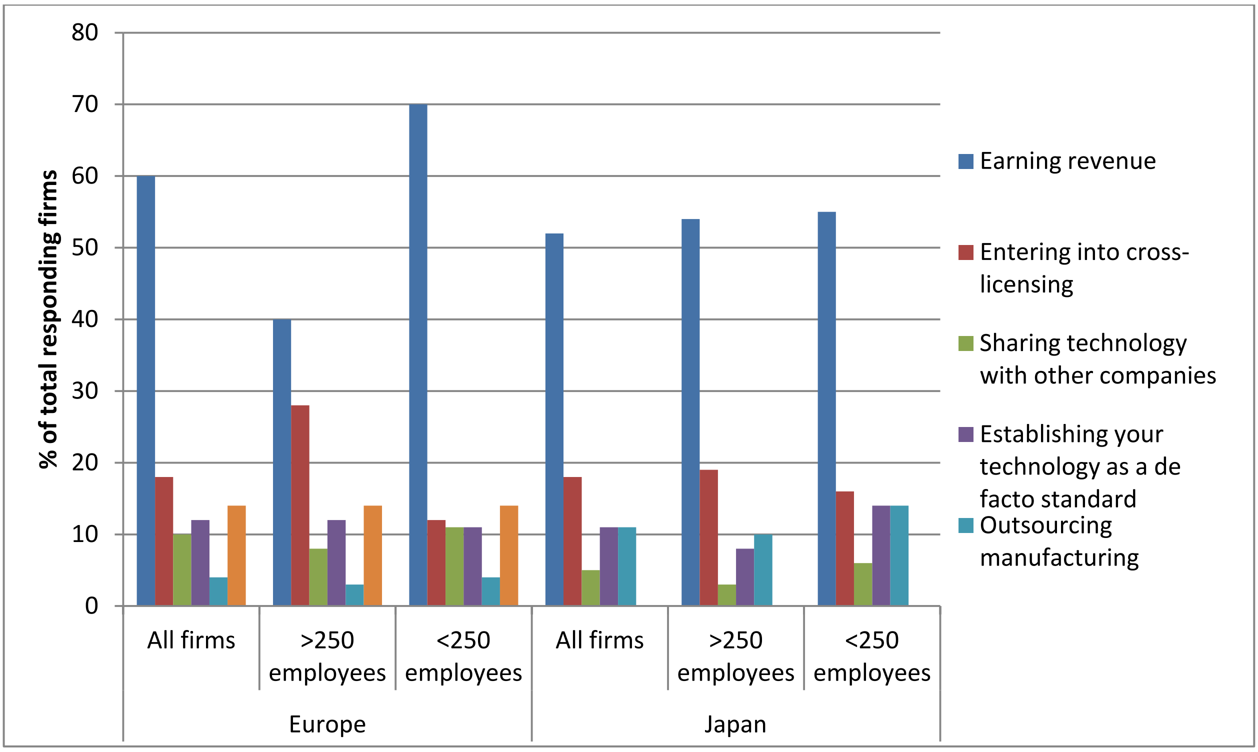
1.8.Firm-level evidence

Despite the relevance of the phenomenon, statistical information on the topic is still scarce and incomplete. To better describe the reasons behind and the size of the licensing market, the OECD, in collaboration with the Business and Industry Adisory Committe (BIAC), conducted a survey on the topic across three geographic areas Asia-Pacific (mostly from Japan), Europe and North America (Sheehan, Catalina and Guellec 2004). The survey indicates that licensing activity is becoming an effective channel for diffusion of technological know-how. In the 1990s, approximately 60% of the interviewed firms reported an increase in licensing activity, with the ICT and pharmaceutical sectors being the most active.

Geographically, growth was reported more frequently in Asia-Pacific and North America than in Europe and differentiating by size, larger firms more likely to report increased licensing activity than smaller ones. Investigating the factors influencing the phenomenon, the survey shows that the need to access complementary expertise, followed by the opportunity to accelerate innovation process were the main reasons behind the increase in licensing activity. Moreover, the large majority of the firms, in particularly those in ICT and pharmaceutical, agree on the even greater role played by inward and outward licensing in the next future.

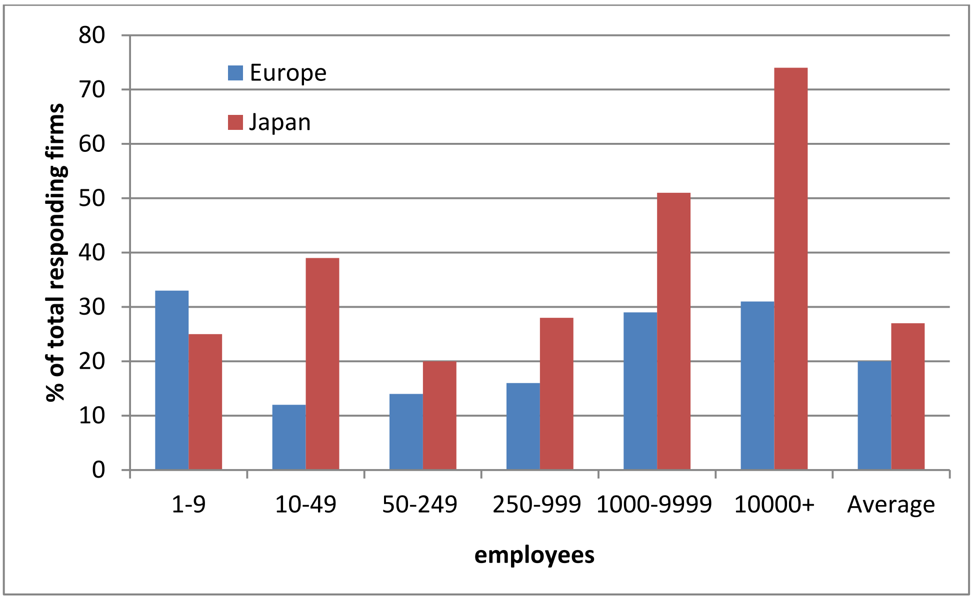
More recently, Zuniga and Guellec (2009) examine a representative sample of 600 European and 1600 Japanese patent-filing firms in 2007 focusing the analysis on licensing out activity. Widespread licensing practise was found among firms, with 35% of European and nearly 60% of Japanese firms declaring licensing of patents. Moreover, a significant number of firms licenses patents to unaffiliated partner, nearly a fifth in Europe and a quarter in Japan. Among European countries, Denmark, Austria and the United Kingdom companies appear to be the most involved in licensing activity, while Sweden and Italy place at the bottom.

Consistently with findings of previous surveys (PatVal-EU 2005), the opportunity of earning revenue is, by far, the first motivation behind out-licensing to third parties in both Europe and Japan. Noticeable, the monetary objective is far stronger for small firms than for large ones in Europe, while there are not significant differences in Japan. Symptoms of the monetary role of patents derive as well from the great importance given to the financial use of patents for raising capital in Europe, notably for venture capital and private equity. The importance increases by far for small and recently founded firms (see Picture 5).



Picture 5: Motivations for licensing out: Share of deals concluded in the previous three years obeying the following motivations
Source: Table 10, Zuniga and Guellec, 2009

The survey deeply investigates the relationship between size and rates of out-licensing activity and confirmed theories and results developed previously (Motohashi 2008, Fosfuri 2006). Both the survey and more controlled exercised clearly stated the existence of a U-shaped relationship, documenting that both very small and very large are more likely to out-license to unaffiliated partners (see Picture 6). Moreover, the age of the firms seems to play a role with younger enterprise reporting a higher rate than older ones.



Picture 6: Licensing of patents to non-affiliated companies
Source: Table 2, Zuniga and Guellec, 2009

Consistently with aggregate evidence from MFT in U.S., licensing activity appears to have increased between 2003 and 2006 in Europe. Among European companies doing licensing in 2006, about 45% reported an increase in licensing revenues, with 8% even reporting dramatic growth. Only 3% declared a decrease while the remaining 50% indicate no change.

Overall, evidences agreed upon the increasing role of licensing since the mid-1990, with important geographical differences but with signs of European firms catching up with Nord American ones. However, despite significant growth rates, in absolute value, the activity of licensing still play a marginal role in the innovation process, with some evident exception for biotechnology and chemical for example. Through a questionnaire-based benchmarking study developed on 154 medium-sized and large European firms belonging to multiple sectors, Lichtenthaler and Ernst (2007) found that licensing revenues account on average for 1,8% of the firms' total operating revenues, with the highest values being lower than 5%. In sum, MFT has grown steadily during the last years, but it is still limited in extent over geographical and industrial scope.

2. Literature review

2.1. Analyzing different definitions for similar phenomena

Last century was characterised by the prevalence of R&D laboratories belonging to large firms focused on exploiting technological knowledge internally. The majority of firms focused on embedding in-house produced technology into products and took technology licensing and other form of outward technology transfer into none or little consideration (Lichtenthaler and Holger 2007). Only in some cases, mainly because of the particular industry structure, e.g. chemical industry (Arora 1997, Teece 1998), companies actively exploit their technological knowledge through licensing agreements.

In research literature, the first reference about the active management of external knowledge exploitation was made in the late 1970s. Ford and Ryan (1977) suggest that the full exploitation of a company know-how may not be limited to its integration in physical products or services. Instead, the arise of technology marketing would allow the firm to better take advantage of its internal resources. However, the effective and successful exploitation through the “market for know-how” requires the development of a coherent corporate strategy as it may have important implication on the firm structure. Teece (1981) acknowledges that markets for technology accelerate the spread of technology worldwide. In fact, licensing and other forms of technology transfer contribute to spreading knowledge to a greater degree compared to reverse engineering and other channels of technology “leak out” based on product market. However, he suggests that a number of inefficiencies affect the market for technology limiting its development.

Despite these early studies, research on technology and knowledge transfer has been scarce and the topic gained the appropriate relevance only at the beginning of the 1990s as external technology exploitation started to be considered more as a strategic option rather than a marginal activity of residual technology commercialisation (Amesse and Cohendet 2001). Moreover, a unique and shared definition of what transfer technology means is not available.

Technology assumes very different forms, and a strict definition is difficult to write down. In general, it can be defined broadly as “useful knowledge, rooted in engineering and science, which usually also draws on practical experience” (Arora and Gambardella 2010, p. 645). Technology, in addition to be embodied in a physical product, can take the form of intellectual property as patens, or intangibles as a design and a software program, or a technical service. Moreover, transfer of technology can be done in several ways. Lichtenthaler (2005) highlights five main channels through which transfer of technology may take place. The most common ways through which transactions involving transfer of knowledge can take place are licensing-out, where royalties are paid to exploit the patent, and cross-licensing. Second, significant flows of technology take place when two companies create joint ventures, e.g. for the joint research and development of a new product, or in the case of acquisition of firms. Third, patents and knowledge can be sold and lead to different monetary reward and technological opportunity compared to a licensing strategy. Forth, technology can be transferred to spin-off of large companies, to create new innovative firms, endowed with technology and specialised asset, in order to enjoy advantages of both a small and a large firm in new product development and commercialisation. Fifth, another important flow of knowledge among firms' boundaries takes place together with the movement of people. Moreover, in addition to these main channels, more ambiguously classifiable transfers exist, e.g. technology transfers that take place together with the provision of associated artefacts. A typical example is the provision of complex machinery and the necessary knowledge to use it.

Not negligible is a further distinction between trade of technology and innovation. The former refers to transactions for existing technologies while the latter consists in contract for the research and development of new or improved products and processes. As defined in the Antitrust Guidelines for the Licensing of Intellectual Property (U.S. Department of Justice 1995) markets for technology "consist of the intellectual property that is licensed and its close substitutes, that is the technologies or goods that are close enough substitutes significantly to constrain the exercise of market power with respect to the intellectual property that is licensed".

Overall, boundaries are difficult to mark, the relevant literature on technology transfer is fragmented and each specific research stream takes into consideration different types of technology transfers under which knowledge can be exchanged.

Arora et al. (2001), to address the phenomenon, introduced the term "market for technology" to refer to a transaction which focus is the trade of knowledge or technology rather than a physical artefact. The general criterion behind the definition is to consider part of MFT transactions of artefacts for which the costs of developing the knowledge embodied in the artefacts significantly exceeds those of physically produce the artefact. Thus, MFT includes transactions ranging from pure licensing and cross-licensing agreement to wider technology "packages" that involve the exchange of patents together with know-how and services. Moreover, also transactions concerning designs, software and technical services can be included in MFT being "goods" acquired mainly for the knowledge embodied in them. On the contrary, some relevant forms of technology exchange as joint ventures and acquisitions are excluded. Joint ventures are considered forms of cooperation mainly oriented to develop new knowledge, while acquisitions do not involve only the exchange of patents on existing knowledge, but also competencies and capabilities to develop new technologies.

A similar stream of research on the phenomenon gained importance recently, including the licensing of technology perspective into a more comprehensive approach to knowledge management. Following Lichtenthaler's (2005 p. 233) definition, "External Technology Commercialisation (hereafter ETC) describes an organization's deliberate commercializing of knowledge assets to another independent organization involving a contractual obligation for compensation in monetary or non-monetary form". ETC includes inter-organisational collaborations (mainly alliances built for knowledge exploitation purpose), knowledge sale (with transfer of ownership) and divestment of company units (as spin-off) in addition to more common licensing-out agreement (taking into consideration both licensing and cross-licensing). Therefore, differently from MFT, the scope of ETC is broader and goes beyond specific types of knowledge transaction embracing organisational co-ordination and corporate strategy.

Beside the outward flow of technology, previous literature has given considerable attention to the other side of these transactions, that is, the acquisition perspective. Various theoretical and empirical studies have deeply investigate external technology acquisition, to understand the key factors that affect make-or-buy decision in R&D, as costs and risk incurred, absorptive capacity of the organisation, and ability to integrate new knowledge in the innovation process (Kurokawa 1997, Cohen and Levinthal 1990).

For the purpose of this study, being interested in the macro and micro factors that foster or limit the proliferation of outward technology transaction, I stick to the MFT definition given by Arora et al. (2001). Thus, I include in technology transactions all range of licensing agreements, even those concerning technology "packages", and I also take into consideration transaction flows under the form of technical services. By contrast, with this study I am not covering technology flows in R&D joint ventures, alliances or acquisition. Moreover, I am not taking into consideration university licensing, only focusing on transactions that take place among firms. During the study, I will focus the attention to outward transactions, addressing the practise with the term licensing agreement or MFT, while I will not consider inward transactions of R&D.

2.2.MFT objectives

A number of previously analysed factors, boosted division of innovative labour and MFT in recent years, and lead to the affirmation of practises that go far beyond the marginal activity of commercializing residual technologies (Amesse and Cohendet 2001). The increasingly important opportunity to externally exploit in-house produced technology has important implication for corporate strategy, as it allows a better technology portfolio management (Arora, Fosfuri and Gambardella 2001). Depending on the firm's particular technology strategy, dimension and other factors, market for technology assumes different importance and it is pursued to achieve different objectives. Previous literature has mainly focused on conceptual approaches, often addressing one specific objective or opportunities arising in a specific industry (Grindley and Teece 1997). By contrast, recently, Koruna (2004) attempts to establish a general overview of the main opportunities given by markets for technology (see Picture 7).

Firms may decide to license to pursue strategic objectives such as:

- Gain access to knowledge: In a highly competitive market, even firms that invest a considerable part of their turnover in R&D need to have access to other's inventions and knowledge. Shorter product and technology life cycles accompanied by growing technology convergence make acquisition of technological knowledge a requirement more than an option for many firms (Lichtenthaler 2008). In support of this idea comes the high number of firm acquisitions drove by the willing to acquire the firm's knowledge and patent right portfolio. MFT and licensing agreements allow a technology holder firm to successfully trade knowledge without dismantling its structure neither through acquisition by nor merge into the acquiring company.
- Obtain freedom to operate: this is the case of cross-license agreements entered by two or more firms in order to protect themselves against current and future mutual infringements in a specific field. The use of patents as "bargaining chips" in order to obtain freedom to operate is common in sectors driven by cumulative-technology (Reitzig 2003) or characterised by a high-degree of technology overlap (Grindley and Teece 1997) e.g. telecommunications, semiconductors and electronics. Generally, agreements made for this purpose cover a group of patents and address a specific "field of use". For the fixed term of the agreement, the firms are free to operate without the risk of patent infringement and litigation in the case of development of a product embodied with technology patented by other firms.
- Set industrial standards: firms may actively look for licensees, even with competitors, not for revenue reasons, but mainly to commercialise their own products successfully (Reitzig 2004). A firm may charge low royalties rates in order to ensure the wide adoption of the technology and establish a de facto market standard (Grindley and Teece 1997). Earning from the technology will come later from product sales in the expanded market. This practice assumes greater importance in a context of positive network externalities, where the value of the network, and in this case the utilization of the technology, is strictly connected with the number of the network's members (Katz and Shapiro 1985).
- Realizing learning effects: as in other commercial agreements such as alliances and joint ventures, learning in R&D may be the objective and the outcome of transactions of knowledge. Market for technology allows firms to fill the gap in specific areas and increase the speed of a firm's R&D activities through the learning effect (Lichtenthaler 2005). However, the ability to exploit external knowledge assumes a critical role in the process of technology transfer. The receiving firm has to ensure sufficient "absorptive capacity", that is the ability to recognise, assimilate and apply external information in order to realise the learning effect (Cohen and Levinthal 1990).

Beside strategic objectives, MFT also offers monetary opportunities by generating revenue flows and not pursuing the choice of the internal exploitation of the technology.

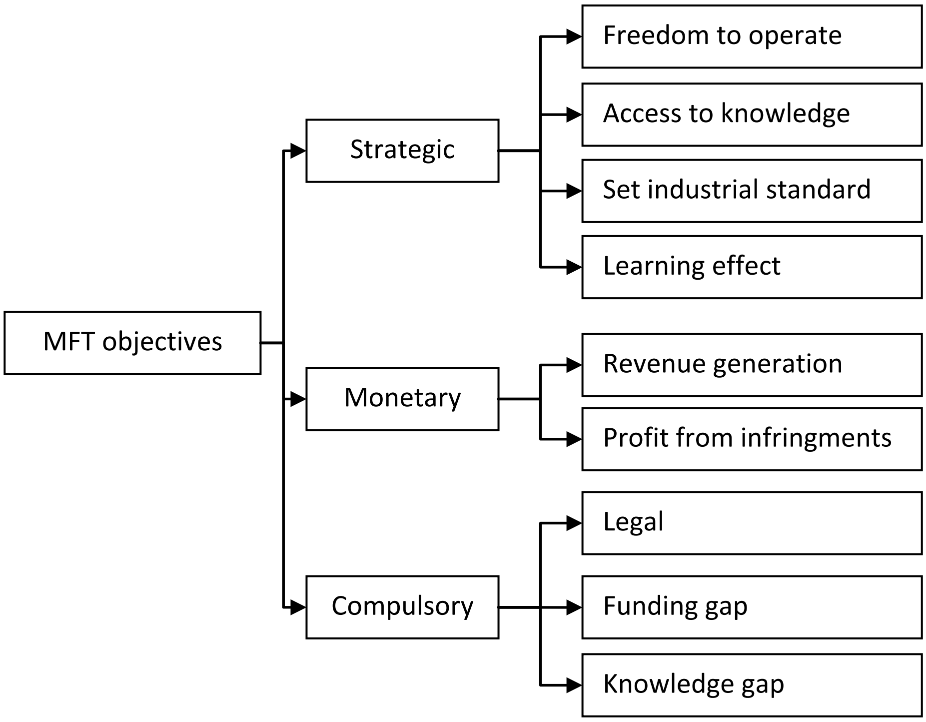
The main monetary aspects are:

- Generating revenues: it refers to the purely financial aspects of transfer of knowledge. For instance, Down Chemical and Lucent Technologies have earned millions of US dollars licensing part of their patent portfolio (Arora, Fosfuri and Gambardella 2001). The most popular example is IBM, whose revenues for patent and technology licensing agreements reach the value of $1.9 billion in 2001, up from the $30 million in 1990 (Grindley and Teece 1997, Chesbrough 2003). Evidence of a similar increase has also been documented in chemical industry (Arora 1997).
- Profiting from infringements: because of ICT revolution, intended or unintended patents infringement can be easily detected (Rivette and Kline 2000) and exploited to grand a consistent stream of revenues. This practice may assume both defensive and offensive characteristics and its use may range from “justified” legal actions to protect proprietary knowledge to the aggressive exploitation of possibly “trivial” patents as in the case of “patent sharks” (Reitzig, Henkel and Schneider 2010).

In addition to the previous strategic and monetary aspects, Lichtenthaler (2008) introduced a third dimension to include cases in which MFT may be a compulsory choice. Drawing on his work, I further expand these aspects to include transfers of knowledge caused by external obligations or internal shortage of competencies and resources. Examples may be:

- Legal: compulsory transfers of knowledge include actions not made to achieve strategic or monetary objectives but realised to comply with antitrust law and other regulations (Lichtenthaler 2008). In this case, licensing of technology may weaken the firm’s technological position in the product market but avoid punitive measures from regulators.
- Funding gap: a firm may, due to temporary or permanent lack of financial resources, not be able to embody its technology in a product and successfully bring it to the market. Forced by bad financial condition, the firm may, not voluntarily, pursue a monetary strategy, and exploit externally the technological innovation through the MFT.
- Knowledge gap: similarly to the previous case, a firm may be forced to enter MFT because of its lack (and incapacity to get from the market) of those human capital resources needed to enter the market for products. Given that successful production and commercialisation of a product require adequate competencies, a firm, after a careful analysis of the trade-off between building or acquiring specific competencies and license or sell the developed technology, may be forced by its peculiar condition to pursue external exploitation through MFT.

Despite the strict classification, it is more frequent to find examples of firms pursuing a combination of two or more objectives rather than pure manichean business model (Koruna 2004).



Picture 7: Overview of the systematisation of ETC objectives
Source: Adapted from Lichtenthaler (2008)

As confirmed by recent studies, licensing and other technology transfer practises are increasingly taken into consideration by firms, and assume a particularly relevant role for both very small- and large-sized firms (Zuniga and Guellec 2009, Fosfuri 2006). However, reasons and objectives behind the choice to externally exploit technology differ greatly for the two typologies of firms.

Large-sized firms are involved in a variety of activities and the management of their technological portfolio as well as licensing-out are aspects under growing consideration as firms are developing capabilities and resources to successfully take advantage of MFT. As highlighted by Amesse and Cohendet (2001), knowledge transfer is increasingly pursued to achieve strategic and monetary objectives, and it is no more a mere practise of residual technology commercialisation. Consistently Lichtenthaler (2008) suggests that strategic objectives are becoming increasingly important with significant differences across industries and according to characteristics of the specific technology.

Conversely, small firms, with limited or absent manufacturing and commercial facilities, and therefore not in a position to exploit themselves their inventions, may be more attracted from the “compulsory” monetary aspects of licensing such as the generation of revenues.

This is particularly true for New Technology-Based Firms (hereafter NTBFs). As all new firms, NTBFs are generally not fully integrated from the beginning, and usually undergo a research and development phase. At foundation, they closely resemble technology specialist companies, firms characterised by few downstream assets and a strong orientation towards licensing such as fabless or chipless firms in semiconductor or R&D specialist in biotechnology. Moreover, being small firms and often little diversified, possible applications of the new technology are likely to fall outside of the in-house competencies. Therefore, in deciding how to exploit their technology, small firms and start-ups must carefully balance benefits and costs of building in-house production facilities and commercialisation activities against rents that are lost by a licensing deal. Their particularly constrained financial condition may play a major role in the decision.

After having depicted a general framework of objectives valid for small and well-established firms, hereafter, the study will focus on the micro and macro determinants of commercialization strategies from the perspective of high-tech start-ups.

2.3. Macro determinants and analytical framework of commercialisation strategy for NTBFs

New Technology Based Firms are often the result of an innovation or a new idea brought to the market by a technology entrepreneur. These firms are generally identified as young start-ups operating in high-tech sectors and characterised by great flexibility and dynamism. Storey and Tether (1998) attribute to Artur D. Little (1977) the merit of having coined the name and having first defined NTBFs as “independently owned businesses established for not more than 25 years and based on the exploitation of an invention or technological innovation which implies substantial technological risks”. This definition has commonly been accepted as standard even if other authors have, through the years, proposed more restricted or broader definitions (Storey and Tether 1998).

Being generally young, small and technology-oriented, NTBFs commonly face shortage of adequate financial resources and market knowledge (Colombo and Grilli 2005, 2007) and these deficiencies may play an important role in shaping firms’ strategies, for example allowing the innovator to pursue only a limited number of strategic options at any time (Bhidé 2000). Let us consider a start-up intending to launch its new technology and profit from it. The choice between entering the product market, and therefore pursue a competition strategy, or “selling” the idea to an incumbent, cooperation strategy, requires a careful analysis of costs and benefits of each option. The entry into the product market requires a firm to heavily invest in production and marketing facilities, and develop key capabilities in downstream activities. Moreover, a firm launching a new product must be ready to face the tough competition of incumbents ready to cut prices and imitate the just-introduced functionalities. Conversely, negotiation in the market for ideas exposes firms to expropriation problems and transaction costs. Moreover, "shortsighted" firms, without understanding the true potential of their innovation, may sell at a low price a highly successful innovation.

Previous literature has identified five fundamental macro aspects that a start-up has to take into consideration and may heavily influence the entrepreneur ability to extract rent from innovation.

2.3.1. Appropriability

According to Teece (1986), the regime of appropriability plays a determinant role in determining who profits from innovation and thus deeply influence the innovator's decision of whether to exploit the innovation in-house or through MFT. Generally, a regime of appropriability defines the level of protection of someone's innovation from imitation and it can be considered a function of two main factors: the efficacy of legal mechanism and the ease of replication (Teece 2000).

The first dimension includes all the legal instruments such as copyright, trade secrets, patents and trademark and refers to their ability to secure a rent from innovation and to limit "inventing around" practises. Patents have traditionally been considered the strongest mechanism of protection, and in theory, they can be sufficient to confer the monopoly of the invention for a limited time in return for a public disclosure. Gans and Stern (2003) suggest that formal intellectual property mechanisms such as patents are more appropriate for market for ideas transactions compared to informal mechanisms, such as trade secrecy and speed-to-market, because the firsts allow the firm to disclose technology maintaining a strong bargaining power and keeping the opportunity to preclude development to the counterpart. However, as patents can be circumvented or be difficult to contest, other forms of protection, as know-how and trade secrets, have an important role as complements of patented technology as reported by Robbbin's (2006) study. Arora and Fosfuri (1998) point out that stronger patent rights may facilitate entry by specialized firms and contribute to vertical disintegration of the chemical industry. Beside theoretical considerations, empirical evidences are mixed. The relationship between strength of patents and MFT's propensity has been well documented by several studies (Lamoreaux and Sokoloff 1998). A clear example it is represented by the chemical industry, where patents have traditionally been important (Levin, et al. 1987) and where MFT has early developed (Anand and Khanna 2000). Moreover, using a sample of Massachusetts Institute of Technology start-ups, Gans et al. (2002) find that stronger and more effective IP protection not only increases the return from innovation, but also affects positively the relative return of cooperation as regards to go-it-alone strategy and thus facilitate the further development of MFT. By contrast, Cassiman and Veugelers (2002), analysing a sample of Belgian firms, find that more effective legal mechanisms are unrelated to the likelihood of entering cooperative R&D arrangements. More recently, Arora and Ceccagnoli (2006) provide a potential resolution of the mixed evidence on the topic. Differentiating according to firm's size, they find that an increase in the effectiveness of patent protection has a positive impact on MFT's propensity in firms lacking the specialized complementary assets to commercialised by their own the technology on the market for products. By contrast, in firms endowed with the necessary specialized assets, stronger IP protection positively influences the licensing behaviour but reduces the propensity toward MFT commercialisation. Consistently, Hall and Ziedonis (2001) provide evidence that in the semiconductor industry small firms are more likely to patent their technology in order to license it.

The second dimension refers to the nature of knowledge. Besides being seen as a problem to be overcome in MFT, the tacit nature of knowledge represents a powerful mechanism against imitation of innovations. In fact, the less articulated and codified knowledge assets are the more difficult and costly they are to transfer, as a successful transaction may require face-to-face communication and personal feedbacks. For the same reason, knowledge assets are also rather difficult to imitate (Teece 2000). Ambiguousness and the existence of different possible interpretations make reverse engineering techniques ineffective and increase time and cost of imitation. Overall, the partial "inarticulability" of knowledge increases the strength of the appropriability regime making more difficult to understand and replicate the technology on your own.

		Inherent replicability	
		Easy	Hard
Intellectual property rights	Loose	Weak appropriability	Moderate appropriability
	Tight	Moderate appropriability	Strong appropriability

Table 1: Appropriability regimes for knowledge assets
Source: Teece (2000)

Altogether, stronger IPR and tacit knowledge generally put the entrepreneur in a stronger position in front at both competitors and potential licensees.

A tight appropriability regime, more often the exception rather than the rule, enables the entrepreneur to translate his idea into market value at least for a period of time (Teece 1986). Thanks to the start-up's relatively strong position, it can have access to complementary resources solely by means of a contract. If the assets required are specialised or cospecialised, the contractual relationship may be exposed to hazard. However, strong intellectual property right should enable the innovator to retain almost entirely the profit either accessing incumbents' assets or building them. Consistently with this idea, Gans et al. (2002) provide empirical support to a positive relationship between strength of IPR and returns granted by cooperative strategies.

The level of appropriability protection has a direct impact on the so-called expropriation problem faced by innovators. In fact, the definition of property rights for a physical good is complex but to some extent relatively easy compared to intangible goods. Dealing with technology and ideas, even the partial disclosure of knowledge to the buyer, necessary to allow him to understand and evaluate the technology, may be enough for him to exploit the technology without paying for it (Arrow 1962). Once the information has been revealed, it is hardly impossible to prevent the buyer from using or reselling it. On the other side, absent or limited disclosure, further increases asymmetry of information and introduce inefficiency in the MFT. As showed by Akerlof (1970), information asymmetries, and thus impossibility to understand "fair" quality and value of the innovation, can prevent MFT from functioning, as the presence of "lemons" drives out "good" ideas.

The innovator, therefore, faces a dilemma: without revealing his idea, he cannot find buyers and this behaviour leads to market failure; on the other side, disclosure of technology may lead to imitation and lost of its rent. However, Lamoreaux and Sokoloff (1998 p. 21) suggest that probably "scholars have overemphasized the information problems associated with contracting for new technological developments in the market". As pointed out by Arora and Gambardella (2010), at least two aspects can possibly mitigate the problem. First, contracting solutions and institutional arrangements may reduce information asymmetries. Second, it is not always true that the licensor hold useful private information. Sometimes, the counterpart may be better informed about the potential applications of the licensor's technology. So far, empirical studies on the lemons problem in MFT are scarce and limited to the pharmaceutical sector, and results are still controversial (Pisano 1997).

In sum, a stronger regime of appropriability significantly affects the efficiency of technology-licensing contracts, by influencing both the possibility to extract returns from innovation and the level of disclosure, and thus enhancing incentives to license. However, stronger protection may, in some instances, generate offsetting effects and reduce propensity towards MFT according to firm's size.

2.3.2. Complementary assets

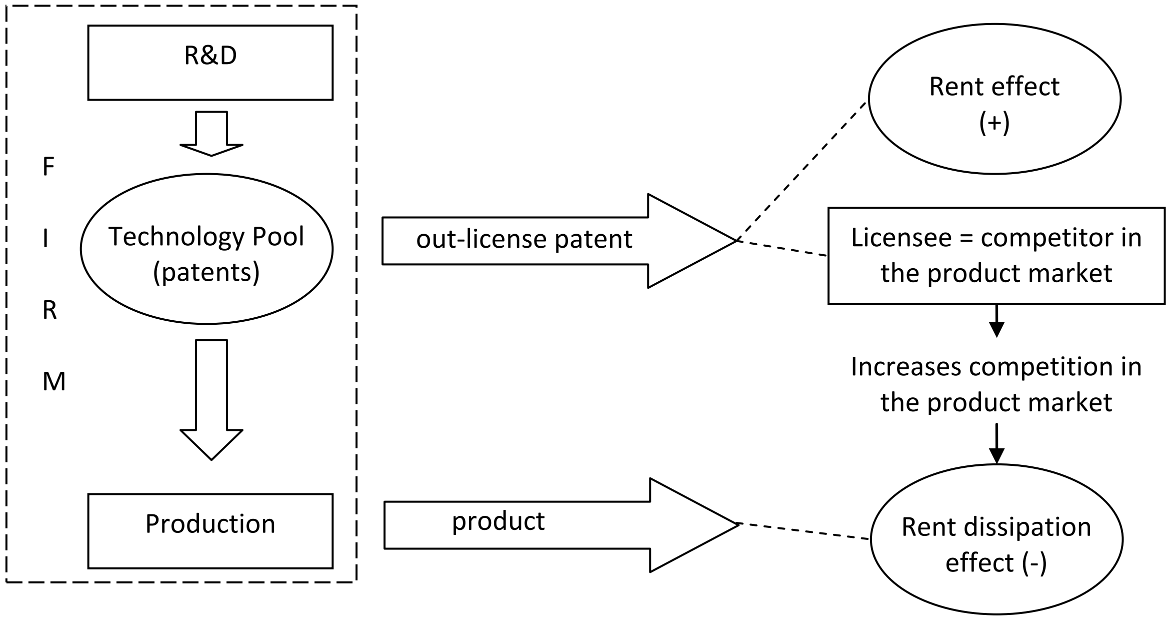
A second factor, which plays a key role in defining a firm's strategy and positioning, is the existence and necessity of complementary assets, including manufacturing and marketing facilities, distribution channels and brand-name recognition. Being knowledge a typical intermediate good, in order to generate a return it needs to be traded on MFT or be embedded into products sold on market for product (Teece 2000). Therefore, manufacturing and marketing assets, required to "package" technology into a valuable good for the final customer, can play an important role and affect the firm competitive advantage. Considering a firm willing to pursue a go-it-alone strategy, the ownership and control of the required complementary assets significantly influence the innovator's bargaining position and, thus, affects his opportunity to get an appropriate rent from innovation (Teece 1986). When the required assets are already owned by the knowledge owner, there is no issue. If the required complementary assets are generic, i.e. they do not need to be tailored to the innovation, the firm may be able to have access to important resources at low cost. However, if assets are specific and controlled by other players, usually incumbents, the firm faces the dilemma of either pursue a competition strategy and, thus, develop costly-to-build required assets, or choose cooperative commercialisation through technology licensing. In sum, difficulty in acquiring specialized complementary assets may hinder the firm's entry into the product market, increasing the attractiveness of MFT.

This is particularly true for start-up innovators in high technology sectors as shown by Colombo and Grilli (2006), who provide empirical evidence of the importance of accessing complementary assets for NTBFs. High-tech start-ups, typically unlikely to possess manufacturing and commercial facilities and thus having to face the sunk cost of product market entry, are more likely to earn return from innovation through the MFT rather than through competition in the market for product. As showed by Lerner and Merges (1998) almost all successful start-ups in the biotechnology sector have either transferred their innovation through licensing agreements, entered into downstream alliances or been acquired by competitors. As explanation of the phenomenon, Gans and Stern's (2000) analytical model shows that the higher the importance or concentration of complementary assets, the greater the incentive to pursue a technology licensing strategy instead of competition. Rothaermel (2001) documents that incumbents in the pharmaceutical sector highly benefited from innovation developed by biotechnology start-ups thanks to the necessity of the latter to access complementary assets owned by the former. Consistently, McGahan and Silverman (2006), analysing different situations characterised by a strong or feeble importance of complementary assets, give empirical support to the role of complementary assets for product market commercialisation. Kollmer and Dowling (2004), investigating technology commercialisation strategy for NTBFs, document that the presence of marketing and sales facilities has a negative impact on licensing propensity.

In sum, the presence of complementary assets plays an important role in influencing propensity to license technology, in particularly for small firms.

2.3.3. Competition

Prior studies on technology transfer have generally assumed a model where a single technology holder also acts as monopoly producer of the good. This often implies licensing not be profitable on its own, but attractive only to pursue other strategic objectives. However, typically, technology holders compete among them, and it may be the case that a technology holder, operating in the market for product, also competes with other producers. Arora and Fosfuri (2003) develop an analytical model, where multiple technology holders compete both in MFT and in market for products and try to understand whether competition in the product market influences propensity towards licensing practices.



Picture 8: Revenue effect and rent dissipation effect of out-licensing
Source: Motohashi (2008) and Arora and Fosfuri (2003)

In deciding whether to license or not, the firm has to take into account two factors: first, the "revenue effect" due to the royalties earned by the licensor, and second the "rent dissipation effect" due to the increased competition in the product market generated by the licensee's presence. In fact, once the licensee comes to the market, the licensor's monopoly may be destroyed or at least his market share reduced. The equilibrium between the two effects may be influenced by various factors such as the degree of product differentiation across technologies (Arora and Fosfuri 2003) and whether the commercialisation of technology takes place inside the firm's own industry (i.e. the licensee is a competitor) or outside (Lichtenthaler 2005).

The previous framework may also help in explaining the relationship between licensing propensity and firm size. Large producers have relatively less to gain from licensing, as the revenue effect may be offset by the "rent dissipation effect" caused by increased competition in the product market. By contrast, small firms have much more to gain from technology commercialisation being able through this practise to appropriate of innovation rents without entering into tough product market competition. In fact, smaller firm, typically with little or no stakes in the downstream product market, suffer less from the "rent dissipation effect" of additional producers in the product market (Arora and Fosfuri 2003). Consistently several studies found that small firm specialized in supplying technology are less incline to compete in the product market with goods which embed out-licensed technology. This particular behaviour has been documented in the semiconductor (Hall and Ziedonis 2001), biotechnology (Arora and Gambardella 1990) and software security sector (Giarrattana 2004).

In sum, the level of competition faced by a firm in the product market has a significant effect on the type of strategic choice. This generally lead small and recently established firms to be more incline towards an external commercialisation strategy than internal exploitation.

2.3.4. Transaction costs

Another important factor that influences technology commercialisation strategy is transaction costs. The search and discovery of a buyer (or seller) and the evaluation of his offer (or request) play an important role in economic decision-making (Stigler 1961). Due to the specific nature of market for technology, transaction costs are a matter of concern. The actors of MFT must decide how much time to allocate to search for counterparts, and how much time to spend with them (Smith, Venkatramanb and Dholakia 1999). High search cost may induce the individual to undertake a sub-optimal decision or renounce to the deal. Findings from Zuniga and Guellec (2009) point out the importance of this factor. Results of their survey indicates that for 25% of the firms in the sample the identification of the counterpart has been a major obstacle, while for another 17% difficulties encountered during the negotiation phase have hampered the process.

A possible way to reduce search and bargaining costs is through the very recently developed online knowledge markets, virtual marketplaces as FlintBox and Yet2, conceived to facilitate listing, search and exchange of knowledge assets. There are reasons to believe that online marketplaces may lower cost of searching granting access to a more distant and heterogeneous audience, as well as standardizing the representation of information (Dushnitsky and Klueter 2011). This new tool may further increase MFT thanks to better efficiency in matching potential sellers and buyers.

Not negligible is also the role of intermediaries in reducing transaction costs. Gans et al. (2002) argue that third-party "brokers", such as venture capitalists, may have a positive impact on the formation of licensing agreement for start-ups. Thanks to long-term experience and reputation, those intermediaries can both facilitate the matching of buyers and sellers of knowledge assets and certify the quality of innovation.

Moreover, as highlighted by Lichtenthaler and Ernst (2007 p. 38), "reputation for past performances serves as an imperfect substitute for direct knowledge" and thus may be particularly valuable in highly uncertain contests. Thus, reputation may help firms to overcome MFT imperfections, such as transaction costs and risks of opportunistic behaviours, and enhance firms' opportunity to extract rent from innovation through transfer of knowledge assets.

In sum, transaction costs play a relevant role and may even hinder MFT transactions. However, recently developed virtual marketplaces and efforts made by intermediaries may significantly lower difficulties related to discovering and negotiation with potential partner. In addition, firms with a sound track record can enjoy some advantages further lowering transaction inefficiencies.

2.3.5. Uncertainty and corporate crown jewels

To conclude, uncertainty about the value of the patent may drive firms to a negative attitude towards external commercialization of knowledge, fearing the possibility to give away revolutionary discoveries at low price. In fact, the skeweness of the distribution of the economic value of patents (Scherer and Harhoff 2000, Gambardella, Harhoff and Verspagen 2008) and the uncertainty about the possible specific license's position in this distribution influence the firm's propensity towards MFT. This specific reluctance in entering MFT is often referred as "fear of giving away corporate crown jewels" (Kline 2003).

2.4. Micro determinants of MFT choice

Technological competences have long been regarded as the most important core competence for NTBFs, as knowledge and skills enable ventures to develop and grow thanks to technological innovation. The availability of financial resources, that allow the effective and successful development of the firm, also has received great attention by scholars. Thus, beside the previously analysed macro determinants, I next consider how these two firm-level factors may influence NTBFs' technology commercialisation strategies.

2.4.1. The effect of financial constraint on technology commercialisation

Financial capital is one of the necessary and most important resources that allow a firm to begin, develop and operate. Given the limitation of the entrepreneur personal capital, almost always other sources of financing are required. When financial resources of the founders are insufficient to finance R&D and other tangible investments at the appropriate scale, even the most potentially successful and revolutionary idea may be at risk. In this case, the role played by external finance, such as equity financing provided by business angels, venture capitalists etc, or credit and bank loans, may be determinant.

Due to their nature, NTBFs are more likely than other firms to suffer from capital market imperfections (Westhead and Storey 1994). Despite European NTBFs show a lower failure rate than start-ups in less technologically advanced sectors (Storey and Tether 1998), these firms are perceived by the most as businesses at high-risk because of the technological content of their products and services. Moreover, NTBFs, given their small size, are little diversified as they tend to focus on the development of few, more often one, technologies and products. This exposes ventures operating in high-tech sectors to high risk of failure. Those factors, together with capital market imperfections, may lead start-ups operating in high technology business, to suffer from the so-called "funding gap" (Carpenter and Petersen 2002, Westhead and Storey 1994).

2.4.1.1. Equity and debt financing for NTBFs

Previous literature has given considerable theoretical and empirical attention to capital structure of firms. The pecking order theory (hereafter POH), developed by Myers and Majluf (1984), suggests that the existence of information asymmetries induces the firm to use first internal sources of finance instead of external financing. When internal sources are exhausted, the firm will opt for debt rather than equity. Empirical validation of the pecking order theory, conducted on samples of large corporations, has provided considerable support to the hypothesis (Shyam-Sunder and Myers 1999, Titman and Wessels 1988). Several studies have confirmed the validity of POH also for small firms (Berger and Udell 1998, Berggren, Olofsson and Silver 2000). However, the predictions of the POH are not confirmed for NTBFs.

Research literature agrees that, consistently with the pecking order theory, NTBFs tend to use first internal sources of finance instead of outside sources (Giudici and Paleari 2000, Bank of England 2001, Hogan and Hutson 2005). However, when founders' endowments are not sufficient, whether a start-up opts for equity or debt is still controversial even if, overall, equity financing seems to enjoy a number of advantages over debt.

First, NTBFs are likely to suffer from great information asymmetries. According to the agency cost theory, strong information asymmetries between the entrepreneur and the capital provider play a crucial role and lead to adverse selection and moral hazard problems as founders are generally assumed to be better informed about quality, risk and future perspective of their innovation (Stiglitz and Weiss 1981). Banks generally face great problems in understanding and assessing high technology firms (Oakey 1984). Despite large banks are willing to provide finance to NTBFs, because of the difficulties faced in evaluating technical projects, they tend to charge high interest rates and to ration credit quantity (Bank of England 2001). The cumulated experience of banks in assessing risk and evaluate projects of usually large firms operating in conventional sector gives no advantage for the evaluation of high-tech start-ups born around an innovative idea and thus hardly comparable. Thus, in case of debt financing, difficulties in assessing innovation potential, exacerbated by moral hazard and the risk of opportunistic behaviour, may lead to credit rationing actions by lending institutions (Jaffee and Russell 1976). Moreover, as monitoring of NTBFs activities is particularly difficult, entrepreneurs may be further stimulated to engage in risky activities (Jordan, Lowe and Taylor 1998).

On the contrary, equity providers specialized in funding young start-ups, such as business angels and venture capitalists, are assumed to be better equipped to overcome information asymmetries and moral hazard problems (Gompers 1995, Gompers and Lerner 2001). As suggested by Diamond (1984), venture capitalists benefit from increasing return of scale in analysing and monitoring a "homogeneous" class of start-ups. Differently from other intermediaries, venture capitalists are more likely to be aware of risks and opportunities, as they share with innovators a higher understanding and knowledge of technology and market potentiality (Dahlstrand and Cetindamar 2000). Not negligible it is also the role they play in the financed firms, being usually actively involved in the management of the firm (Gorman and Sahlman 1989, Sahlman 1990). Their active involvement allows them to keep the entrepreneur's interests aligned with their own and thus reduce the risk of opportunistic behaviours. Moreover, they coach and support the managers of the start-ups in taking operative and strategic decisions in order to take full advantage of possible opportunities. At last, network ties and endorsement may help in finding possible cooperation partners and signal the quality of the start-up to uniformed third parties, improving the venture performance (Stuart, Hoang and Hybels 1999). In favour of this idea, Hsu (2004) documents that entrepreneurs are willing to accept a discount on the valuation of their start-up in order to affiliate with more reputable venture capitalists.

Second, the typically intangible nature of NTBFs' assets can be a severe problem, in particular for debt financing. Young firms in high-tech sectors are characterised by a great amount of intangible assets, e.g. the entrepreneur human capital, but these can hardly be used as collateral for bank loans (Hart and Moore 1994). Consistently, as highlighted by Hall (2002), generally, during the first phases of development, NTBFs invest at least half of their money in wages and salaries of highly educated scientists and engineers in order to create valuable knowledge. This tacit and still under-developed know-how can hardly be used as collateral. Physical investments, regularly used as guarantee by developed firms, if existing, are so specific that present little collateral value in any case. In fact, investment are generally designed to develop or embody (e.g. prototype) R&D results, therefore being highly firm (or at best industry) specific (Carpenter and Petersen 2002).

Third, the distribution of return from high-tech investments is highly skewed mainly because the financial success of R&D projects is generally low as can be deduced from the distribution of value of patents (Gambardella, Harhoff and Verspagen 2008). Given the difficulties in assessing properly technology value and thus the firm's likely future performances, previous achievements and reputation (i.e. the firm's track record) may play a positive role in increasing investors' confidence (Gompers and Lerner 1998).

In sum, for the previously highlighted reasons, equity financing provided by venture capitalists seem to enjoy some advantages over debt as source of capital for NTBFs. However, empirical studies on the topic report controversial results.

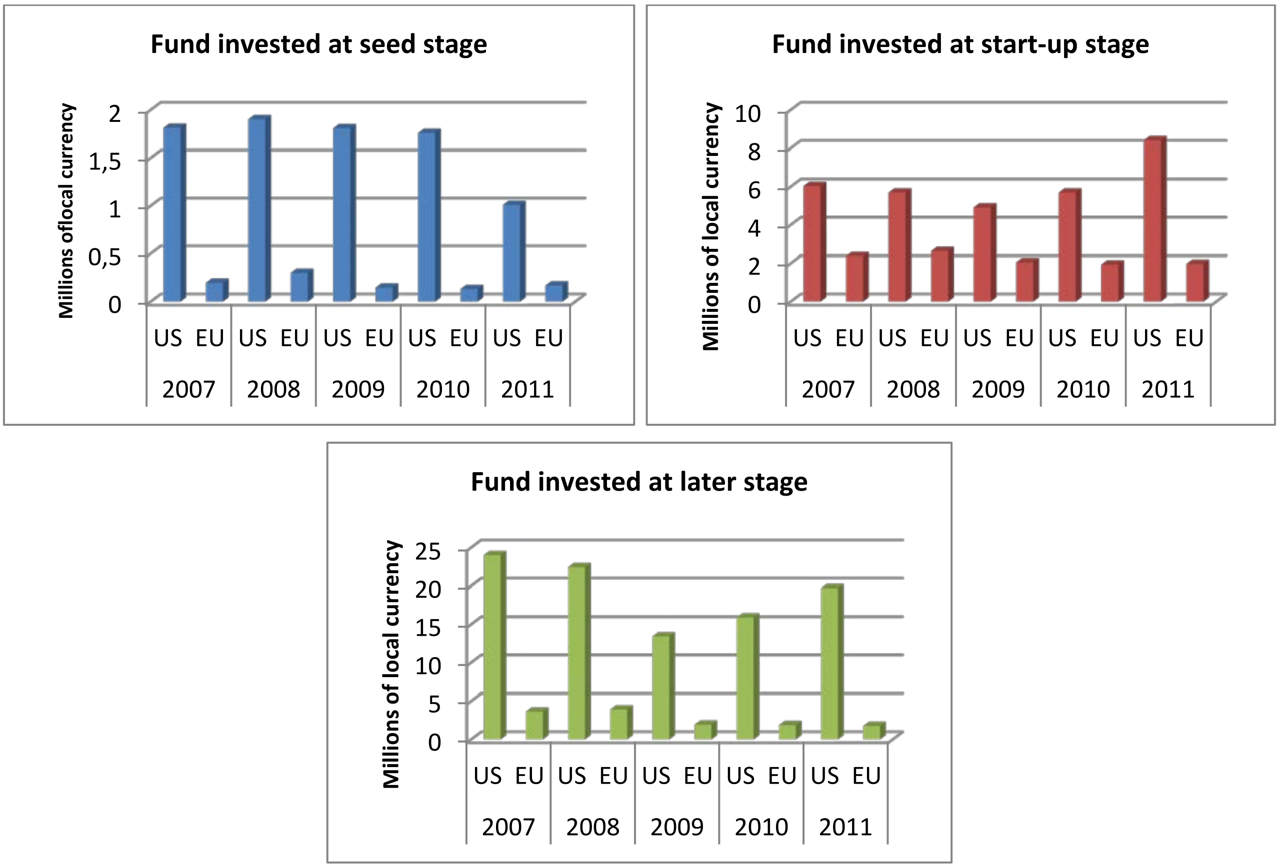
A first stream of literature argues in favour of a preference for equity to debt, in contrast with the prediction of the pecking order theory. Hogan and Hutson (2005), in a recent survey on Irish NTBFs operating in the software industry, find that high-tech start-ups tend to choose equity financing rather than debt. As possible explanation, they suggest the existence of greater information asymmetries with banks than with equity providers. Similarly, Carpenter and Petersen (2002), analysing a sample of US high-tech small and medium size firms, find that these firms make little use of debt. Consistently, Sau (1997) introduces a revised version of the pecking order theory, suggesting that external equity is preferred by innovative firms.

On the contrary, Giudici and Paleari (2000) from the analysis of a sample of Italian technology-based small firms, observe that nearly 75% of start-ups are financed by the founding team's personal capital and debt represents the second source of funds. Consistently, Manigart and Struyf's (1997) study on a sample of Belgian high-tech start-ups, confirmed bank loans to be the second source of financing after the entrepreneur's personal capital and before equity.

To conclude, empirical results document that, despite the multiple advantages enjoyed by venture capital, banks, in some countries, play a relevant role in financing high-tech start-ups.

2.4.1.2. Market Based versus Bank Based system

The previous section has depicted the importance of venture capital in financing the development of NTBFs. However, the venture capital industry developed only recently, and with important differences among countries. In the US, the venture capital industry was already well developed in the early 80s (Sahlman 1990), and has been at the heart of the financing of the Silicon Valley's high-tech firms. By contrast, most of European countries have seen a late development of this source of financing, and still nowadays, it occupies a marginal role compared to the United States and the United Kingdom. As documented by Bottazzi et al. (2002), despite a considerable growth between 1995 and 2000, the number of venture capital firms and the amount of fund invested are still significantly lower in Europe compared to US. More recent data confirms that the gap between US and Europe remains high nowadays. As Picture 9 clearly documents, the amount of funds invested in start-ups at different stages in Europe ranges merely between a third and a tenth of what invested in US. Further significant differences exist within Europe. Picture 10 clearly states the different amount of venture capital invested as percentage over GDP among countries in the world. Some European countries as the UK and Sweden report the highest activity of venture capitalists worldwide, while, on the contrary, other countries as Italy, Germany and Austria have a much less developed venture capital industry.



Picture 9: Fund invested by venture capitalists in US and EU at different stages
Source: NVCA and EVCA

According to several studies, a strong relationship between the type of financial system, market-based or bank-based, and the extent of venture capital finance exists (Black and Gilson 1998). Market-based economies are generally those where the majority of financial assets are traded on financial markets. By contrast, bank-based countries, are those where the bulk of financial assets consist of bank loans and direct loans. Given the multitude of factors that influence the economic system, the "dichotomisation" of countries in two classes is hard. However, research literature is rather in agreement on the definition of US, UK and Canada as market-based systems and Germany, Japan, France and Italy as mainly bank-based economies (Rajan and Zingales 1995, 2003, Demirguc-Kunt and Levine 1999).

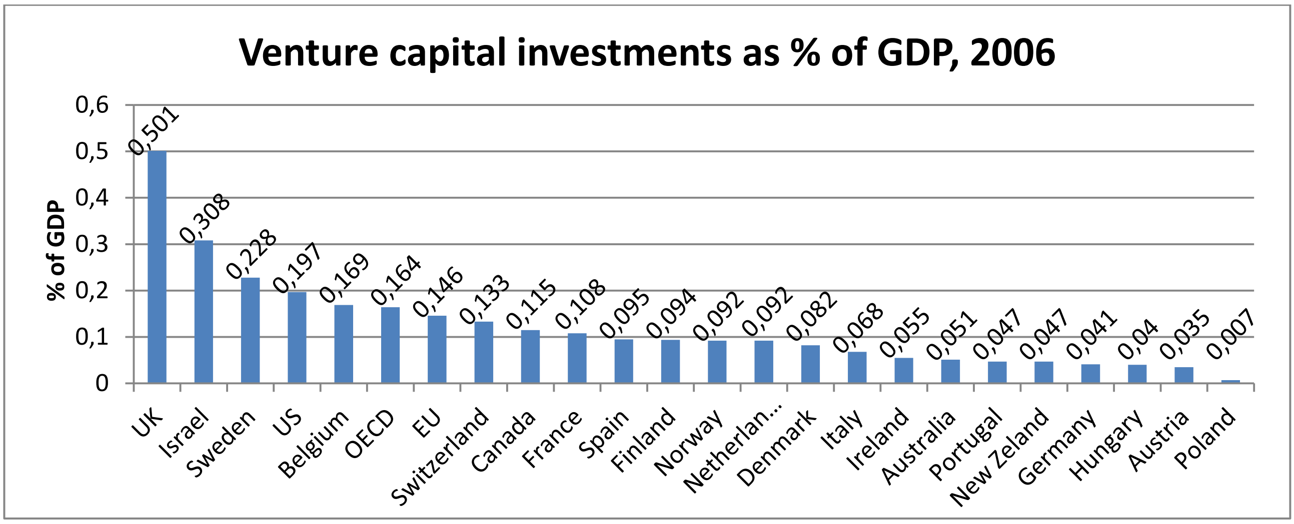
Research literature on whether a market-based or a bank-based system is more efficient in allocating capital and thus foster economic performance is still controversial. Many authors have stressed the advantages of having either a bank system or a market-based economy[1] and so far empirical research has failed in giving a complete and widely accepted answer to the debate. For instance, Rajan and Zingales (1998), analysing a panel of 42 countries and 36 industries, find that industrial sectors more heavily dependent on external finance grow significantly faster in economies with more developed financial

[1] Being the detailed analysis of the advantages and disadvantages of having both a bank-based and a market-based system out of the purpose of this study, I recommend the reading of Beck and Levine (2002) and Rajan and Zingales (1998) for a deeper analysis and a complete literature review on the topic.

markets. By contrast, Beck and Levine's (2002) empirical study shows that the belonging to either a market-based or a bank-based system gives no advantages to industries which depend heavily on external finance.

A related stream of literature investigated the relationship between financial structure and innovative activity. Brown et al. (2009), analyzing a sample of publicly traded high-tech firms, suggest that financial supply may have been a determinant of the finance-driven cycle in R&D experienced in the US. Based on firm-level data, they show that the dramatic boom in R&D in the nineties in US depended significantly on high-tech small firms' ability to access either cash flow or external equity. Martinsson (2010) extends Brown et al.'s (2009) research analyzing a sample of European high-tech firms, and investigates whether UK's market-based system differs from other countries' bank-based system in terms of equity supply. Consistently to what previously documented in US, British small firms experienced an increase in supply of external equity and used these funds to invest in R&D. By contrast, high-tech firms based in continental Europe, were only able to invest funds generated from internal cash flow and, thus, reported a significantly lower degree of investment in R&D.

In sum, previously cited literature does not confirm unambiguously the relationship between the type of financial based system predominant of a country and economic growth. However, it is not negligible that market-based economies are characterised by a more developed venture capital industry. Moreover, given the advantages enjoyed by equity over debt in financing high-tech start-ups, in bank-based economies firms may suffer from pronounced funding gap.



Picture 10: Venture capital investments as percentage of GDP, 2006
Source: OECD Science, Technology and Outlook 2008, based on data from ECVA, NVCA, CVCA, AVCAL, NZVCA, Asian Venture Capital Journal

2.4.1.3. Effect of debt rationing on technology commercialisation choice

Given the relative recent development of MFT, a still limited stream of literature has focused on commercialisation strategies for high-tech start-ups explicitly taking into consideration licensing agreements as a feasible development strategy. Only few studies investigate licensing agreements between small and established firms, mainly focusing on the allocation of property rights between young biotechnology and established pharmaceutical companies (Lerner and Merges, 1998) and within ICT firms (Elfenbein and Lerner, 2003). Overall results highlight that a positive relationship exists between the allocation of property rights and the bargaining power of the parties, which usually penalise R&D-intensive firms.

Despite the importance and attention received by NTBFs financing sources and methods, studies that take into consideration the effect of financial issue faced by start-ups entrepreneur on the commercialisation strategy, distinguishing between licensing technology and embedding knowledge into products, are much scarce. Aghion and Tirole's (1994) analytical model suggests that R&D is likely to be conducted in an integrated firm if capital resources are relatively important compared to human competencies. By contrast, when financial resources play a significant role and are scarce, the R&D is likely to be fragmented among several firms. Greis et al. (1995) analyse a sample of biotechnology firms and test the existence of both environmental factors and firm-specific barriers at different development stages. They find that, once the research and development phase is concluded, funding availability is one of the two most significant variables in explaining their propensity towards external partnering for manufacturing. Consistently, Feldman and Ronzio's (2001) survey on biotechnology start-ups in US documents that 80% of the interviewed firms are willing to integrate downward and to control their own manufacturing facilities. However, the decision to pursue a go-it-alone strategy is heavily contrasted and in many cases hinder by lack of capital.

Recently, given the importance held by venture capital in the development of start-ups, some studies analyse its role in favouring competitive or cooperative commercialisation strategies. The common wisdom highlights the positive influence of venture capital towards a product market strategy, as it provides start-ups with capital to acquire or build the necessary manufacturing assets (Chesbrough 1998). However, Hsu (2006, 2001), highlighting the role venture capitalists play as intermediaries, suggests that VC-financed start-ups are more likely to pursue a cooperative commercialisation, either through alliance or licensing, than in-house expropriation. The positive relationship between being VC-backed at foundation and a cooperative strategy has been documented on a multi-sector sample of 696 US start-ups. However, a similar study based on a sample of British and German start-ups could not document a significant impact of being VC-backed on the commercialisation strategy (Haeussler 2011).

Considering the necessity of start-ups to access or build complementary assets in order to embed innovation technology into a new product, the difficulty they encounter due to the small bargaining power, the considerable financial constraints they face, and the different role venture capitalist and banks may play in financing and support NTBFs, I obtain the following hypotheses:

HP1) ceteris paribus, the restricted access to debt financing, in a "bank based country" as Italy, may drive NTBFs to "renounce" to a product market strategy in favour of external commercialisation of the technology.

2.4.2. The relationship between human capital and technology commercialisation

2.4.2.1. Personal characteristics of NTBFs' founders

Literature research has given considerable importance to the personal characteristics of NTBFs' founders in order to find significant drivers of start-ups performance and growth, and most studies demonstrate that NTBFs' founders' background significantly differs from those of more "typical" entrepreneurs.

First, with regard to academic achievements, several studies have showed that NTBFs' founders have a significant higher level of educational attainment compared to those of founders of other types of new business (Storey and Tether 1998, Westhead and Storey 1994). More recently, figures from the Patval (PatVal-EU 2005) report indicate that 76% of European inventors reached a tertiary level of education (Master of Science or Bachelor) and more than a quarter completed a PhD. Moreover, with regard to the field of study, Licht et al. (1995) report that the majority of the founders has an engineering background.

Second, most of NTBFs' founders are older than other business starters (Donckels 1989), and are likely to have been previously employed in large firms (Storey and Tether 1998, CIRET 2002).

Third, in the formation of entrepreneurial teams, sociological studies highlighted the role of homophily and network ties as key drivers (Aldrich, Carter and Ruef 2002). The tendency to associate and bond with similar individuals is strong and generally leads to the creation of team of founders who share similar competencies. These derive mainly from their academic education and previous work experience. Coherently with what predicted by previous social studies, evidences from the RITA dataset on Italian NTBFs shows that among the founding team 80% of the members have similar prior experience (Colombo and Piva 2008). Moreover, operating in high technology sectors, founders of these firms are more likely than others to have worked in R&D or engineering departments rather than in production or commercial units.

In sum, high-tech start-ups are likely to possess both a high level of academic education and some years of working experience. However, the founding team of NTBFs tend to be quite homogeneous and particularly rich of technical experience but considerably poor of production, commercial and managerial competencies (Westhead and Storey 1997).

As highlighted by Cooper and Bruno (1977 p. 21), “for a new, high-technology firm, the primary assets are the knowledge and skills of the founders”. This is particularly true at foundation, when the start-ups, due to transaction costs and information asymmetries face the difficult challenge to expand the founder knowledge-base (Penrose 1959). First, costs incurred in searching and selecting suitable candidates are likely to represent a considerable investment for a start-up (Spence 1973). Second, given the characteristics of smallness, newness and the high risk perceived, possible candidates may decline the firm’s employment offer in favour of places in more reliable and well-established firms. Third, enterprises like NTBFs, at the forefront of technology development, are more likely than other to be affected and constrained by the availability of skilled managers and other personnel (OECD 1998). Thus, information asymmetries, the inexistence of a track record for newly founded start-ups and their high-tech nature make difficult for these firms to recruit necessary competencies on the job market. In support of this idea, studies on the coaching function of venture capital firms provide evidence that the presence of venture capitalists help the “professionalization” of the start-up (Hellmann and Puri 2002). Venture capitalists represent an important resource, providing competencies in fields where start-ups lack of internal competencies. Moreover, external investors may favour the recruitment of key figures for the development of the business as manager operating in sales and marketing.

In sum, taking into consideration both that at foundation NTBFs’ competencies reflect mainly those of their founders and the academic and working experience of NTBFs’ founding teams, it is reasonable to expect these firms to have a significant shortage of human capital in key functional areas and, this in turn, may impact the strategic decisions, development and growth.

Given the fine-grained analysis needed to understand whether shortage of competencies in specific functional areas may impact a firm’s strategy, for the purpose of this study, I will use as direct as possible indicators of founder’s human capital. Thus, in addition to distinguishing between academic and work experience, I follow Becker’s (1975) distinction between the generic and specific components of human capital. The term generic refers to general knowledge acquired and developed through education and work experience. On the contrary, specific human capital refers to competencies and skills directly applicable in the job and includes, for example, industry-specific capabilities developed during prior work experience in the same industry. Moreover, I also distinguish education and work experience according to the nature of knowledge acquired, with the former differentiated between technical and economic background, and the second among technical, productive and commercial experience.

2.4.2.2. Effects of NTBFs' human capital on technology commercialisation strategies

Previous literature has deeply investigated the role played by the human capital "embedded" in the founding team. Numerous studies analyse whether the level of education attainment, the years of previous work experience, and the heterogeneity of the founding team influences the likelihood of survival, performance and growth of new firms with different significant results (see e.g. Storey and Tether, 1998; Colombo and Grilli, 2005).

A related stream of literature investigates whether competencies and knowledge resources affect firm boundaries and strategic decisions. Building on Langlois and Robertson (1995), capabilities of a firm have generally been grouped into two sets: direct or core capabilities are those necessary to create and develop a product such as R&D, production and commercial skills, while indirect or ancillary capabilities refer mainly to the firm's ability to interact with customers, suppliers and other external actors. Araujo et al. (2003) argue that direct capabilities shape the boundaries of the firm, mainly influencing make-or-buy decision and forward/backward integration. Empirical evidence of this idea can be found in a case study research conducted by Argyres (1996). From the analysis of interviews held with managers and engineers of various California-based firms, he shows that integration decisions seem to be driven by a firm's ability to exploit its core competencies in adjacent activities. Further evidence is provided by the semiconductor industry (Leiblein and Miller 2003). The empirical analysis suggest that the greater the firm's experience in manufacturing, the higher its propensity to vertically integrate the production process. By contrast, previous experience acquired in negotiating and contracting with sourcing partner helps in the identification of trustworthy partner and in mitigating opportunistic behaviour, thus, reducing the likelihood of vertical integration. In sum, the firm's endowment of capabilities directly related to the creation, development, production and commercialisation of a product plays an important role in influencing strategic choices as defining the firm's boundaries.

Taking into consideration NTBFs, Van der Meer and van Tilberg (1984), examining a sample of University spin-off in Netherland, reported that shortage in marketing and production competencies represents a major obstacle to their development. Moreover, several studies highlight the role played by the lack of managerial competencies and entrepreneur knowledge in NTBFs (Autio 1995, OECD 1998). The analysis of Italian NTBFs conducted by Politecnico di Milano (CIRET 2002) supports previous studies, reporting that more than 65% of NTBFs' founders of the sample attended a technical or scientific academic education and only 22% had an education in social sciences fields. Moreover, more than 50% of the founders with a prior experience, hold technical positions in R&D or engineering, almost 14% come from production and 21,6% were employed in commercial activities.

Despite the peculiar characteristics of NTBFs' funding teams, so far, studies that explicitly take into consideration the relationship between the founders' human capital endowment and technology commercialisation decisions is almost inexistent. As far as I know, only a recent study of Kasch and Dowling

(2008) investigated whether the firm's experience acquired in different stages of the value chain influences the choice between internal or external exploitation of the developed technology. The empirical analysis conducted on a sample of 114 firms operating in the biotechnology industry shows that previous higher level of direct capabilities increases the likelihood of internal exploitation. However, the study does not differentiate among direct capabilities, deriving from experience gained in different functional areas.

Taking into consideration the peculiar characteristics of NTBFs founders and previous research literature on the topic, I derive the following hypotheses:

HP2) ceteris paribus, the shortage of skills in production and marketing areas and the rich endowment of technical competencies at foundation, may drive NTBFs, to pursue external exploitation of technology rather than a product strategy.

HP3) ceteris paribus, the greater the homogeneity of competencies, both educational and job-related, among the founding team at foundation, the higher the likelihood of a firm to pursue internal exploitation rather than external exploitation.

HP4) ceteris paribus, the shortage of managerial competencies at foundation have a positive influence of the likelihood of external exploitation of technology

2.5.Licensing: a short-term opportunity or a long-term strategy?

After having described implications of micro and macro determinants at foundation, I shift the perspective to the long-term.

Previous literature has given great importance to the study of new ventures development, and a significant branch of the literature has proposed theoretical and empirical evidence of a stage-development path for entrepreneurial ventures. Kazanjian (1983), reviewing prior studies, finds more than twenty different stage-development models, each different in terms of number of stages and aspects addressed. However, the common characteristic is the presence of a sequence of stages through which organisations pass and the assumption of a product market strategy at the base of growth. Even in the case of a high-technology venture, the common view is that start-ups are created for the specific purpose of developing a new technology that will be embedded into a product (Kazanjian 1984). This will be launched on the product market by the same start-ups. The objective of new ventures is therefore "limited" to the product market and consists mainly in defining, developing and marketing a physical artefact. So far, only few studies have offered a theoretical analysis of external technology exploitation as a development strategy for start-ups (Gans and Stern 2003).

2.5.1. NTBFs' role in modern economy

Previous literature has deeply investigated the role of NTBFs in the economy, and most of previous analyses see NTBFs as a great source of economic development and highlight their capacity to create direct and indirect employment and wealth (Storey and Tether 1998). Coherently with this view and as a way to close the gap with US, the European Union introduced a set of public policy measures to support the creation and development of NTBFs (Storey and Tether 1998). The creation of Science Parks, the provision of financial support and advisory services are only some of the measures put in place by governments of the EU, and underline the great attention and emphasis given to NTBFs as a vector of creation of employment and innovation. A number of studies focused on high-tech start-ups' organic growth and their higher profitability compared to start-ups in other sectors. Westhead and Storey's (1994) analysis of a sample of British NTBFs shows that employment growth in NTBFs is significantly higher than in "comparable" firms in other sectors. Similarly, Nerlinger (1995), studying a sample of German high-technology start-ups, finds that firms in high-technology industries grow faster than the average. Fairly, product strategy has been considered the best way to achieve success and growth. In fact, a firm, if supported by strong product demand, is able to develop quickly, increase dramatically the number of employees and reach high profitability (Kazanjian 1984).

Despite previous ideas, a different stream of literature has offered a new interpretation to the economic role of NTBFs and has questioned their desire for growth. Evidence shows that NTBFs, compared with start-ups in other fields, report a greater employment rate but, on average, their growth in absolute term is rather modest (Storey and Tether 1998). Stories similar to those of Apple or Microsoft are definitely rare in Europe and the characteristics of firms born and developed in the Silicon Valley are difficult to find elsewhere. As suggested by Mustar (1994), analysing a sample of French NTBFs, in Europe there is an absence of fast growing high-tech firms comparable with the US. However, the remarkably high survival rate documented in UK (Westhead and Storey 1997) and Italy (Santarelli and Sterlacchini 1994) suggests that they are not entirely an artificial phenomenon, even if in the past their growth potential may have been overemphasized.

Based on this evidence, Autio (1994) proposes a new role for NTBFs, stressing their technology transfer effect on industrial innovation networks. According to his view, high-tech start-ups act mainly as suppliers of technologies, which they invent, develop and then transfer in several ways, being market for ideas a major one. Empirical evidence suggests that the majority of high-tech firms remains small expertise companies, which do not wish to obtain rapid organic growth (Storey and Tether 1998). Fontes and Coombs (2001), recognising both the unique endowment of technological competencies of NTBFs and the numerous limitation that can hinder their development, suggest that NTBFs act as agents of technology transfer. Financial constraints and shortage of competencies in some areas limit NTBFs' ability to commercialise the developed technology, and therefore, "NTBFs' technological dynamism will only be fully expressed if other actors are involved" (Fontes and Coombs 2001, p. 81).

Previous literature has widely investigated linkages and agreements established between NTBFs and well-established firms to compensate for start-ups shortcomings (Eisenhardt and Schoonhoven 1996, Colombo and Grilli 2006). However, the recent development of MFT gives additional opportunities for high-tech start-ups to extract rent from innovation not competing with established incumbents but feeding incumbent with newly developed technologies through licensing agreements. NTBFs have the chance to act as "ideas factories", that is, firms endowed with high technological competencies and focused on research and development of new promising technologies commercialized in collaboration with downstream players (Arora and Gambardella 1994, Gans and Stern 2000). As suggested by Gans and Stern (2003), high-tech start-up from being considered possible competitors become fertile source of new innovations allied in the reinforcement of incumbent market power. High-tech start-ups, unable to successfully compete in the product market, adapt their strategy and objectives to pursue external exploitation as a long-term strategy, feeding incumbent with new licensed ideas. Under this view, NTBFs are able to achieve financial success and assure future survival through a MFT' oriented strategy, abandoning the paradigm of organic growth.

Evidence of the previously highlighted idea can be found in the biotechnology and pharmaceutical industry. Despite biotechnology is commonly depicted as a highly innovative and technological sector, market leadership in the pharmaceutical industry, sector which exploits biotechnology innovations, has remain relatively unchanged over the past 25 years (BioWorld Publishing 1998). This does not mean that biotechnology products have not been commercialised, but it underlines the great propensity of biotechnology NTBFs to reach an agreement with pharmaceutical incumbents to proceed with the commercialisation process instead of going alone through all the steps of the product development and marketing.

In sum, given the relatively newness of the born and spread in the world on NTBFs, research literature is still controversial on their role in the economy. However, MFT's expansion may definitely influence NTBFs' development path and, thus, to have an impact on high-tech start-ups' role in the economy.

2.5.2. Market for technology as a long-term strategy?

Due to limited financial resources and human capital at foundation, start-ups innovators are likely to be able to pursue only few strategic options at a time (Bhidé 2000, Veugelers and Cassiman 1999). A high level of diversification among different research projects and products may, in particular at foundation, reduce the firm efficacy in completing and successfully achieve its objectives. Gans and Stern (2003) remark the importance of deeply and carefully analyse risks and benefits of pursuing a MFT oriented strategy or entering the market for product and coherently define the firm' strategy and positioning. Transition from one form of exploitation to the other is possible, but the change is associated with important transition costs and the necessity to gain experience in new fields. For example, start-ups entering the product market generally make heavy and sunk investments in developing both productive and commercial facilities. By contrast, operating in the market for ideas, a firm develops capabilities and skills that allow the innovator to effectively tackle negotiation, disclosure and appropriability issues. In both cases, the transition from a MFT oriented to a product market strategy and vice versa leads to issues related to the different exploitation of previously built assets and gained skills.

However, changes of firm-level factors, which influence the firm's strategy at foundation, may offer some opportunities or remove previously encountered constraints, and drive the firm to opt for a strategic change. For example, the improvement of the firm's financial condition thanks to retained earnings and higher reputation among investors, or a greater capacity to expand the firm's human capital competencies through recruitment of managers and other skilled personnel, may allow the firm to modify its strategy and positioning.

Concerning financial resources, it is reasonable to presume that older firms enjoy some advantages in the availability of funds over just-founded start-ups. First, previous innovations, if successful, guarantee a certain stream of revenues, which is likely to improve the firm's financial condition. As pointed out by Berger and Udell (1998), funds provided by the principal owner increase substantially as the firm from the start-up phase moves into its 4^{th}-5^{th} year of life. A plausible origin of these funds is the accumulation of retained earnings coming from successful exploitation of previous innovations. Depending on the particular financial condition of the firm, these financial resources can be invested directly in the development of new technologies or products, or be used as collateral to obtain further debt to invest in the firm. Second, the existence of a track record may significantly advantage more "mature" and aged firms compared to recently founded start-ups. Previous successes and network ties increase the entrepreneur reputation and credibility among investors, thus representing an advantage for the firm in obtaining new funding (Shane and Cable 2002). The track record generally reduces information asymmetries helping the investor to better understand the business and the entrepreneur's behaviour. In a nutshell, as a firm develops and presumably obtains success, it also gains access to additional financing which is generally precluded to start-ups at early stages of development, especially in high-tech sectors.

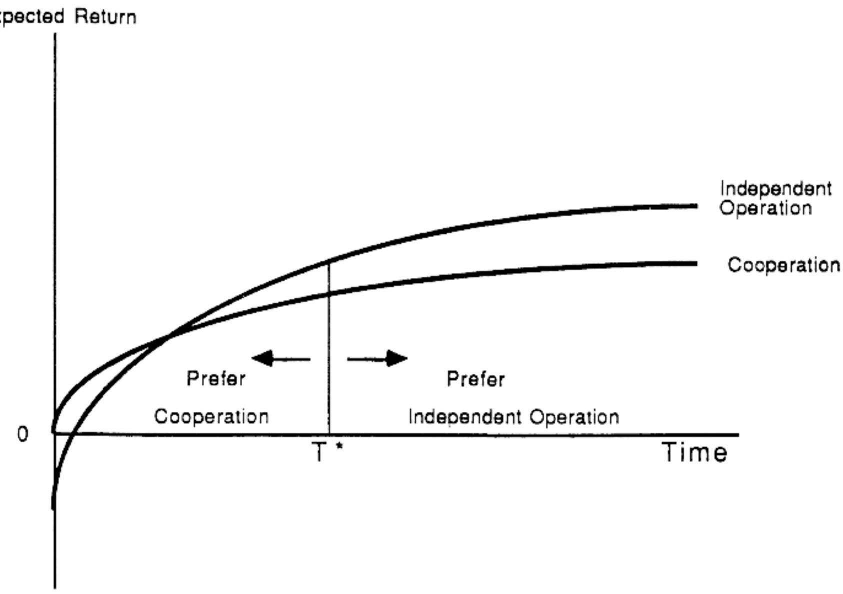
Similar considerations apply for human capital resources. At foundation, a firm's competencies are generally restricted to those of the founders (Cooper and Bruno 1977). However, during development, new people are recruited and the knowledge-base is usually enlarged and may cover new areas. It is reasonable to expect that the firm's age has a positive impact on the easiness of recruitment as prospective candidates perceived as less risky a venture that has already survived few years compared to a joust-founded venture. Finally, network ties, that develops and become stronger and stronger as time rolls by, may give the opportunity to acquire valuable resources once unknown.

In sum, the improvement of the firm's financial condition and the higher capacity to expand the firm's human capital may allow a firm to change its technology commercialisation strategy. NTBFs that have already developed production and commercial facilities are likely to maintain their presence in the product market. In fact, devoting to a product strategy, a firm makes sunk investments necessary to build manufacturing departments and establish distributions channels. Once in place, the firm is likely to fully exploit its assets embodying developed technology into physical artefacts and commercialising goods on the product market (Arora, Fosfuri and Gambardella 2001). Innovators are thus in the position of being "forced" to develop new technologies which exploit complementary assets in place, in order to maximize utilisation of manufacturing and commercial facilities.

Differently, start-ups, which pursue a MFT's oriented strategy at foundation, maintain higher flexibility, as the firm's investments are mainly addressed to the development of the knowledge-base (Hall 2002) and R&D projects. The almost non-existence of sunk investments, in addition to the venture's better financial condition and the greater opportunity to recruit skilled personnel, allow the firm to take into consideration other ways to exploit future innovations.

External commercialisation of technology may well represent a long-term strategy, since the profitability from products may be substituted by rents from licensing. However, such strategy may have some important pitfalls as, in particular for small firms, the licensor is unlikely to get the full return from innovation (Caves, Crookell and Killing 1983). As highlighted by Anton and Yao (1994), the inefficiency of contracts for transfer of technology and important differences in bargaining power may significantly reduce the innovator ability to extract rent from innovation. Moreover, in case of royalty-based contracts, the innovator's earning heavily depends on the effort profuse by its licensee in the commercialisation of the technology, thus resulting in "the firm being unable to control its own fate" (Arora, Fosfuri and Gambardella 2001, p. 241).

By contrast, just-founded start-ups, unlikely to possess in-house capabilities for independent commercialisation through the market for product, and thus entering MFT's contracts in order to successfully and rapidly commercialise their innovations, may, given the improved financial condition and greater accessibility to the job market, switch to a product market strategy. As suggested by Shan (1990) and shown in Picture 11, independent commercialisation requires higher initial investments, but generally put the innovative firm in a position of monopoly, allowing the firm to extract a greater return in the long-term compared to a cooperative strategy. Therefore, as proposed by Connell and Probert (2010), NTBFs starting operating as "soft company", that is acting as a consultant, providing R&D contracts and licensing developed technology, can gradually build-up capabilities and market knowledge, improve financial condition and get better access to both the job market and the market for capital and thus moving to a "hard company" business model.



Picture 11: Expected return over time to an innovating firm with alternative organizational strategies
Note: The graph is for illustration purpose only. No assumption is made about the curvature of the lines
Source: Shan (1990)

So far, the extant literature investigating licensing behaviour of firms has mainly focused on the relationship between firm size and licensing propensity, assuming firm's size to be highly correlated with the existence of complementary assets (Motohashi 2008). A recent survey on 600 European patent-filing firms in 2007 shows that small European firms, with less than 9 employees, and large ones, with more than 1000, are more willing to license compared to medium-sized companies (Zuniga and Guellec 2009). More specific econometric tests suggest a U-shape relationship between size and licensing activity to non-affiliated companies. Consistently, Motohashi (2008), analysing a sample of 1981 Japanese firms, finds that licensing propensity is negatively related to the firm's size. However, licensing propensity does not decrease monotonically, but rather increases for firms classified as large. For small firms the reasons behind this phenomenon is rooted into the absence of manufacturing and commercial facilities. Conversely, large firms may be willing to exploit externally non-core technologies, or pursue other strategic objectives, with licensing activity representing an option non mutually exclusive with self-production. Recently, the higher propensity towards licensing-out deals among small firms compared to medium-sized ones has been confirmed by Gambardella et al. (2008) on a sample of European firms and by Kani and Motohashi (2012) on a survey of Japanese firms.

On the contrary, the relationship between a firm's age and its propensity toward MFT has received considerably less attention and the results are still controversial. Zuniga and Guellec's (2009) survey on European patent-filing firm suggests that licensing propensity to non-affiliated company is inversely correlated to the firm's age. Motohashi (2008), differentiating between start-ups and non start-ups across several industries, finds weak support to the higher licensing propensity of start-ups compared to older firms. By contrast, Kasch and Dowling (2008), analysing a sample firms operating in the US biotechnology industry, find no significant relationship between firms' age and licensing propensity.

Taking into consideration pros and cons of both strategies, and grounding on the above lines of reasoning, I formulate the following hypothesis:

HP5) a negative relationship exists between a firm's age and its licensing propensity, as NTBFs that started pursuing external exploitation as main strategy tend to shift to a product base strategy because of the improved financial conditions and increased ability in filling knowledge gap.

3. Sample and data

3.1.The RITA dataset

The sample used for the test of the hypotheses derives from the RITA database, a dataset developed by the Research on Entrepreneurship in Advanced Technology Observatory based at Politecnico di Milano. The project aims at collecting several characteristics of Italian NTBFs in order to acquire and extend knowledge of high-tech start-ups in Italy. The RITA database was first created in 1999 and has been regularly updated and extended in the year 2002, 2004, 2007 and 2009. The current version includes characteristics of 1863 start-ups matching the requirements of:

- being founded between January 1st, 1983 and June 30th, 2008;
- operating in high-tech sectors both in manufacturing and in services industries;
- being independent at foundation, i.e. not controlled by another business organisation even though other firms may hold a minority shareholding in the start-up.

This latter condition is particularly important because it excludes firms that may be forced to pursue strategic objectives dictated by the controlling company. Thanks to this requirement, I can assume start-ups to put in place, at foundation and in the following years, what they repute to be the best available strategy.

For the construction of the RITA population, given the lack of official statistics on the NTBFs world in Italy, a number of different sources were used. The main source for the identification of the population of Italian high-tech start-ups has been the archive provided by the Italian Chambers of Commerce. However, also other sources has been used such as lists provided by national industry associations, on-line and off-line commercial firm directories and lists of participants in industry trades and expositions. Information provided by the national financial press, specialised magazines and other sectoral studies was also taken into consideration. The selection and sampling procedure lead to a sample composed of 7,322 firms, which has been contacted for potential inclusion in the dataset. The current version of the database contains information on the 1863 firms that answered the survey and were independently operating at the end of April 2009.

Data contained in the RITA database were collected from two types of sources. First, each firm included in the sample received by fax or e-mail a questionnaire aimed at collecting qualitative and quantitative data.

The questionnaire was organised in four sections constructed to collect:

- general information of the start-up useful to identify the firm and its main sector of activity and to understand size and internal organisation. Moreover, this section investigates the amount and source (e.g. deriving from products, services or technology) of the firm's turnover both at foundation and in 2007;
- information of the financial structure of the firm such as composition of equity capital at start-up, information on requests for and offers of risk capital and whether the firm took advantage of public financing;
- information on firm's innovative activity such as the use of mechanisms to protect intellectual property, the "exploitation" of "incubator" facilities and the establishment of cooperative agreements.
- information on the human capital characteristics of the founding team such as age, educational attainment, previous work experience etc. of each member.

In order to obtain highly reliable data, answers were examined and reviewed by educated personnel and, when necessary, phone or face-to-face interviews and clarifications were made with firms' owner-managers.

In addition to information obtained from answers to the questionnaire, additional data was collected through secondary sources. Data on NTBFs' patent activity were collected from the Esp@ce.net research engine. Financial and economic data was obtained from the AiDA and Cerved commercial databases. Nowadays, the RITA database represents the most complete source of information available on Italian NTBFs.

3.2.The sample

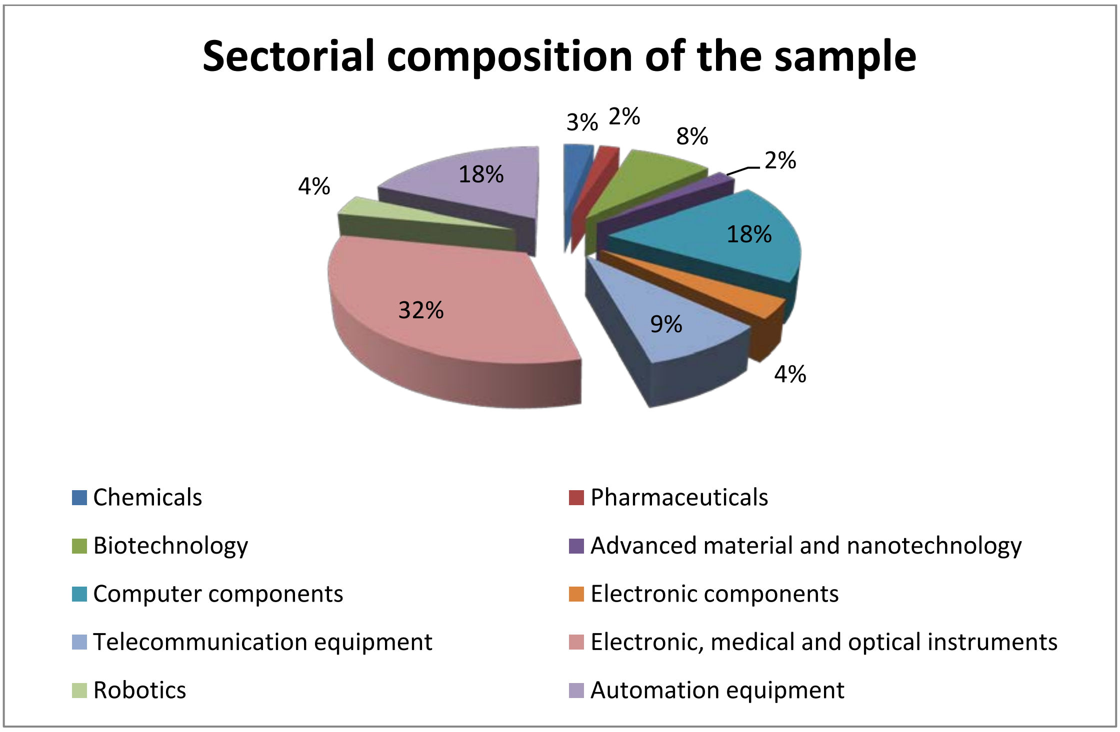
The sample, extracted from the 2009 version of the RITA dataset, is made up of 201 start-ups for which I were able to build a complete dataset relating to the dependant variables of interest of the econometric analysis. Firms in the sample belong to the following sectors (see Table 2 and Picture 12):

- Chemicals: it includes firms operating in chemicals (NACE code 20), pharmaceuticals (NACE code 21), biotechnologies, advanced materials and nanotechnologies (NACE code 72).
- ICT manufacturing: it includes firms operating in computers and electronic components, telecommunication equipment, optical, medical and electronic instruments (NACE code 26)
- Robotics and automation: it includes firms operating in robotic and automation equipment (NACE code 28)

The dataset is quite large and provides a number of fine-grained explanatory variables regarding both human capital and financial structure of the firms. I believe the dataset to be the best source of information regarding Italian NTBFs, and to be particularly adequate to the test of the hypotheses. Despite all this, there is no presumption to have a random sample. In fact, as previously highlighted by Colombo and Grilli (2005, 2007) at least three factors had an impact on the construction of the database. First, both the notions of new ventures and high-tech sector may be defined in different ways (Little 1977, Hatzichronoglou 1997). Second, the absence of official statistics make difficult to identify unambiguously the universe of Italian NTBFs and any measures of representativeness are available. To conclude, as it is usual with survey-based data, the sample suffers from a survivorship bias, i.e. the tendency to exclude firms that did fail before the survey was conducted. This may generate a sample selection bias difficult to control.

<table>
<tr><th>Sector</th><th>No. of firms</th><th>%</th><th>Groups</th><th>No. of firms</th><th>%</th></tr>
<tr><td>Chemicals</td><td>6</td><td>3%</td><td rowspan="4">Chemicals</td><td rowspan="4">31</td><td rowspan="4">15,4%</td></tr>
<tr><td>Pharmaceuticals</td><td>4</td><td>2%</td></tr>
<tr><td>Biotechnology</td><td>17</td><td>8,5%</td></tr>
<tr><td>Advanced material and nanotechnology</td><td>4</td><td>2%</td></tr>
<tr><td>Computer components</td><td>36</td><td>17,9%</td><td rowspan="4">ICT manufacturing</td><td rowspan="4">126</td><td rowspan="4">62,7%</td></tr>
<tr><td>Electronic components</td><td>7</td><td>3,5%</td></tr>
<tr><td>Telecommunication equipment</td><td>18</td><td>9%</td></tr>
<tr><td>Electronic, medical and optical instruments</td><td>65</td><td>32,3%</td></tr>
<tr><td>Robotics</td><td>7</td><td>3,5%</td><td rowspan="2">Robotics and automation</td><td rowspan="2">44</td><td rowspan="2">21,9%</td></tr>
<tr><td>Automation equipment</td><td>37</td><td>18,4%</td></tr>
<tr><td>Total</td><td>201</td><td>100%</td><td></td><td>201</td><td>100%</td></tr>
</table>

Table 2: Sectorial composition of the NTBFs' sample



Picture 12: Sectorial composition of the sample

3.3.Descriptive statistics of the sample

Among all the information provided, for the purpose of this analysis I take into consideration the following data:

- *Technology exploitation strategy*: firms were asked to specify the amount of sales deriving from the commercialisation of products, services and technology.
- *Characteristics of the founding team*: it includes data related to the educational attainment, the type of education (technical or economic), prior work experience and previous managerial activities of each member of the founding team.
- *Financial structure*: it includes data related to the origin of funding capital and whether the firms suffered from credit rationing at foundation.

3.3.1. Market for technology propensity

According to previous studies, licensing and other transfer of technology mechanism have been common in the chemical industry at least since the 1950s (Anand and Khanna 2000). A large stream of literature analyses interactions and licensing contracts among biotechnology and pharmaceutical firms (Gambardella 1995, BioWorld Publishing 1998). More recently, Sheehan et al. (2004), analysing data collected through an OECD survey, documented a high propensity towards in-licensing and out-licensing in pharmaceutical and ICT industries.

However, in this study, I consider transfer of technology not only limited to licensing, but more broadly I take into consideration propensity towards MFT. As previously highlighted, technology assumes very different forms, and a strict definition is difficult to write down. Even more ambiguous and blurred is the definition of what a transfer of technology is and under which forms it can take place. For the purpose of this study, given the information collected in the questionnaire, I build on the definition given by Arora et al. (2001) and thus consider market for technology's transactions those that focus is the trade of knowledge or technology rather than a physical artefact. Under this view, MFT includes transaction ranging from pure licensing and cross-licensing agreement to wider technology "packages" that involve the exchange of patents together with know-how and services. Moreover, also transactions concerning technical services can be included in MFT being goods acquired mainly for the knowledge embodied in them. Therefore, for the purpose of this study, beside turnover deriving from the sale of technology and from royalties of the licensed technology I also take into consideration, for firms operating in typical manufacturing sectors, the turnover originates from services. I believe services provided by a typical manufacturing firm to represent mainly transfer of know-how and technical services.

The descriptive statistics in Table 3 show a great propensity towards MFT for NTBFs at foundation. Firms in chemical and automation sector are more reluctant to engage in product manufacturing and commercialisation than those in ICT. However, it is relevant the quote of firms engaging in MFT strategy in ICT manufacturing, considering that the sample does not include firms mainly operating in ICT services.

	Sample firms	Firms prevalently MFT oriented[2]			
Industry	No. of (a)	No. at foundation (b)	(b/a) %	No. in 2007 (c)	(c/a) %
Chemical	31	17	54.8	16	51.6
ICT Manufacturing	126	53	42.1	45	35.7
Robotics and Automation	44	25	56.8	17	38.6
Total	201	95	47.3	78	38.8

Table 3: Firms propensity towards MFT across industries

Conscious of the difficulties and possible problems arising from the extension of the previous idea of MFT's transactions to more service oriented sectors as those related to production of software and provision of internet and telecommunication services, I test the robustness and validity of the econometric

[2] The differentiation of firms between those pursuing a MFT strategy and those pursuing a product strategy has been made taking into consideration the percentage of technology on the total turnover and using the mean value as threshold for the differentiation.

models on a larger sample including firms belonging to these two sectors. The analyses and the econometric models conducted on the larger sample are available in Appendix 3, Table 20 and Table 21.

3.3.2. Human Capital of NTBFs

As highlighted by Cooper and Bruno (1977 p. 21), “for a new, high-technology firm, the primary assets are the knowledge and skills of the founders”. Several studies documented the greater endowment of human capital of NTBFs compared to other small firms (Storey and Tether 1998, Westhead and Storey 1994). The PatVal-Eu (2005) survey on licensing behaviour in Europe highlights that human capital endowment of innovators in higher than those of other personnel, and it vary considerably across European countries. Despite an European average of 76% of innovators having a university degree and slightly more than 25% having completed a PhD, Italy is quite far from this numbers, with only 56% of innovators with a university degree and a mere 3% with a PhD. Despite the slight difference between an innovator and a NTBF’s founder and the limitation of the sample in use to three manufacturing sectors, descriptive statistics of the academic background of NTBFs’ founding teams are comparable (see Table 4).

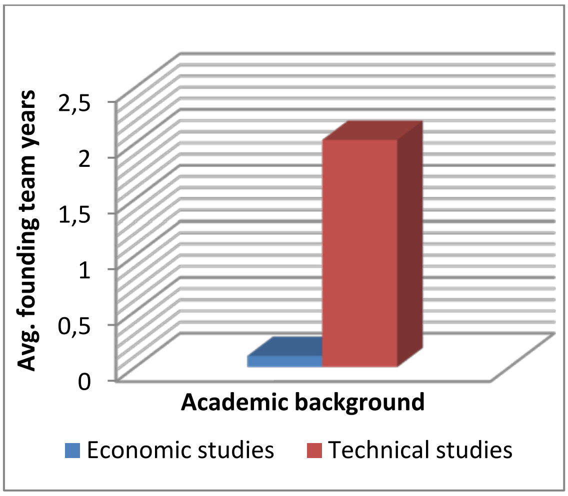
Industry	No. of founders	Founders with PhD	% PhD	Founders with Bachelor	% Bachelor
Chemical	52	10	19.2	42	80.8
ICT Manufacturing	242	5	2.1	111	45.8
Robotics and Automation	87	1	1.1	34	39.1
Total	381	16	4.2	187	49.1

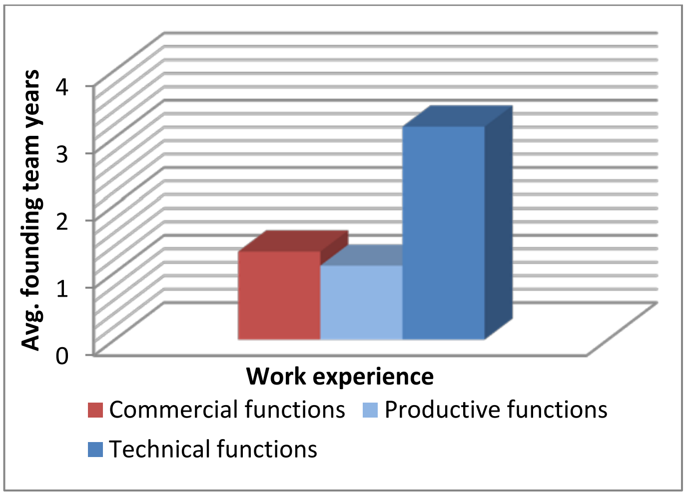
Table 4: Academic attainment of NTBFs' founders across industries

A deeper analysis of the academic attainment of the founding teams in the sample (see Table 5 and Picture 13) shows that, besides a considerable academic experience gained in technical (e.g. engineering and scientific) fields, NTBFs’ founders significantly lack of economic knowledge. Moreover, the analysis of the working experience indicates that NTBFs’ founding teams have a significant previous experience gained in technical functions (e.g. R&D) while work experience gained in both productive and commercial functions is considerably lower.

Industry	Average academic years spent in:		Average working years spent in the same industry in:		
	Economic studies	Technical studies	Commercial functions	Productive functions	Technical functions
Chemical	0.10	3.77	0.20	1.91	2.18
ICT Manufacturing	0.13	1.67	1.74	0.80	2.84
Robotics and Automation	0.03	1.84	0.80	1.46	4.75
Total	0.10	2.03	1.31	1.10	3.16

Table 5: Academic and working background of NTBFs' founding team across industries





Picture 13: Academic and working background of NTBFs' founding team across industries

In a nutshell, previous descriptive statistics highlight the high level of educational attainment of NTBFs' founders, considered by research literature the main driver of both higher level of NTBFs' likelihood of survival and performance compared to other small firms. However, the lack of homogeneity between both academic background and work experience of NTBFs' founding teams may have several repercussions on the firm ability to successfully exploit technological innovations.

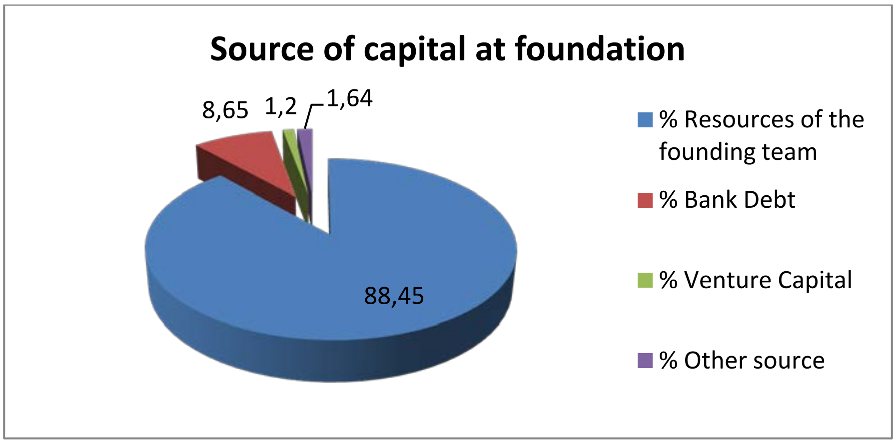
3.3.3. Financing constraints of NTBFs

Previous literature has given considerable theoretical and empirical attention to capital structure of firms, highlighting in particular financial constraints placed on NTBFs. Given the limitedness of venture capital funding in Italy (see Picture 9 Picture 10), and the belonging of Italian economy to a bank-based system according to several sources (Rajan and Zingales 1995, 2003, Demirguc-Kunt and Levine 1999), I focus on credit constraints.

Coherently with previously cited theoretical literature, only 3.5% of the firms of the sample received venture capital funds at foundation. Moreover, as can be seen in Table 6 and Picture 14, besides the personal resources of the founding team, debt provided by banks represents by far the second source of financing of the NTBFs in the sample. This is consistent with the RITA survey (2002) conducted across a greater number of industrial sectors.

Industry	% Resources founding team	% Bank Debt	% Venture Capital	% Other source
Chemical	85.45	11.94	1.23	1.39
ICT Manufacturing	92.56	5.52	0.67	1.11
Robotics and Automation	78.57	15.35	2.74	3.33
Total	88.45	8.65	1.2	1.64

Table 6: Financing sources at foundation



Picture 14: Financing sources at foundation

Concerning credit constraints (see Table 7), almost 25% of the firms in the sample would have desired more credit at foundation. Moreover, to 27.5% of those NTBFs that desired more credit and asked for it, bank financing was refused.

Industry	% firms desired more credit	% firms credit refused
Chemical	26.66	24.13
ICT Manufacturing	24.36	36.36
Robotics and Automation	25.58	25.00
Total	24.60	27.50

Table 7: Credit constraints of NTBFs across industries

In sum, information on the sample indicates both the importance of banks as provider of funds to Italian NTBFs and the existence of a significant funding gap at foundation. Given the importance of financial resources to the successful development of a firm, financial constraints may play an important role in shaping NTBFs' technology exploitation strategy.

3.3.4. Changes in the firms' strategy

The relationship between firms' ages and their propensity toward MFT has received so far little attention and the results are still controversial (Zuniga and Guellec 2009, Motohashi 2008, Kasch and Dowling 2008). Descriptive statistics of the sample in Table 8 show the firms' change in strategy through the years. The number of firms that chose to pursue a MFT strategy at foundation and later changed in favour of a market for product strategy is relevant, 28 firms, 31% of those pursuing a MFT strategy at foundation. By contrast, firms changing the other way round are considerably less (only 10). Through a deeper analysis made through econometric models, I am going to investigate whether a negative relationship between the firm's propensity toward a particular strategy and its age exists.

Year of foundation	No. of firms	No. of firms MFT Foundation[3] (a)	No. of firms MFT 2007	No. of firms MFT →Product (b)	% (b/a)	No. of firms Product →MFT
1983	1	1	1		0%	
1984	4	2	1	1	50%	
1985	4	3	1	2	67%	
1986	6	1	1		0%	
1987	6	2	2		0%	
1988	8	3	2	1	33%	
1989	1	1	1		0%	
1990	6	4	2	2	50%	
1991	5	1	0	1	100%	
1992	4	0	0			
1993	10	2	3		0%	1
1994	14	5	4	2	40%	1
1995	5	1	1		0%	
1996	8	5	4	1	20%	
1997	4	2	2	1	50%	1
1998	15	10	5	5	50%	
1999	8	3	2	2	67%	1
2000	6	3	2	2	67%	1
2001	9	6	4	2	33%	
2002	11	4	2	2	50%	
2003	10	6	4	2	33%	
2004	10	4	5	1	25%	2
2005	18	11	12	1	9%	2
2006	16	9	10		0%	1
Total	**189**	**89**	**71**	**28**	**31%**	**10**

Table 8: Descriptive statistics of firms' change in strategy across years[4]

[3] As seen before, the differentiation of firms between those pursuing a MFT strategy and those pursuing a product strategy has been made taking into consideration the percentage of technology on the total turnover and using the mean value as threshold for the differentiation.

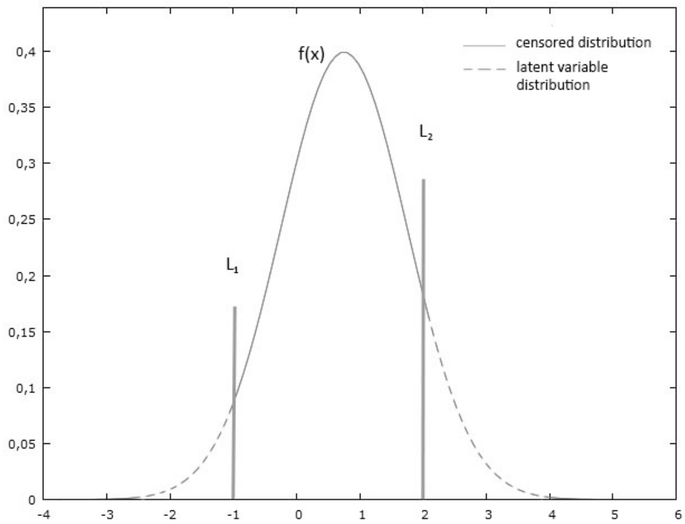
[4] Firms founded in 2007 have been excluded from the tale as the year of foundation coincides with 2007, and therefore it is not possible to verify the transition between the two strategies.

4. Econometric models

4.1.Methodology for the test of the first proposition

The test of the proposition could not have been done through a simple linear probability model, therefore, given the characteristics of the dependent variable, i.e. the percentage of technology sale on total turnover, I opted for the two-limit tobit and the probit models. These two allow us to investigate the factors that influence the firm strategic choice taking into consideration the censored nature of the dependant variable.

In fact, the distribution that applies to this sample is a mixture of discrete and continuous parts. As can be seen in the Picture 15, to the censoring points, known as lower and upper limits, is assigned the full probability of the censored zone. This aspect may lead to a number of shortcomings when applying the linear regression model. For this reason, several authors have suggested the use of models for censored data or binary choice models (Greene 2003, Maddala 1992).



Picture 15: Two-tail censored distribution

4.1.1. The two-limit tobit model

The censored regression model, also known as tobit model, was first proposed by Tobin in 1958 (Tobin 1958). As highlighted by Tobin, the model was proposed to address the peculiar characteristics of the dependent variable of many economic surveys. The variable has a lower or upper limit, and the limiting value may be assumed by a substantial number of observations. Because the censored variable is not observed over its entire range the mean and the variance of the variable are biased, with the former shifting right or left depending on the censoring point while the latter is reduced because of the cut of the distribution tail (see Picture 15). This leads to the ineffectiveness of the ordinary linear regression.

Given the peculiar characteristics of the dependent variable of the model, which assumes continuous values within a lower limit (0) and a upper limit (100), I use a particular version of the tobit model called two-limit tobit model. Grounding on Tobin, Rossett and Nelson (1975) presented an extended version of tobit model appropriate for cases in which the dependent variable is subject to both upper and lower censoring. Some observations are censored and assume the lower or upper limitation value, while the remaining, being uncensored, take on a wide range of value between the limits. The application of the ordinary least squares (OLS) regression, in addition to the impossibility to constraint $x_i'\beta$ to the 0-1 interval, suffers from at least three other problems. First, parameter estimates are biased and inconsistent, because the dependent variable has upper and lower limits and this is not taken into consideration by the model. Second, as demonstrated by Maddala and Nelson (1975), when the disturbances are heteroscedastic the resulting OLS estimates of limited-dependent-variable models are not even consistent. Third, selection bias has to be taken into account. For these reasons, although feasible generalised least squares could be a solution, a valid alternative approach is the two-limit tobit model proposed by Rossett and Nelson.

The dependent variable y_i assumes the following values:

$$y_i = \begin{cases} 0 \ \ if & y_i^* \leq L_1 \\ y_i^* \ if & L_1 \leq y_i^* \leq L_2 \\ 1 \ \ if & y_i^* \geq L_2 \end{cases}$$

where:

y_i^* is a latent variable not observed for values smaller than $L_1$and larger than L_2.

L_1 and L_2represent respectively the lower and the upper limit of the observed dependent variable.

The two-limit tobit model can be represented as:

$$y_i^* = x_i'\beta + \varepsilon_i$$

where:

x_i is a vector of independent variable, that is factors affecting the firm propensity towards MFT

β is a vector of unknown parameters

ε_i is the disturbance assumed to be normally distributed, with a zero mean and standard deviation σ.

Through the maximization of the likelihood function, I obtain the estimate of the β vector, which is the direct measure of the explanatory's variables on the latent dependent variable y_i^*.

$$E(y_i^*|x) = \beta' x$$

However, as pointed out by Maddala (1983), unconditional expected value is given by:

$$E(y_i) = P(y_i = L_{1i}) \cdot L_{1i} + P(L_{1i} < y_i^* < L_{2i}) \cdot E(y_i|L_{1i} < y_i < L_{2i}) + P(y_i = L_{2i}) \cdot L_{2i}$$

which in the specific case assume the form of:

$$E(y_i) = x_i'\beta\left[\Phi\left(\frac{1 - x_i'\beta}{\sigma}\right) - \Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sigma\left[\phi\left(\frac{-x_i'\beta}{\sigma}\right) - \phi\left(\frac{1 - x_i'\beta}{\sigma}\right)\right] + 100\left[1 - \Phi\left(\frac{1 - x_i'\beta}{\sigma}\right)\right]$$

Unlike in OLS regression, the tobit coefficients cannot be interpreted directly as estimates of the magnitude of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable (Greene 2003). Only their signs of the coefficient can be taken into consideration to understand the direction of change in probability and marginal intensity as the explanatory variables change (Maddala 1992). In fact, while

$$\frac{\partial E(y^*|x)}{\partial x_k} = \beta_k$$

the total marginal effect of a change in an independent variable x_k on the expected value of the dependent variable is given, in this case, by:

$$\frac{\partial E(y|x)}{\partial x_k} = \beta_k\left[\Phi\left(\frac{100 - x_i'\beta}{\sigma}\right) - \Phi\left(\frac{x_i'\beta}{\sigma}\right)\right]$$

4.1.2. The probit model

An alternative approach to the use of a two-limit tobit model consists in the analysis through a binary choice econometric model. In this typology of models, the dependent variable can assume only two values, 0 and 1. The choice between the probit or logit model may have been mainly driven by mathematical convenience, while it is difficult to favour one or the other on theoretical ground (Greene 2003). The two distributions are very similar except for the tails, which are considerably heavier for the logistic distribution. Therefore, differences should be seen only for extremely small or large value.

Between the two, given that the Heckman two-step selection model in use to test the second proposition performs a probit analysis, I am going use the probit model.

As seen for the previous two-limit tobit analysis, the model can be expressed as:

$$y_i^* = x_i'\beta + \varepsilon_i$$

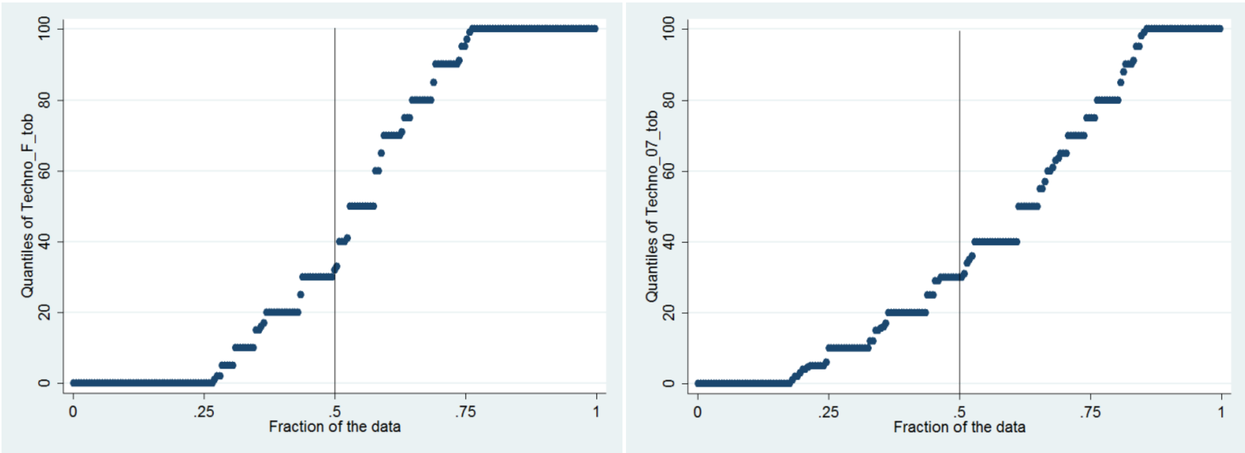
The dependent latent variable y^* is continuous in the interval between $-\infty$ and $+\infty$, but it is not observed. By contrast, I observe the discrete variable y_i°, which assumes only the values of 0 or 1. Despite the conventional threshold in binary choice model is zero, for the purpose of this study I take the median value (M_i) of the distribution as threshold.

Therefore, the discrete observed dependent variable assumes the following values:

$$y_i^\circ = \begin{cases} 0 & if\ y_i \leq M_1 \\ 1 & if\ y_i > M_1 \end{cases}$$

Given the following distribution graph, (see Picture 16) I define:

$$M_1 = 32$$
$$M_2 = 30$$



Picture 16: Distributions of the values of the dependant variable at foundation and in 2007

Therefore, I obtain a binary dependent variable that fits the probit model:

$$Prob(y^\circ = 1|x) = \int_{-\infty}^{x'\beta} \phi(t)dt = \Phi(x'\beta)$$

As seen for the tobit model, the parameters of the model are not the marginal effects, since these latter are given by:

$$\frac{\partial E[y^\circ|x]}{\partial x} = \phi(x'\beta)\beta$$

4.2. Variables of the models for the test of hypotheses 1-2-3-4

4.2.1. Dependent variables

The two models used in the econometric analysis require a dependent variable with slightly different characteristics:

- *Technology share (**techno_f_tob**)*: to investigate the company commitment to the use of MFT as a viable alternative to the market for product, I took into consideration the percentage of the firm turnover deriving from the "sale of knowledge" at foundation. With the term "sale of knowledge", I include royalties from licensed technology and earnings deriving from research contracts and technical services. The variable values range between 0 and 100, being continuous in the interval.

- *Technology share probit (**techno_f_prob**)*: the variable is equal in meaning to the previous one but it differs in value. Because the dependent variable in the probit model assumes only the values of 0 or 1, the dependant variable has undergone a dichotomisation procedure as better explained later.

4.2.2. Macro determinant related independent variables

- *Appropriability regime (**approp_med**)*: according to Teece (1986) appropriability regime influences the ability of a firm to extract rents from its innovations. A technology appropriability regime depends mainly on the type of technology and its mechanism of legal protection. Previous studies indicated patents as efficient property rights mechanisms in sectors as biotechnology and pharmaceuticals (Allen 2003, Gans, Hsu and Stern 2002). As a proxy of the level of the appropriability regime, I calculated the percentage of firms using patents on the total number of firms in the same industry at time of the survey. It is worth remarking that this measure is calculated as mean value of the aggregated classification, i.e. chemicals, ICT manufacturing, robotics and automation.
- *Competitiveness (**compet_med**)*: previous literature highlights the role of competition in influencing how to exploit technology. According to Eisenhardt and Schoonhoven (1996) and Pisano (1990) the number of competitors in a sector is a good proxy of the level of competition. In this study, I calculate the mean degree of competition for the three macro-industries.
- *Complexity of the market (**complex_med**)*: the variable controls for complexity in the market. It is calculated taking into consideration the percentage of sales made with the first two customers. In this study, I calculate the mean degree of complexity for the three macro-industries.

4.2.3. Human competencies related independent variables

- Education: previous academic experience may affect the likelihood of internal or external exploitation of technology. For this reason I take into consideration three explanatory variables:
    - *Years of economic education (**yeco_edu**)*: it represents the average number of years of founders' education spent in economics, management and political sciences at university level;
    - *Years of technical education (**ytech_edu**)*: it represents the average number of years of founders' education spent in technical fields at university level;
    - *Education Herfindal Index (**herf_edu**)*: it represents the Herfindal index calculated as $1 - \sum_{i=1}^{2}(yearsedu_i)^2$ with *yearsedu* being the percentage of years spent by funders in economic (or technical) education on the total.

- *Work experience*: I believe previous work experience in the same sector of the firm but in different areas such as technical, production and commercial to influence the firm strategy. For this reason I consider four potential explanatory variables:
    - *Years in technical functions (**ytech_wexp**)*: it represents the average number of years of founders' work experience acquired in technical functions in the same sector of the start-up before firm's foundation.
    - *Years in production functions (**yprod_wexp**)*: it represents the average number of years of founders' work experience acquired in production related roles in the same sector of the start-up before firm's foundation.
    - *Years in commercial functions (**ycomm_wexp**)*: it represents the average number of years of founders' work experience acquired in commercial in the same sector of the start-up before firm's foundation.
    - *Work experience Herfindal Index (**herf_wexp**)*: it represents the Herfindal index calculated as $1 - \sum_{i=1}^{3}(yearswexp_i)^2$ with *yearswexp* being the percentage of years spent in category *i* out of the total. The three categories taken into consideration are: technical, production and commercial experience.
- *Managerial experience (**dmanager**)*: dummy variable that assumes the value of 1 if one or more members of the founding team have previously held a management position.

4.2.4. Financial capabilities related independent variables

- *Request of more credit at foundation (**more_cred_f**)*: dummy variable that indicates whether the firm would have desired a greater amount of credit at the agreed interest rate at foundation. A value of one indicates the firm's desire of more credit.

4.2.5. Independent control variables

- *Number of operative founders (**n_fondop_f**)*: I include this variable to control for the founder's team size. The number of members of the founder's team influences the total years of academic and work experience of the team. Moreover, a bigger team may present a higher diversification among technical, production and commercial work experience as well as between economic and technical academic knowledge. The variable represents the number of operative founders in the firm at foundation.
- *Years of non-specific work experience (**yother_wexp**)*: it represents the average number of years of founders' work experience acquired in sectors that differ from the one the NTBF is operating in.
- *Venture backed at foundation (**vcbacked_f**)*: dummy that assumes a value of 1 if either corporate venture capitalists or independent venture capitalist provided funds at foundation, zero otherwise.

- *Bank backed at foundation (**bank_debt_f**)*: dummy that assumes a value of 1 if banks provided funds (under the form of debt) at foundation, zero otherwise.
- Period of establishment of the start-up: previous studies often included firm age as a control for the specific time-period of foundation and for taking into account specific macro-economic conditions in place at time of the firm's inception (Kasch and Dowling 2008, Kollmer and Dowling 2004). In fact, period-specific condition may positively or negatively influence the firm ability to extract value from innovations through market for technology or product market. For this reason I consider three control variables:
  - *Foundation between 1980 and 1989 (**period81_90**)*: dummy variable that assumes a value of 1 if the firm has been established between 1980 and 1989, zero otherwise.
  - *Foundation between 1990 and 1999 (**period91_00**)*: dummy variable that assumes a value of 1 if the firm has been established between 1990 and 1999, zero otherwise.
  - *Foundation between 2000 and 2009 (**period01_10**)*: dummy variable that assumes a value of 1 if the firm has been established between 2000 and 2009, zero otherwise.

4.3.Model specification

In order to test the previously highlighted hypotheses, I develop a number of models:

1. Model to analyze the relationship between both NTBF's human capital endowment and financial constraints, and the firm's propensity towards MFT at foundation:

$$\begin{aligned} techno\_f = {} & \beta_0 + \beta_1(compet\_med) + \beta_2(complex\_med) + \beta_3(approp\_med) + \beta_4(yeco\_edu) \\ & + \beta_5(ytech\_edu) + \beta_6(ytech\_wexp) + \beta_7(yprod\_wexp) + \beta_8(ycomm\_wexp) \\ & + \beta_9(dmanager) + \beta_{10}(more\_cred\_f) + \beta_{11}(n\_fondop\_f) + \beta_{12}(yother\_wexp) \\ & + \beta_{13}(vcbacked\_f) + \beta_{14}(bank\_debt\_f) + \beta_{15}(period91\_00) + \beta_{16}(period01\_10) \end{aligned}$$

2. Model to analyze the relationship between both NTBF's human capital heterogeneity and financial constraints, and the firm's propensity towards MFT at foundation:

$$\begin{aligned} techno\_f = {} & \beta_0 + \beta_1(compet\_med) + \beta_2(complex\_med) + \beta_3(approp\_med) + \beta_4(herf\_edu) \\ & + \beta_5(herf\_wexp) + \beta_6(dmanager) + \beta_7(more\_cred\_f) + \beta_8(n\_fondop\_f) \\ & + \beta_9(yother\_wexp) + \beta_{10}(vcbacked\_f) + \beta_{11}(bank\_debt\_f) + \beta_{12}(period91\_00) \\ & + \beta_{13}(period01\_10) \end{aligned}$$

The two models have been tested following a hierarchic approach and using both the tobit and Probit model.

4.4. Methodology for the test of hypothesis 5

4.4.1. The Heckman two-step model with tobit

The test of the second proposition requires a different approach, as I would like to know whether firms having entered the MFT at foundation maintain their strategy through time or shift instead towards a go-it-alone strategy. The analysis of this proposition is made through the Heckman (Heckman 1979) two-step selection model.

The model can be written as a system of equations as follow:

the sample selection equation

$$z_i^* = w_i'\gamma + u_i$$

$$z_i = \begin{cases} 1 \; if \; z_i^* > M_1 \\ 0 \; if \; z_i^* \leq M_1 \end{cases}$$

and the basic outcome equation

$$y_i = x_1'\beta + \varepsilon_i$$

where:

y_{1i} is the dependant variable observed only when z_i^* is greater than

z_i^* is the dependant variable of the sample selection equation observed for all values of the sample

x_i and w_i are vectors of independent variables, which are the factors affecting the sample selection and the others affecting the strategy choice respectively

β and γ are the vectors of unknown parameters

ε_i and u_i are disturbances with $u_i \sim N(0,1)$, $\varepsilon_i \sim N(0, \sigma^2)$ and $corr(u_i, \varepsilon_i) = \rho$

Despite the parameters of the model can be estimated by maximum likelihood, the two-step procedure presented by Heckman is more commonly used (Greene 2003) as it require less restrictive assumptions on the disturbances. For the purpose of this study, the dependant variable y_1 represents the percentage of technology on total turnover measured in 2007 and z_i indicates whether the firm at foundation was pursuing a MFT strategy or not.

Ignoring for a moment the double censorship of the dependant variable, ordinary square regression performed on the selected sample, for instance OLS of percentage of technology on total sales on its determinants, using only data of firms pursuing MFT strategy already at foundation, would lead to inconsistent estimates of β (Greene 2003). In fact, after few simple steps, it demonstrable that:

$$E(y_1 \mid y_1 \; is \; observed) = x_i'\beta + \beta_\lambda \lambda_i(\alpha_u)$$

where $\alpha_u = \left(\frac{w_i'\gamma}{\sigma_u}\right)$ and $\lambda_i(\alpha_u) = \phi\left(\frac{w_i'\gamma}{\sigma_u}\right) \Big/ \Phi\left(\frac{w_i'\gamma}{\sigma_u}\right)$, this last called the inverse Mills ratio, a function of the probability that an observation is selected into the sample. The exclusion of the inverse Mills ratio from the regression equation would lead to a specification error of omitted variable and to inconsistent estimates of β.

For the purpose of this study, I am going to use a modified version of the model proposed by Heckman, replacing the OLS model with a tobit model as second step of the estimation procedure.

- Step 1: estimate the sample selection equation on the complete sample through a probit model to obtain the estimates of γ and, then, for each observation compute the inverse of Mills ratio $\hat{\lambda}_i$.
- Step 2: estimate β and $\beta_\lambda = \rho\sigma_e$ of the equation of interest through a two-limit tobit regression of y_i on the vectors x and $\hat{\lambda}$ on the censored sample.

It can be shown that the standard errors in the outcome equation are not corrected. There are two reasons for this. First is heteroscedasticity that can be treated using robust standard errors. Second, there are unknown parameters in λ_i. Therefore, additional source of variation in the compound disturbance and correlation across observations has to be taken into account (Greene 2003). However, given the analytical complexity and the current unavailability of correction formulas in case of tow-limit tobit model as second step, computation of standard errors will be made through the bootstrap technique.

4.5.Variables of the models for the test of hypothesis 5

In addition to the previous variable in use for the first class of models, I introduced a new series of variables to test the factors that may affect the strategy in the long term.

4.5.1. Dependent variables

- *Technology share in 2007 (**techno_07_tob**)*: coherently with the previously seen variable measured at foundation, I took into consideration the percentage of the firm turnover deriving from the "sale of knowledge". With the term "sale of knowledge", I include royalties from licensed technology, and earnings deriving from research contracts and technical services. The variable values range between 0 and 100, being continuous in the interval. In this case, the value refers to the year 2007.

4.5.2. Independent variable

- *Age in 2007 (**age**)*: I believe experience gained by a firm to play a significant role in shaping its strategy. For this reason, I introduce as explanatory variable the age of the firm, as proxy of the firm experience, measured at the end of 2007.

- *Age in 2007 (**age2**):* to better characterise the model and take into consideration potential quadratic effects I introduce the quadratic term of age.

4.5.3. Control variables

I take into account a series of events that may have influenced the firm's strategy since foundation.

- *Public financing (**fin_aftf**):* dummy variable that indicate whether the firm has received public funding since foundation. A value of 1 indicates that the firm applied and has been grated local of national subsidy.
- *Alliances:* the entry into either technological or commercial alliances may significantly influence the firm's strategy. For this reason I take into consideration this aspects with two dummies variables:
    - *Technological alliance (**altech_aftf**):* dummy variable that assumes a value of 1 if the firm has entered a technological alliance since foundation.
    - *Commercial alliance (**alcomm_aftf**):* dummy variable that assumes a value of 1 if the firm has entered a commercial alliance since foundation.
- *Venture capital (**vc_aftf**):* the financing of the NTBFs by venture capitalists may influence the firm's strategy. Thus, I introduce a dummy variable that assumes the value of 1 if either independent or corporate venture capitalists provided funds to the NTBF.

4.6. Model specification

In order to test the fifth hypothesis, I implement the following sample selection model:

3. $$techno\_07 = \beta_0 + \beta_1(compet\_med) + \beta_2(complex\_med) + \beta_3(approp\_med) + \beta_4(age) + \beta_5(age2) + \beta_6(fin\_aftf) + \beta_7(altech\_aftf) + \beta_8(alcomm\_aftf) + \beta_9(vc\_aftf)$$

Considering as selection equation the following one:

$$techno\_f = \beta_0 + \beta_1(compet\_med) + \beta_2(complex\_med) + \beta_3(approp\_med) + \beta_4(yeco\_edu) + \beta_5(ytech\_edu) + \beta_6(ytech\_wexp) + \beta_7(yprod\_wexp) + \beta_8(ycomm\_wexp) + \beta_9(dmanager) + \beta_{10}(more\_cred\_f) + \beta_{11}(n\_fondop\_f) + \beta_{12}(yother\_wexp) + \beta_{13}(vcbacked\_f) + \beta_{14}(bank\_debt\_f) + \beta_{15}(period91\_00) + \beta_{16}(period01\_10)$$

5. Empirical results

The following section analyses the empirical results of the econometric analysis performed to test the validity of the hypotheses previously illustrated. Descriptive statistics of all the variables used and their correlation are available in Appendix 1, Table 14, Table 15, Table 16 and Table 17.

Before proceeding with the exploration and analysis of the results, I want to remark that the analysis is performed to take into consideration the firm-level determinants that affect the propensity towards a MFT's technology exploitation strategy. Differently from Palomeras (2007), who analyses how the characteristics of the innovation such as importance (e.g. number of citation received), innovativeness and scope affect the patent holder willingness to license, given the characteristic of the database in use, I take into consideration only the firm's human capital competencies and financial constraints. As future line of research, it would be undoubtedly interesting to better characterise licensing propensity thought the collection of both firm-level and technology-level characteristics.

5.1. Empirical analysis of the firm's human capital and financial constraints effect on strategy

Coherently with the logic followed in the explanation of the hypotheses, I start taking into consideration factors affecting the strategy of a firm at foundation. Table 9 and Table 10 present the estimates of the first model introduced (Model 1), which tests the relationship between both NTBF's human capital endowment and financial constraints, and the firm's propensity towards MFT at foundation. The model has been tested with a tobit and probit analysis, in addition to an ordinary least square analysis for comparison purposes. The analysis has been conducted following a hierarchic approach, in order to test for robustness of explanatory variables.

Let us first focus the attention on the technological regime. The three variables $compet\_med$, $complex\_med$ and $approp\_med$, common to all the models presented, characterise the technological regime. With the exception of $approp\_med$, the coefficients are coherent with expectations and altogether moderately significant. Both a higher perceived competition and a greater complexity of the market increase the likelihood towards a MFT's prevalent strategy. Altogether, Wald tests conducted in all models strongly refuse the null hypothesis that the coefficients of $compet\_med$, $complex\_med$ and $approp\_med$ be jointly equal to zero, thus revealing the important influence of the technological regime on the firm's commercialisation strategy.

Turning the attention to the role of the founding team's human capital competencies, in general, academic and work experience in technical fields positively and significantly influences the propensity towards MFT's exploitation of technology. Both estimates of coefficients of $ytech\_edu$ and $ytech\_wexp$, performed with the tobit and probit analysis, document a significant and positive impact of these two factors on the dependant variable. The tobit analysis also highlights a negative and weakly significant relationship between the years of work experience spent in commercial functions ($ycomm\_wexp$) and the propensity towards MFT. This is coherent with hypothesis 2, as the shortage on commercial skills drives NTBFs to opt to transfer knowledge assets instead of entering market for products. The estimation of marginal effects gives us the opportunity to quantify the effect of human capital competencies on MFT propensity. For instance, relying on the tobit analysis of model 1b and 1c (Table 9), every additional year spent by the founding team in economic education increases the firm propensity toward MFT by more than 3%. Taking into consideration years spent in technical functions, the increase is higher than 1%.

As further support to the relevance of variables characterising founding team's human capital competencies on the firm's strategy, the null hypothesis that the coefficients of those variables ($yeco\_edu, ytech\_edu, ytech\_wexp, yprod\_wexp\ and\ ycomm\_wexp$) be all equal to zero is rejected at conventional confidence level of 5% by all Wald tests. These estimates are robust to the introduction of control variables as can be seen in model 1c.

Altogether, estimates support hypothesis 2 and shows that the founding team's competencies gained in different areas, namely technical and commercial fields, influence the firm technology exploitation strategy.

Further insights of the importance of human capital derive from the analysis of the sign and significance of the dummy variable that indicates whether at least one of the members of the founding team has previously held managerial positions. The coefficient estimated through the tobit analysis is negative, thus indicating that previous managerial experience tend to influence the firm strategy towards a product market exploitation of technology. Taking into consideration the tobit analysis of model 1b, the coefficient value, estimated through marginal effects for discrete change from 0 to 1, is relevant (-12.751*) and indicates the great influence of past managerial experience. No clear evidence comes from the probit analysis that does not give controversial results but fails in supporting significantly the tobit analysis.

The econometric analyses give no support to hypothesis 1, as the dummy variable $more\_cred\_f$ does not reach the confidence level of 10% in any models. This seems to indicate that credit rationing by banks, thought existing, has not a significant impact on the firm technology exploitation strategy.

The introduction of a set of control variables, intended to take into consideration other factors such as whether the firm was venture backed at foundation, the numerousness of the founding team and its experience in other sectors, and the period of establishment of the firm, confirm previous results without affecting significantly neither the values and signs of the coefficients nor their level of confidence.

In order to further control for robustness of the probit analysis, deriving from a dichotomization of the firm strategy between MFT and product market competition, I test the same models using as threshold the mean value instead of the median. The probit analysis, available in Appendix 2, Table 18, strongly confirms previous results. Thus, I conclude that the use of neither the median nor the mean value as threshold is determinant for the probit outcome.

To sum up, the econometric analyses point out a significant influence of the founding team's human capital and previous managerial experience on MFT exploitation propensity, while do not provide neither empirical support nor contradicting indication on the supposed positive relationship between credit rationing and the firm's strategy.

Model 1 Two-limit tobit analysis: the dependant variable is techno_f_tob and varies between 0 and 100 Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1						
Model / Variable	Tobit	Tobit	Marginal effects at mean	Tobit	Marginal effects at mean	OLS
	1a	1b	1b	1c	1c	1c
β_1 compet_med	21.702 (17.877)	30.869 (17.422)*	17.864 (10.073)*	26.879 (17.280)	15.847 (10.184)	16.694 (9.983)*
β_2 complex_med	76.585 (30.453)**	56.649 (30.012)*	32.784 (17.375)*	59.109 (29.756)**	34.849 (17.546)**	37.819 (17.500)**
β_3 approp_med	-38.701 (53.468)	-27.407 (50.277)	-15.861 (29.084)	-49.440 (52.063)	-29.150 (30.652)	-22.799 (29.837)
β_4 yeco_edu		9.450 (14.311)	5.469 (8.278)	4.962 (14.321)	2.925 (8.442)	2.964 (8.597)
β_5 ytech_edu		6.653 (2.521)***	3.850 (1.452)***	5.421 (2.612)**	3.196 (1.535)**	3.051 (1.533)**
β_6 ytech_wexp		2.157 (0.985)**	1.249 (0.570)**	2.351 (1.106)**	1.386 (0.650)**	1.332 (0.632)**
β_7 yprod_wexp		-0.547 (1.389)	-0.317 (0.803)	0.032 (1.434)	0.019 (0.846)	0.134 (0.798)
β_8 ycomm_wexp		-2.401 (1.428)*	-1.390 (0.825)*	-2.699 (1.515)*	-1.591 (0.893)*	-1.531 (0.848)*
β_9 dmanager		-22.232 (13.105)*	-12.751 (7.366)*	-25.545 (13.533)*	-14.874 (7.665)*	-13.521 (7.879)*
β_{10} more_cred_f		5.840 (12.849)	3.379 (7.425)	1.361 (13.424)	0.802 (7.914)	-0.102 (7.883)
β_{11} n_fondop_f				5.919 (5.233)	3.490 (3.081)	2.866 (2.913)
β_{12} yother_wexp				0.306 (0.784)	0.180 (0.462)	0.032 (0.458)
β_{13} vcbacked_f				-42.246 (47.847)	-23.393 (23.292)	-15.178 (23.499)
β_{14} bank_debt_f				3.768 (16.083)	2.222 (9.480)	3.959 (9.416)
β_{15} period91_00				2.135 (16.551)	1.259 (9.976)	1.081 (9.579)
β_{16} period01_10				24.112 (16.334)	14.143 (9.464)	12.457 (9.432)
β_0 constant	-185.445 (108.652)	-188.565 (107.348)*		-198.723 (108.099)*		-104.832 (62.283)*
Wald test:						
$\beta_1=\beta_2=\beta_3=0$		4.11 (3)***		4.40(3)***		4.31 (3)***
$\beta_4=\beta_5=\beta_6=\beta_7=\beta_8=0$		3.28 (5)***		2.84 (5)**		2.79 (5)**
no. firms	201	162		162		162
Pseudo R2	0.0081	0.0257		0.0323		0.2048
LR chi2	10.74(3)**	29.06(10)***		36.50(16)***		2.33 (16)***

Table 9: Two-limit tobit model 1

Model 1					
Probit analysis: the dependant variable is techno_f_prob, a dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the median calculated on the sample Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1					
Model / Variable	Probit	Probit	Marginal effects at mean	Probit	Marginal effects at mean
	1a	1b	1b	1c	1c
β_1 compet_med	0.338 (0.286)	0.614 (0.351)*	0.244 (0.139)*	0.569 (0.356)	0.226 (0.142)
β_2 complex_med	1.429 (0.496)***	1.350 (0.611)**	0.537 (0.243)**	1.388 (0.615)**	0.552 (0.245)**
β_3 approp_med	-0.510 (0.842)	-0.242 (0.976)	-0.096 (0.388)	-0.365 (1.031)	-0.145 (0.410)
β_4 yeco_edu		0.173 (0.288)	0.069 (0.114)	0.113 (0.291)	0.045 (0.116)
β_5 ytech_edu		0.131 (0.051)**	0.052 (0.020)**	0.114 (0.054)**	0.045 (0.021)**
β_6 ytech_wexp		0.047 (0.020)**	0.019 (0.008)**	0.041 (0.023)*	0.016 (0.009)*
β_7 yprod_wexp		-0.010 (0.026)	-0.004 (0.010)	-0.010 (0.028)	-0.004 (0.011)
β_8 ycomm_wexp		-0.034 (0.030)	-0.014 (0.012)	-0.044 (0.032)	-0.018 (0.013)
β_9 dmanager		-0.279 (0.255)	-0.110 (0.101)	-0.289 (0.270)	-0.115 (0.106)
β_{10} more_cred_f		0.275 (0.262)	0.108 (0.101)	0.187 (0.278)	0.074 (0.109)
β_{11} n_fondop_f				0.075 (0.108)	0.030 (0.043)
β_{12} yother_wexp				-0.007 (0.016)	-0.003 (0.007)
β_{13} vcbacked_f				-0.790 (1.063)	-0.295 (0.334)
β_{14} bank_debt_f				0.185 (0.326)	0.073 (0.127)
β_{15} period91_00				-0.042 (0.328)	-0.017 (0.131)
β_{16} period01_10				0.204 (0.323)	0.081 (0.127)
β_0 constant	-4.103 (1.733)**	-5.286 (2.154)**		-5.310 (2.222)**	
Wald test:					
$\beta_1=\beta_2=\beta_3=0$		10.52 (3)**		9.76 (3)**	
$\beta_4=\beta_5=\beta_6=\beta_7=\beta_8=0$		14.01 (5) **		11.29 (5)**	
no. firms	201	162		162	
Pseudo R2	0.0414	0.1151		12.78	
LR chi2	11.53 (3)***	25.77(10)***		28.62(16)**	

Table 10: Probit model 1

In order to provide empirical support to hypothesis 3 and further test the validity of hypotheses 1 and 4, I introduce a second model aimed at gathering a different aspect of the founding team's human capital competencies. Through the introduction of two Herfindal's indexes, aimed at representing the level of heterogeneity of academic studies and previous work experience of the firm's founders, I test whether more "mixed" teams tend to opt for a market for product strategy.

In accordance with hypothesis 3, the tobit analysis shows a negative relationship between both heterogeneity of academic studies and work experience, and propensity towards MFT. Moreover, a Wald test reject (weakly) the null hypothesis that the coefficients of $herf\_edu$ and $herf\_wxp$ be jointly equal to zero (χ^2 (2)=2.50*). The probit analysis leads to less strong results, confirming weakly that higher heterogeneity of the founding team's academic competencies decreases the likelihood of the firm pursuing a MFT commercialization strategy. In sum, the econometric model points out that NTBFs characterised by "more homogeneous" founding teams tend to have a higher propensity toward MFT exploitation of technology, being usually rich of technical competencies and short of commercial skills.

Moreover, the tobit analysis of model 3 further confirms both the sign and the level of significance of the effect of previous managerial experience on the firm strategy at foundation, remarking the validity of previous estimates. By contrast, also this analysis fails in supporting hypothesis 1 at conventional confidence level thought not providing contrary evidence.

Additional tests, made for robustness check purpose using the mean as threshold, confirm the indication provided by the tobit analysis (available in Appendix 2, Table 18).

In sum, previously analysed empirical results point out a negative relationship between the founding team's heterogeneity of academic studies and work experience and the willingness to exploit technology through the MFT. Moreover, the models further confirm the relevance of previous managerial experience and do not point out any significant results of the effect of credit rationing on MFT propensity at foundation.

Model 2 Two-limit tobit analysis: the dependant variable is techno_f_tob and varies between 0 and 100 Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1						
Model / Variable	Tobit	Tobit	Marginal effects at mean	Tobit	Marginal effects at mean	OLS
	2a	2b	2b	2c	2c	2c
β_1 compet_med	21.702 (17.877)	26.087 (17.931)	14.564 (10.008)	23.775 (17.722)	13.596 (10.134)	15.083 (10.068)
β_2 complex_med	76.585 (30.453)**	72.832 (30.688)**	40.662 (17.135)**	77.163 (30.385)**	44.126 (17.369)**	48.417 (17.480)***
β_3 approp_med	-38.701 (53.468)	-29.600 (52.057)	-16.525 (29.047)	-52877 (53.088)	-30.238 (30.307)	-23.982 (29.764)
β_4 herf_edu		-24.558 (11.695)**	-13.710 (6.051)**	-20.299 (12.086)*	-11.608 (6.897)*	-11.316 (7.022)
β_5 herf_wexp		-13.186 (11.869	-7.362 (6.629)	-24.296 (14.066)*	-13.894 (8.023)*	-13.077 (8.111)
β_6 dmanager		-25.998 (13.443)*	-14.356 (7.238)**	-28.484 (13.850)**	-16.060 (7.566)**	-14.824 (7.948)*
β_7 more_cred_f		1.537 (13.075)	0.858 (7.299)	1.509 (13.864)	0.863 (7.928)	-0.532 (8.009)
β_8 n_fondop_f				6.038 (5.374)	3.453 (3.069)	3.045 (2.990)
β_9 yother_wexp				0.568 (0.817)	0.325 (0.466)	0.167 (0.470)
β_{10} vcbacked_f				-58.103 (47.999)	-29.858 (19.649)	-24.294 (24.050)
β_{11} bank_debt_f				-8.761 (16.385)	-5.000 (9.311)	-2.704 (9.472)
β_{12} period91_00				-1.159 (17.182)	-0.663 (9.825)	-0.821 (9.786)
β_{13} period01_10				24.615 (16.897)	14.005 (9.501)	12.940 (9.571)
β_0 constant	-185.445 (108.652)	-165.442 (110.524)		-183.157 (110.705)		-98.279 (62.951)
Wald test:						
β_1=β_2=β_3=0		3.72 (3)**		4.44 (3)***		4.60 (3)***
β_4=β_5=0		2.50 (2)*		2.50 (2)*		2.24 (2)
no. firms	201	162		162		162
Pseudo R2	0.0081	0.016		0.024		0.1539
LR chi2	10.74(3)**	17.48 (7)**		27.10 (13)**		2.07 (13)**

Table 11: Two-limit tobit model 2

Model 2 Probit analysis: the dependant variable is techno_f_prob, a dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the median calculated on the sample Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1					
Model / Variable	Probit	Probit	Marginal effects at mean	Probit	Marginal effects at mean
	2a	2b	2b	2c	2c
β_1 compet_med	0.365 (0.286)	0.477 (0.334)	0.190 (0.133)	0.438 (0.341)	0.174 (0.136)
β_2 complex_med	1.398 (0.496)***	1.547 (0.587)***	0.615 (0.233)***	1.619 (0.600)***	0.644 (0.238)***
β_3 approp_med	-0.562 (0.841)	-0.273 (0.945)	-0.108 (0.376)	-0.428 (0.990)	-0.170 (0.394)
β_4 herf_edu		-0.424 (0.220)*	-0.169 (0.087)*	-0.367 (0.233)	-0.146 (0.092)
β_5 herf_wexp		-0.243 (0.222)	-0.096 (0.088)	-0.245 (0.268)	-0.097 (0.106)
β_6 dmanager		-0.314 (0.245)	-0.125 (0.097)	-0.309 (0.261)	-0.123 (0.103)
β_7 more_cred_f		0.182 (0.248)	0.072 (0.097)	0.138 (0.270)	0.055 (0.106)
β_8 n_fondop_f				0.078 (0.104)	0.031 (0.042)
β_9 yother_wexp				-0.008 (0.016)	-0.003 (0.006)
β_{10} vcbacked_f				-0.950 (0.937)	-0.342 (0.262)
β_{11} bank_debt_f				-0.025 (0.311)	-0.010 (0.124)
β_{12} period91_00				-0.075 (0.032)	-0.030 (0.128)
β_{13} period01_10				0.249 (0.315)	0.099 (0.124)
β_0 constant	-4.108 (1.734)**	-4.449 (2.050)**		-4.630 (2.131)**	
Wald test:					
β_1=β_2=β_3=0		10.15 (3)**		10.05 (3) **	
β_4=β_5=0		4.31 (2)		2.93 (2)	
no. firms	201	162		162	
Pseudo R2	0.0433	0.0674		0.0861	
LR chi2	12.08 (3)***	15.10 (7)*		19.29 (13)	

Table 12: Probit model 2

5.2.Empirical analysis of strategic changes over time

The previous section has highlighted the relevance of human capital competencies of NTBF's founders over the pursued technology commercialisation strategy at foundation, driving in some cases high-tech start-ups short of competencies in important fields to choose exploitation through MFT. However, in hypothesis 5, I argue that the "soft company" business model presents a number of pitfalls and thus, NTBFs, whether possible, tend to switch strategy in favour of product market competition and a "hard company" business model. The empirical research is conducted through a sample selection analysis on the firms that pursued technology commercialisation through MFT at foundation, investigating a number of factors that possibly influence the firm's strategy.

The econometric analysis detailed in Table 13 reports only the second step of the procedure, being the first one the model 1c available in Table 10. Econometric results point out a significant and negative relationship between the strategy put in place by NTBFs in 2007 and firms' age (age coeff=-6.047**). The relationship has been modelled with the addition of a quadratic term ($age2$) that have a positive and weakly significant coefficient. The outcome, therefore, is consistent with hypothesis 5 and documents an increasing propensity in favour of product market strategy as the firm gets more experienced (U-shaped relationship). The positive quadratic term signal a potential offsetting effect of the linear term in the long term. The null hypothesis that both coefficients of age and $age2$ be jointly equal to zero in model 3 is rejected by a Wald test ($\chi^2(2)$=5.70*).

The econometric model has been tested taking into consideration a number of control variables such as whether the NTBF received a public or venture funding, or it entered either a commercial or a technological alliance. Despite all these factors may influence at some level the firm's strategy, none of the coefficient of these variables have been found significant at conventional confidence levels. The inverse Mills ratio term ($lambda$), taking into consideration sample selection bias, is statistically non-different from zero.

For comparison purpose, the analysis has been conducted also through a Heckman two-steps model, aware of the difficulties encountered by OLS regression with censored data. Econometric results are comparable and not significantly different from those obtained with the probit-tobit procedure.

To sum up, in accordance with hypothesis 5, empirical tests point out a moderately-strong and negative relationship between the years of a firm's activity since foundation and its propensity towards a MFT commercialisation strategy.

Model 3		
Probit + tobit and Heckman two-steps analysis: the dependant variable is techno_07_tob and varies between 0 and 100 Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1. Bootstrap replication 500		
Model / Variable	Probit + Tobit	Heckman two-steps
	3a	3b
β_1 compet_med	22.224 (18.817)	17.495 (11.170)
β_2 complex_med	50.744 (35.389)	45.655 (24.449)*
β_3 approp_med	49.483 (61.277)	17.598 (32.468)
β_4 age	-6.047 (2.897)**	-4.979 (2.114)**
β_5 age2	0.229 (0.129)*	0.188 (0.088)**
β_6 fin_aftf	0.098 (12.139)	-0.591 (8.053)
β_7 altech_aftf	7.440 (14.523)	7.976 (9.554)
β_8 alcomm_aftf	0.154 (14.993)	-2.296 (9.185)
β_9 vc_aftf	-26.414 (32.624)	-20.666 (22.039)
β_0 constant	-118.308 (126.194)	-92.666 (80.929)
lambda	14.742 (20.502)	16.346 (15.478)
Wald test:		
$\beta_4=\beta_5=0$	5.70 (2)*	5.82 (2)*
no. firms	81	81
LR chi2	11.73 (10)	11.15 (9)

Table 13: Heckman and Probit-Tobit analysis of model 3

Conclusions and future lines of research

This study proposes new insights into the analysis of high-tech start-ups' propensity towards market for technology both at foundation and in the long term.

After having depicted and documented the growing importance of knowledge in modern economy, the increasing division of innovative labour due to the "changing technology of technical change", and the rise and fast development of the market for technology, I proposed a literature review of the main factors affecting firms' propensity towards MFT. Prior research literature has mainly concentrated on macro-level factors, such as the regime of appropriability, the necessity of complementary assets, competition in the product market, the relevance of transaction costs and the "fear of giving away crown jewels", altogether representing the technological regime. Only recently, a number of authors took into consideration firm-level factors, such as characteristics of the technology (Palomeras 2007), direct capabilities and financial resources (Kasch and Dowling 2008), and experience gained in the product market (Motohashi 2008). I take advantage of a dataset, unique for completeness and level of detail on Italian NTBFs belonging to several sectors, to test whether the firm's human capital competencies and financial conditions have an impact over propensity towards MFT at foundation.

Concerning the first point, NTBFs have generally been regarded as highly endowed with well-educated founders and personnel, characterised by high-level competencies and work experience in technical fields (engineering and natural sciences). However, NTBFs' founding teams generally present a significant shortage of less technical skills and capabilities, i.e. those related to business studies and economics. I empirically found a strong positive relationship between the founding team's endowment of technical education and experience on the propensity to exploit technology through MFT. By contrast, experience gained in commercial functions decrease the likelihood of technology commercialisation through MFT in favour of the entering into market for product competition. Altogether, results point out the strong relevance of founder's human capital on the firm's technology exploitation strategy at foundation.

The analysis of another aspect of NTBFs founding teams' competencies, heterogeneity, point out that teams composed by members with more heterogeneous academic and work experience less likely opt for MFT. A reasonable explanation is that more "mixed" teams, being endowed with a wider set of skills that covers all stages from R&D to commercialisation, do not need to face the difficult task of recruiting skilled personnel, having in-house all the necessary competencies. The absence, or limitedness, of "knowledge gap" increases the likelihood of product market exploitation of technology.

Further researches have taken into consideration the role of previous managerial experience. I argue that the presence of members with prior work experience gained in managerial functions may drive NTBFs to opt for market for product competition instead of commercialisation through MFT. Managerial competencies may reduce difficulties encountered in effectively developing the firm's structure and organisation, difficulties harder to be overcome in organisations operating in all steps of the value chain. In addition, network ties, likely to be developed holding managerial positions, may facilitate both recruitment of skilled personnel as well as search and provision of funds at foundation. Empirical tests confirm the idea, showing that the presence, in the founding team, of members with previous managerial experience significantly decreases the likelihood of commercialisation of knowledge through MFT at foundation.

Concerning the second point, NTBFs have generally been regarded as business at high-risk because of the technological content of their products and the dynamic environment they operate in. I argue that this factor, in addition to capital market imperfections, may lead NTBFs to suffer from a pronounced funding gap and, in turn, be unable to exploit through market for product their technology. In fact, competition into the product market generally requires heavy sunk investments, necessary to access or build complementary assets such as manufacturing and distribution facilities. Given the commonly accepted classification of Italy as a bank-based country, and the empirical confirmation of the low activity of venture capitalist in this county, I took into consideration constraints imposed by lending institutions. In discordance with what argued, I do not find either significant support or contradicting indication to the relationship between credit rationing suffered by NTFBs and strategies put in place by firms at foundation.

In addition to the analysis of how firm-level factors may affect technology commercialisation strategies at foundation, in this study, I take into consideration NTBFs' strategy evolution, investigating whether MFT's strategy may well represent a long-term strategy or its efficacy is limited to the short-term. Previous literature has hypothesized controversial roles for NTBFs in the economy. A first stream of literature emphasises their role as agent of growth and creation of employment. By contrast, other authors stress NTBFs' technological transfer effect on industrial innovation network, arguing that they represent more agents of transfer of technology than agents committed in the development and commercialisation of technological products. In the first case, NTBFs follow the paradigm of the high-tech fast growing firms typical of the US Silicon Valley. In the second case, NTBFs may well be represented as "ideas factories", firms endowed with high technology competencies and focused on R&D of promising technologies commercialised in collaboration with downstream players. I argue in favour of the first hypothesis. In fact, beside several advantages, as the opportunity to extract rent from innovation without the necessity to build costly assets and acquire additional specific competencies, MFT's strategy has a number of pitfalls. Firms adopting MFT's strategy are unlikely to be able to get the full return from innovation, and their earnings heavily depend on the effort profuse by the licensee, resulting in "the firm being unable to control its own fate" (Arora, Fosfuri and Gambardella 2001, p. 241). Moreover, the improvement of financial condition, and the higher ability to recruit skilled personnel from the job market thanks to built reputation and network ties, may increase the firm's propensity towards market for products. In accordance with the hypothesis, empirical tests show a significant and negative relationship between the firm's age, as proxy of the acquired experience, and the likelihood to pursue MFT strategy. This argues in favour of the development of the "soft company" business model in place at foundation into the "hard company" business model, as the firm gets "experienced" and improves its financial condition.

The econometric analysis has been conducted on a sample of Italian NTBFs extracted from the RITA dataset. In addition to the presented econometric analyses, models have been tested for robustness check and outcomes are available in Appendix 2 and Appendix 3.

To summarise the results, I found a strong and significant influence of the founding team's human capital endowment on the firm's propensity to exploit technology through MFT. The econometric models do not give support nor contradicting indications on the effect of existing credit constraints on the likelihood of technology commercialisation through MFT. At last, I found that technology exploitation through MFT tend not to be a long-term strategy, as firms tend to opt for product market competition in the long run.

As future line of research, it would be undoubtedly interesting to better characterise micro determinants of licensing propensity thought the collection of both firm-level and technology-level characteristics. Moreover, possible future lines of research would undoubtedly investigate, with more fine-grained and accurate measures, NTBFs' financial constraints at foundation, taking into greater consideration the role of banks as providers of funds. To conclude, additional empirical studies are necessary to establish NTBFs' strategy development through time, in order to better understand NTBFs' contribution to modern economy.

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Appendix 1

1.1. Descriptive statistics

Variable	Number of observations	Mean	S.D.	Minimum	Maximum
techno_f_tob	201	46.403	41.464	0.000	100.000
techno_f_prob	201	0.498	0.501	0.000	1.000
compet_med	201	3.647	0.496	2.500	4.472
complex_med	201	2.093	0.195	1.914	2.750
approp_med	201	0.253	0.163	0.000	0.750
yeco_edu	176	0.104	0.511	0.000	5.000
ytech_edu	176	2.028	2.253	0.000	7.500
ytech_wexp	173	3.166	5.533	0.000	26.500
yprod_wexp	173	1.105	3.961	0.000	37.000
ycomm_wexp	173	1.313	3.991	0.000	26.333
herf_edu	176	0.468	0.492	0.000	1.000
herf_wexp	173	0.584	0.472	0.000	1.000
dmanager	188	0.239	0.428	0.000	1.000
more_cred_f	191	0.246	0.432	0.000	1.000
n_fondop_f	201	2.403	1.101	1.000	8.000
yother_wexp	174	7.704	8.627	0.000	36.000
vcbacked_f	199	0.035	0.185	0.000	1.000
bank_debt_f	199	0.166	0.373	0.000	1.000
period91_00	201	0.393	0.490	0.000	1.000
period01_10	201	0.458	0.499	0.000	1.000

Table 14: Descriptive statistics of the explanatory variables of the econometric models 1 and 2

Variable	Number of observations	Mean	S.D.	Minimum	Maximum
techno_07_tob	201	40.989	36.433	0.000	100.000
compet_med	201	3.647	0.496	2.500	4.472
complex_med	201	2.093	0.195	1.914	2.750
approp_med	201	0.253	0.163	0.000	0.750
age	201	9.174	6.803	0.000	24.000
age2	201	130.209	149.978	0.000	576.000
fin_aftf	201	0.299	0.459	0.000	1.000
altech_aftf	201	0.224	0.418	0.000	1.000
alcom_aftf	201	0.284	0.452	0.000	1.000
vc_aftf	201	0.040	0.196	0.000	1.000

Table 15: Descriptive statistics of the explanatory variables of the econometric model 3

1.2. Correlation matrices

techno_f_tob	1																		
compet_med	0.1462	1																	
complex_med	0.1530	-0.3392	1																
approp_med	-0.1394	-0.7530	0.2358	1															
yeco_edu	0.0544	0.1137	0.0467	-0.0744	1														
ytech_edu	0.1870	-0.2471	0.2585	0.2552	-0.0665	1													
ytech_wexp	0.1411	-0.0583	-0.0217	-0.0024	-0.0777	-0.0791	1												
yprod_wexp	-0.0558	0.0054	0.0257	0.0781	-0.0099	-0.0920	-0.0990	1											
ycomm_wexp	-0.2056	0.0564	-0.1795	-0.0672	-0.0559	-0.1928	-0.0294	0.0744	1										
herf_edu	-0.1323	0.1299	-0.1773	-0.1897	-0.1116	-0.8316	0.0565	0.0033	0.1841	1									
herf_wexp	-0.0454	0.0049	0.0944	0.0670	0.1087	0.2490	-0.6088	-0.2407	-0.2526	-0.1798	1								
dmanager	-0.1042	0.0287	0.0299	0.0436	0.0693	0.0183	0.0909	0.0117	0.1216	-0.1085	-0.0683	1							
more_cred_f	-0.0275	-0.1826	0.0534	0.0195	-0.0507	-0.0203	0.0293	0.1051	0.1673	0.0558	-0.0103	-0.0306	1						
n_fondop_f	0.1172	-0.0102	0.0721	0.0527	0.1484	0.2229	-0.0340	-0.0377	0.0943	-0.3001	0.1578	0.1028	0.1506	1					
yother_wexp	-0.0679	-0.1778	0.0604	0.2920	0.0006	0.0898	-0.3818	-0.1679	-0.1965	-0.0848	0.5164	0.1187	-0.1009	0.0796	1				
vcbacked_f	-0.0526	-0.1118	0.1428	0.0111	-0.0310	0.1182	0.0193	-0.0398	0.0725	-0.1321	-0.0712	0.1468	0.0275	-0.0171	0.0492	1			
bank_debt_f	-0.0543	0.0122	-0.0618	-0.0208	-0.0339	-0.1012	0.0061	0.0725	0.2583	0.0594	-0.1331	0.1827	0.3102	0.1067	-0.1203	-0.0587	1		
period91_00	-0.0998	0.1595	-0.0944	-0.2177	0.0051	-0.1920	-0.0767	0.1043	0.0038	0.1481	-0.0434	-0.0609	-0.0750	-0.0105	-0.0428	-0.0157	-0.0253	1	
period01_10	0.1410	-0.1198	0.0494	0.1505	0.0196	0.2018	0.0447	-0.1462	0.0222	-0.1363	0.0940	0.1060	0.0209	0.1286	0.1552	0.0579	-0.0830	-0.7315	1

Table 16: Correlation among variables of models 1 and 2

techno_07_tob	1									
compet_med	-0.0077	1								
complex_med	0.0650	-0.4596	1							
approp_med	0.1516	-0.6944	0.2830	1						
age	-0.2001	0.1983	-0.0777	-0.2230	1					
age2	-0.1179	0.1756	-0.0955	-0.1694	0.9572	1				
fin_aftf	-0.1526	-0.1664	0.1639	0.0771	0.2443	0.2021	1			
altech_aftf	-0.0264	-0.0205	-0.0939	0.0768	-0.0378	-0.0723	0.2068	1		
alcomm_aftf	-0.0987	0.0108	0.0567	0.0124	0.0397	0.0014	0.2703	0.5719	1	
vc_aftf	-0.1272	-0.2537	0.3652	-0.0070	0.0794	0.0598	0.2752	0.1407	0.2397	1

Table 17: Correlation among variables of model 3

Appendix 2

This section presents the results of a number of econometric tests made to check for robustness of the proposed models.

Table 18 shows the probit econometric analysis of models 1 and 2 using as dependant variable techno_f_prob1, dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the mean value calculated on the sample. The results are overall coherent with previous proposed models, as both the technological regime and the human capital competencies of the founding team have the hypothesized impact on the dependant variable and the level of significance is comparable. By contrast, as see in previous analyses, credit constraints at foundation do not have a relevant impact on the firm's strategy.

Table 19 shows two-limit tobit and probit analyses performed using sectorial dummy variable as substitutes of technological regime's variable. Thus, the macro determinant independent variables are:

- Chemical: dummy variable that assumes a value of 1 if the firm belong to the chemical sector, zero otherwise.
- Ict_manuf: dummy variable that assumes a value of 1 if the firm belong to the ict manufacturing sector, zero otherwise.
- Rob&Auto: dummy variable that assumes a value of 1 if the firm belong to the robotics and automation sector, zero otherwise.

The two models assume the following form:

4) $techno\_f = \beta_0 + \beta_1(chemical) + \beta_2(ict\_manuf) + \beta_3(yeco\_edu) + \beta_4(ytech\_edu) + \beta_5(ytech\_wexp) + \beta_6(yprod\_wexp) + \beta_7(ycomm\_wexp) + \beta_8(dmanager) + \beta_9(more\_cred\_f) + \beta_{10}(n\_fondop\_f) + \beta_{11}(yother\_wexp) + \beta_{12}(vcbacked\_f) + \beta_{13}(bank\_debt\_f) + \beta_{14}(period91\_00) + \beta_{15}(period01\_10)$

5) $techno\_f = \beta_0 + \beta_1(chemical) + \beta_2(ict\_manuf) + \beta_3(herf\_edu) + \beta_4(herf\_wexp) + \beta_5(dmanager) + \beta_6(more\_cred\_f) + \beta_7(n\_fondop\_f) + \beta_8(yother\_wexp) + \beta_9(vcbacked\_f) + \beta_{10}(bank\_debt\_f) + \beta_{11}(period91\_00) + \beta_{12}(period01\_10)$

Overall, the proposed analyses shows a considerably lower level of significance of all the variables, thought results do not provide any contracting indications being the coefficients always coherent with the proposed hypotheses.

Model 1 and 2 Probit analysis: the dependant variable is techno_f_prob1, a dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the mean value calculated on the sample. Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses.			
Model / Variable	Probit 1c	Model / Variable	Probit 2c
β_1 compet_med	0.542 (0.360)	β_1 compet_med	0.419 (0.346)
β_2 complex_med	1.741 (0.625)***	β_2 complex_med	2.005 (0.610)***
β_3 approp_med	-0.877 (1.050)	β_3 approp_med	-0.808 (1.011)
β_4 yeco_edu	0.168 (0.294)		
β_5 ytech_edu	0.152 (0.055)***		
β_6 ytech_wexp	0.054 (0.024)**		
β_7 yprod_wexp	0.005 (0.029)		
β_8 ycomm_wexp	-0.044 (0.036)		
		β_4 herf_edu	-0.544 (0.239)**
		β_5 herf_wexp	-0.396 (0.274)
β_9 dmanager	-0.531 (0.284)*	β_6 dmanager	-0.530 (0.270)*
β_{10} more_cred_f	0.215 (0.291)	β_7 more_cred_f	-0.191 (0.280)
β_{11} n_fondop_f	0.090 (0.110)	β_8 n_fondop_f	0.090 (0.105)
β_{12} yother_wexp	0.004 (0.017)	β_9 yother_wexp	-0.002 (0.016)
β_{13} vcbacked_f	-0.731 (1.114)	β_{10} vcbacked_f	-0.995 (0.53)
β_{14} bank_debt_f	0.378 (0.340)	β_{11} bank_debt_f	0.113 (0.329)
β_{15} period91_00	-0.038 (0.336)	β_{12} period91_00	-0.043 (0.329)
β_{16} period01_10	0.198 (0.328)	β_{13} period01_10	0.263 (0.20)
β_0 constant	-6.044 (2.258)***	β_0 constant	-5.186 (2.163)**
Wald test:			
β_1=β_2=β_3=0	13.46 (3)***	β_1=β_2=β_3=0	14.17 (3) ***
β_4=β_5=β_6=β_7=β_8=0	14.70 (5)**	β_4=β_5=0	6.33 (2)**
no. firms	162		162
Pseudo R2	0.1686		0.1243
LR chi2	37.86 (16)***		27.91 (13)***

Table 18: Probit analysis of models 1 and 2 using the mean value as threshold

Model 4 and 5 Two-limit tobit analysis: the dependant variable is techno_f_tob and varies between 0 and 100 Probit analysis: the dependant variable is techno_f_prob, a dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the median calculated on the sample Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses.					
Model / Variable	Tobit 4	Probit 4	Model / Variable	Tobit 5	Probit 5
β_1 chemical	-34.599 (19.831)*	-0.560 (0.379)	β_1 chemical	-31.417 (20.262)	-0.486 (0.367)
β_2 ict_manuf	-30.304 (14.076)**	-0.476 (0.275)*	β_2 ict_manuf	-35.356 (14.393)**	-0.556 (0.270)**
β_3 yeco_edu	11.213 (14.684)	0.221 (0.285)			
β_4 ytech_edu	4.152 (2.659)	0.101 (0.052)*			
β_5 ytech_wexp	1.391 (1.102)	0.025 (0.022)			
β_6 yprod_wexp	-0.514 (1.471)	-0.012 (0.027)			
β_7 ycomm_wexp	-2.866 (1.521)*	-0.050 (0.031)			
			β_3 herf_edu	-15.421 (12.220)	-0.324 (0.229)
			β_4 herf_wexp	-10.639 (14.144)	-0.038 (0.261)
β_8 dmanager	-22.446 (13.764)	-0.216 (0.264)	β_5 dmanager	-24.984 (14.038)*	-0.236 (0.256)
β_9 more_cred_f	-3.182 (13.260)	0.065 (0.260)	β_6 more_cred_f	-3.855 (13.654)	0.042 (0.253)
β_{10} n_fondop_f	7.426 (5.325)	0.092 (0.103)	β_7 n_fondop_f	7.329 (5.489)	0.087 (0.101)
β_{11} yother_wexp	-0.339 (0.763)	-0.015 (0.015)	β_8 yother_wexp	-0.152 (0.791)	-0.016 (0.015)
β_{12} vcbacked_f	-40.338 (45.937)	-0.661 (0.886)	β_9 vcbacked_f	-50.815 (46.359)	-0.733 (0.813)
β_{13} bank_debt_f	-0.923 (16.601)	0.110 (0.325)	β_{19} bank_debt_f	-12.815 (16.781)	-0.094 (0.311)
β_{14} period91_00	10.122 (16.989)	0.062 (0.321)	β_{11} period91_00	8.078 (17.493)	0.030 (0.317)
β_{15} period01_10	30.827 (16.958)*	0.304 (0.322)	β_{12} period01_10	31.547 (17.483)*	0.340 (0.316)
β_0 constant	37.528 (21.087)*	-0.002 (0.398)	β_0 constant	65.595 (22.116)***	0.495 (0.408)
Wald test:					
β_1=β_2=0	2.57 (2)*	3.39 (2)	β_1=β_2=0	3.04 (2)*	4.29 (2)
β_3=β_4=β_5=β_6=β_7=0	2.09 (5)*	9.98 (5)*	β_3=β_4=0	0.98 (2)	2.01 (2)
no. firms	162	162		162	162
Pseudo R2	0.0251	0.0981		0.0175	0.0593
LR chi2	28.39 (15)**	21.98 (15)		19.80 (12)*	13.29 (12)

Table 19: Tow-limit tobit and probit analysis with dummy variables as substitutes of technological regime's variables

Appendix 3

This section shows the results obtained from both the two-limit tobit and probit analyses on a wider sample including, in addition to previous firms, NTBFs belonging to the multimedia content and software sector. Conscious of the difficulties of differentiating from physical artefacts and MFT in case of firms producing software or providing multimedia services, I show that the results are consistent with previous analyses on a sample of manufacturing firms. For firms belonging to the software industry, it has been applied the same criterion used for those in manufacturing sectors, considering the provision of services as transfer of "intangible" knowledge and thus being part of MFT's transactions. By contrast, I consider services provided by firms operating in the multimedia contest sector as their products, and thus only the turnover deriving from the provision of technology has been considered deriving from MFT's transactions. In general, Table 20 confirms previous econometric results. Both the technological regime and the human capital competencies of the founding team are relevant as confirmed by the Wald tests (for instance Tobit model 1c χ^2 (3) =27.34*** and χ^2 (5) =3.48*** respectively). Coefficients of the variables are consistent with previous estimates, and show a positive relationship between the number of years of both academic knowledge and work experience gained in technical fields and the NTBF's propensity towards MFT's commercialisation strategy. Moreover, tobit analyses also highlight the relevance of previous managerial experience within the founding team on the firm's strategy at foundation. Models taking into consideration the level of heterogeneity among founding teams' members, in accordance with previously proposed models, remark the negative and significant relationship between heterogeneity and the firm's propensity towards MFT. To conclude, all the analyses fail in providing significant empirical support, thought not reporting contradicting indications, to the relationship between the firm's faced credit constraints and the strategy put in place at foundation.

Estimates shown in Table 21 confirm the previously highlighted relationship between the firm's gained experience and its propensity towards MFT. As seen before, the relationship has been modelled with both a linear and a quadratic term. Both the "probit plus tobit" Heckman two-step and the common Heckman two-step models show the significance of the negative coefficient of age while the positive coefficient of $age2$ does not reach the conventional confidence level of 10%. Overall, as confirmed (weakly) by the Wald test (χ^2 (2) =5.14*) the firm experience has a relevant impact on the evolution of NTBF's strategy.

Model 1 and 2
Two-limit tobit analysis: the dependant variable is techno_f_tob and varies between 0 and 100
Probit analysis: the dependant variable is techno_f_prob, a dummy variable that assumes the value of 1 if the technology component of firm's turnover is higher than the median calculated on the sample
Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%.
Number of restrictions in parentheses.

Model / Variable	Tobit 1c	Probit 1c	Model / Variable	Tobit 2c	Probit 2c
β_1 compet_med	50.883 (18.280)***	0.794 (0.353)**	β_1 compet_med	50.840 (18.443)***	0.734 (0.346)**
β_2 complex_med	223.503 (25.221)***	3.834 (0.493)***	β_2 complex_med	244.457 (25.532)***	4.094 (0.485)***
β_3 approp_med	-14.137 (50.110)	-0.681 (0.940)	β_3 approp_med	1.746 (50.124)	-0.434 (0.919)
β_4 yeco_edu	-12.379 (8.423)	-0.046 (0.158)			
β_5 ytech_edu	4.868 (2.145)**	0.095 (0.042)**			
β_6 ytech_wexp	2.538 (0.916)***	0.046 (0.016)**			
β_7 yprod_wexp	1.065 (1.205)	0.016 (0.022)			
β_8 ycomm_wexp	-0.479 (1.173)	-0.013 (0.023)			
			β_4 herf_edu	-5.512 (9.191)	-0.123 (0.171)
			β_5 herf_wexp	-34.614 (10.807)***	-0.450 (0.199)**
β_9 dmanager	-18.350 (10.380)*	-0.166 (0.198)	β_6 dmanager	-21.873 (10.355)**	-0.196 (0.193)
β_{10} more_cred_f	4.864 (9.814)	0.139 (0.191)	β_7 more_cred_f	2.803 (9.790)	0.097 (0.185)
β_{11} n_fondop_f	5.881 (3.601)	0.081 (0.071)	β_8 n_fondop_f	7.095 (3.664)*	0.105 (0.071)
β_{12} yother_wexp	0.463 (0.636)	-0.001 (0.012)	β_9 yother_wexp	0.715 (0.641)	-0.002 (0.012)
β_{13} vcbacked_f	2.292 (27.633)	-0.207 (0.521)	β_{10} vcbacked_f	-3.971 (26.706)	-0.270 (0.482)
β_{14} bank_debt_f	-13.121 (13.459)	-0.015 (0.256)	β_{11} bank_debt_f	-16.895 (13.607)	-0.111 (0.249)
β_{15} period91_00	-5.730 (13.212)	-0.218 (0.247)	β_{12} period91_00	-5.526 (13.423)	-0.184 (0.246)
β_{16} period01_10	16.416 (13.070)	0.180 (0.245)	β_{13} period01_10	18.044 (13.176)	0.253 (0.242)
β_0 constant	-632.570 (99.610)***	-111.064 (1.892)***	β_0 constant	-643.589 (101.239)***	-10.854 (1.859)***
Wald test:					
$\beta_1=\beta_2=\beta_3=0$	27.34 (3)***	65.04 (3)***	$\beta_1=\beta_2=\beta_3=0$	31.00 (3)***	72.76 (3)***
$\beta_4=\beta_5=\beta_6=\beta_7=\beta_8=0$	3.48 (5)***	13.10 (5)**	$\beta_4=\beta_5=0$	5.18 (2)***	5.39 (2)*
no. firms	332	332		332	332
Pseudo R2	0.0710	0.2677		0.0673	0.2495
LR chi2	145.45 (16)***	123.15 (16)***		138.01 (13)***	114.80 (13)***

Table 20: Two-limit tobit and probit analysis of models 1c and 2c on a larger sample of NTBFs

Model 3 Probit + Tobit and Heckman two-steps analysis: the dependant variable is techno_07_tob and varies between 0 and 100 Significance level greater than 90%; ** significance level greater than 95%; ***significance level greater than 99%. Number of restrictions in parentheses. Marginal effect of dummy variable is for discrete change from 0 to 1. Bootstrap replication 500		
Model / Variable	Probit + Tobit	Heckman two-steps
	3a	3b
β_1 compet_med	14.512 (18.173)	11.393 (10.363)
β_2 complex_med	37.444 (45.836)	32.049 (28.147)
β_3 approp_med	9.544 (49.017)	-8.251 (26.399)
β_4 age	-2.994 (1.715)*	-2.280 (1.386)*
β_5 age2	0.087 (0.071)	0.072 (0.058)
β_6 fin_aftf	0.750 (7.363)	0.205 (5.436)
β_7 altech_aftf	4.813 (7.859)	3.591 (6.151)
β_8 alcomm_aftf	-2.105 (7.572)	-1.419 (5.932)
β_9 vc_aftf	-37.349 (26.815)	-31.494 (19.425)
β_0 constant	-43.175 (148.763)	-26.946 (88.660)
lambda	-0.412 (15.438)	0.126 (11.615)
Wald test:		
β_4=β_5=0	5.72 (2)*	4.28 (2)
no. firms	153	300[5]
LR chi2	13.59 (10)	9.87 (9)

Table 21: Probit-tobit and Heckman two-step analysis on a larger sample of NTBFs

[5] No of observations 300, uncensored 153, censored 147