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Abstract

New Technology-Based Firms (NTBFs) have gained increasing economic relevance, supported by the recognition that they play an important role in national economies in the appearance of both new, high technology products and of new and emerging industries. Despite their economic importance, a number of alternative definitions for NTBFs are referred to in the literature, many of them adjusted to the aim of the study or the sample under observation. Such a lack of conceptualization reflects the variety of perspectives and interests of researchers, and has led to the need for a coherent framework to study NTBFs. Agreement has yet to be reached on which are the key characteristics of NTBFs. This lack of consensus in the conceptualization of NTBFs hinders the adequate applicability of the concept or a comparison among the different existing studies. Based on a sample of 30 Academic Spin-Offs (ASOs), and applying the criteria inferred conceptually, it was possible to conclude that, contrary to common wisdom, not all ASOs are NTBFs. Additionally, the ASOs classified as NTBFs, according to our criteria, differ significantly from the other ASOs, presenting a higher level of invested capital, higher R&D and internationalization intensity, and founding teams with a higher concentration of individuals with management capabilities.

Keywords: New technology-based firms; Academic Spin-offs; Portugal

JEL-Codes: O30; O32

1. Introduction

New Technology-Based Firms (NTBFs) have gained increasing economic relevance (Cooper, 1971; Autio, 1997a; Bollinger et al., 1983; Storey and Tether 1998a; Grinstein and Goldman, 2006), supported by the recognition that they play an important role in the competitiveness of economies through the appearance of both new, high technology products and of new and emerging industries (Cooper, 1971; Rothwell, 1989; Autio, 1997a).

Associated with the importance of NTBFs and the emergence of new industries, some authors (e.g., Rothwell, 1989) refer to the Fairchild semi-conductor case-study, whose growth went from sales of $0.5 million in 1960 up to $520 million in 1978, and the appearance of several NTBFs as a group with significant economic impact. Another reference in the literature is the case of the computer-aided design (CAD) industry and the Computervision leadership in the USA during the 1980s (Kaplinsky, 1981). Later, Slater (1987) studied some of the then considered 'NTBFs', like DEC, Hewlett-Packard and Apple Computer and the biotechnology industry pioneer Genentech (Autio, 1997a). This link between new technologies and new industries reinforced interest in NTBFs (Dosi, 1984; Rothwell and Zegveld, 1985).

Despite the economic importance of NTBFs, many authors (e.g., Storey and Tether, 1998a; Delapierre et al., 1998; Elorz, 2003; Grinstein and Goldman, 2006) agree that the NTBF definition is not simple and does not reflect homogeneous economic realities, with different authors proposing distinct concepts.

The first definition found in the literature, a starting point in the conceptualization of NBTFs, is described by Cooper (1971: 3): "a firm that emphasizes research and development or that places major emphasis on exploiting new technical knowledge".

A few years later, the Arthur D. Little Group (1977) associated NTBFs with independently-owned businesses established for not more than 25 years and based on the exploitation of an invention or technological innovation implying substantial technological risks. Later, Shearman and Burrell (1988) referenced the term as "new independent firms which are developing new industries" (Storey and Tether, 1998a: 934), whereas Butchart (1987) identified NTBFs as small and medium-sized firms operating in high technology sectors.

Such early definitions of NTBFs reflect the difficulty in its conceptualization. Indeed, performing a review of the studies on NTBFs spanning 16 countries in Europe, Storey and Tether (1998a) confirm that those studies were based on high-tech SMEs rather than 'NTBFs', and in technology-intensive sectors instead of new and emerging industries.

According to the same authors, those studies revealed other weaknesses, including the fact that they embraced both younger and older firms, without providing any information about the independently-owned status of firms.

The use of distinct definitions continues nowadays, with researchers adjusting the concept to the aim of their study or the sample under observation. Specifically, Laranja and Fontes (1998) and Fontes and Coombs (2001) explicitly devise NTBF definitions for the purpose of their studies, with the latter study defining NTBFs, in the context of less advanced countries, as "young independent firms involved in the development and/or diffusion of new technologies" (Fontes and Coombs, 2001: 83). This understanding about the NTBF phenomenon in less advanced countries breaks the direct linkage between new technologies and new industries and proposes an important role for NTBFs as key actors in the diffusion of technological knowledge developed in more advanced economies (Laranja and Fontes, 1998; Fontes and Coombs, 2001).

In sum, although NTBF is a common term in the economic literature and despite the considerable research produced since the 1960s, its definition remains unclear and its application strongly differs among authors, time and space (Autio, 1997a; Bollinger et al, 1983; Storey and Tether, 1998a; Laranja and Fontes, 1998; Fontes and Coombs, 2001). This lack of consensus in the conceptualization of NTBFs prevents adequate empirical application and thus a fruitful comparison of studies in time and space.

This is the motivation and the challenge underlying the present paper. Firstly, the existing definitions of NTBFs are reviewed and systematized, with a view to identifying the key elements that could sustain a new or broader/revised definition. Then, the definition proposed is applied to a set of firms, small and high-tech firms, the so-called ‘Academic Spin-Offs’ (ASOs), trying to assess the extent to which this group of firms might or not be categorized as NTBFs. More specifically, which are the criteria that academic spin-offs have to comply with or not so as to be categorized as NTBFs.

The study is structured as follows. In Section 2, an overview of the relevant literature on the concept of NBTFs is presented, and a new/revised concept is put forward, which includes the main characteristics of NTBFs identified in the literature. Section 3 details the methodological considerations, namely the proxies for the criteria of NTBFs classification applying a bibliometric exercise. The main results of the empirical analysis are discussed in Section 4.

Finally, in Conclusions, the main contributions and limitations of the work, as well as suggestions for additional research on NBTFs, are put forward.

2. Towards a definition of NBTFs: a qualitative and quantitative review of the literature

2.1. The vagueness associated with the concept of NTBFs

The sustainability of economic growth is important to each individual economy and this is the main issue in the literature that discusses the importance of NTBFs (Cooper 1971; Rothwell, 1989; Autio, 1997a; Storey and Tether 1998a; Hogan and Hutson, 2005; Grinstein and Goldman, 2006; Robb and Coleman, 2010). As Freeman (1993: 11) highlights, "economic growth is not merely accompanied by fast growing new industries and the expansion of such industries; it primarily depends on that expansion". According to this understanding, the achievement and maintenance of sustainable rates of growth is directly linked to the capacity of firms and other national actors to innovate and develop new technologies, new products and new industries (Rickne and Jacobsson, 1999; Buganza et al., 2010), assuming that technological change is an important key factor in the explanation of economic growth (Teixeira, 2012).

The issue here is that when we refer to "New Technology-Based Firms", we do no often know exactly what is meant (Autio, 1997a; Storey and Tether 1998a). Frequently, a variety of different concepts are used when analyzing new or small firms with strong technological focus (Rickne and Jacobsson, 1999), for example, new technology-based firms (Autio, 1997a; Laranja and Fontes, 1998; Fontes and Coombs, 2001), small and medium technology-based firms (Mason and Harrison, 1994; Dahlstrand, 1999), small technology-based firms (Meyer and Roberts, 1986; Forrest, 1990; Klofsten and Jones-Evans, 1996), small technology-intensive firms (Keeble et al., 1998), or high technology SMEs (Oakey, 1991).

The different concepts used in the literature induce confusion, denoting the absence of an integrated and coherent theoretical framework. This implies that when analyzing conclusions from different studies, generalizations are practically impossible, as the samples studied are not directly comparable (Storey and Tether, 1998a).

Another observed fact is that many authors adjust the concept of NTBFs to the sample in analysis (Storey and Tether, 1998a; Laranja and Fontes, 1998; Fontes and Coombs, 1996, 2001; Rickne and Jacobsson, 1999).

In reviewing the literature on the concept of NTBFs, it was possible to confirm little cross-referencing, indicating that none of the definitions proposed succeeded in being commonly accepted by other researchers.

Despite the lack of consensus on the concept of NTBFs, there has been significant evolution over the last 50 years, with the emergence of increasingly complex definitions.

One first important commonality in all the surveyed studies (cf. Table 1) refers to the importance of technology in this type of firms (Cooper, 1971; Little, 1977; Autio, 1994; Fontes and Coombs, 1996, 2001; Laranja and Fontes, 1998; Chamanski and Waag, 2001; Candi and Saemundsson, 2008), or the exploitation of new technical knowledge (Cooper, 1971; Little, 1977). In their empirical studies on NTBFs, Autio (1994) and Fontes and Coombs (2001) confirm the association of this type of firms to the development and exploitation of advanced technological knowledge.

It is important to note that the term 'new' may have distinct interpretations (see Table 1). Some authors apply the term to *technology newness* (Fontes and Coombs, 1996, 2001), or simply adjust it to the *youth of the firm* (Rickne and Jacobsson, 1999). Cooper (1971), in his conceptual proposal, suggests the *newness of the technical exploitation*, whereas Little (1977) clearly refers to the *youth of the firm*. This potential duality of interpretations is clearly posited by Delaney (1993: 206), who suggests that "new technologies may be expected to be brought to the market through new firms". Autio (2000), confirming the ambiguity of the concept, adopts and suggests an alternative term, 'new technology-based firm' (NTBF), in an attempt to clarify this point (Hogan and Hutson, 2006).

A large part of the studies (cf. Table 1) use the term 'new' to simultaneously denote *youth of the firm* and *technological newness*. However, when analyzing some conceptual proposals in greater depth, an additional meaning arises for ‘new’ in NTFBs - the emergence of ‘new industries’ (Shearman and Burrell, 1988). Thus, the conceptualization of NTBFs may include not just the *newness of the firm* and the *technology* but also of the *industry*.

Table 1: NTBFs definitions

Studies	Definitions	Key dimensions of the definition			
Cooper (1971)	Firm that emphasizes research and development or that places major emphasis on exploiting new technical knowledge.				
Autio (1994)	Business idea of the firm is essentially based on exploiting advanced technological knowledge developed or acquired in a source of technology.			Technology intensive	
Little (1977)	Independently-owned business established for not more than 25 years and based on the exploitation of an invention or technological innovation which implies substantial technological risks.	New knowledge	Independent		
Bollinger et al (1983)	New and independent firm associated with a small group of founders highly motivated to explore a technically innovative idea.				
Fontes and Coombs (1996, 2001)	New/young and independent firms involved in the development and/or application of new technologies.				
Shearman and Burrell (1988)	New independent firms which are developing new industries.		Independent		
Coeurderoy and Murray (2008)	New and independent high-tech firms formed within the last 10 years.				
Candi and Saemundsson (2008)	New independent firms that develop new products and services based on the technical knowledge of their founders.				
Chamanski and Waag (2001)	New firms developing and serving knowledge- and technology-intensive products or services.	New firm		Technology intensive	
Candi and Saemundsson (2011)	New business entities that develop new offerings based on the knowledge and skills embodied in engineering and the natural sciences.				
Maine et al. (2010)	Young and initially small firms operating in research and development (R&D) intensive sectors.				Small
Klofsten (1994)	Competitive edge derives from engineering know-how of people who work in the firm and its subsequent transformation into products or services for a market.				
Rickne and Jacobsson (1996, 1999)	Firm whose strength and competitive edge derives from the know-how within natural science, engineering or medicine of the people that work in the firm and its subsequent transformation into products or services for a market.				
Butchart (1987)	Small and medium-sized firms operating in high technology sectors.				Small
Oakey et al. (1988)	Small firms with a higher inherent innovative potential than large firms and small firms in general.				

The interpretation of *newness* encompasses different perspectives and constitutes an important discussion on the development of NTBFs in less advanced *versus* technologically advanced economies (Fontes and Coombs, 1996, 2001; Laranja and Fontes, 1998), breaking the 'traditional' association of NTBFs with the introduction of new technologies and new industries, becoming thus more related to technological acquisition, transformation and diffusion. The association between new technologies and new industries has been inflated in Europe and even in the USA (Oakey, 1994), being this linkage restricted in geography, sectors and time-specific contexts.

Another key characteristic of NTBFs (cf. Table 1) is the *independence* of the firm. Accordingly, in a NTBF the capital must be mainly owned by the entrepreneurial team (Little, 1977; Shearman and Burrell, 1988; Fontes and Coombs, 1996, 2001). This characteristic has its source in the seminal work of Roberts and Weiner (1966), in their study on the spin-offs in Route 128, clearly identifying a small nucleus of people as NTBFs founders, and proving that the firm was totally independent, in that it was not a part (or subsidiary) of a large firm (Bollinger et al., 1983). In this sense, to be independent means that the majority of the social capital of these firms still belongs to the entrepreneurial team (Rickne and Jacobsson, 1999).

It is also possible to identify the association of NFBFs with their size. Some authors, such as Butchart (1987), Oakey et al. (1988) and, more recently, Maine et al. (2010), clearly define NTBFs as small firms.

In sum, four central aspects are to be considered when defining NTBFs: technology newness and new industry emergence, age of the firm, size of the firm, and finally independence.

Adopting more encompassing definitions, some authors identified characteristics related to the high level of education and know-how associated with NTBF founders. Laranja and Fontes (1998: 1026) specifically mention "a small venture team with a strong educational background in science and engineering", and Rickne and Jacobsson (1999: 203) assume that the "NTBFs competitive edge derives from the know-how within natural science, engineering or medicine of the people who work in the firm". Indeed, some recent empirical studies emphasise this aspect, arguing that specific human capital is more important for the performance of NTBFs in relation to other aspects, and that the performance of a NTBF can improve through the combination of heterogeneous yet complementary skills (Colombo et al., 2004; Colombo and Grilli, 2005b; Ganotakis, 2010).

This initial overview of the concept of NTBF confirmed the difficulty of a unique and universal interpretation, and further indicated that the construction of the concept encompasses different dimensions. In order to get a clearer and quantitative view on this issue, a bibliographic exercise was conducted, which is detailed in the next section.

2.2. A quantitative/bibliometric account of the concept of NTBF

A quantitative review was conducted on the characteristics of NTBFs, supported by the search and gathering of related papers published in economic journals. The search was based on the bibliographic database SciVerse Scopus (from Elsevier), restricted to the subject area of 'Social Sciences and Humanities'.[1]

The selection criterion was the expression 'New technology-based firms' in the fields 'Article title, abstract, keywords' and with no restrictions in terms of data range, for articles or reviews. This search resulted in a set of 134 papers, 118 articles and 16 reviews, over a period of 30 years (from 1981 to 2011). After reviewing the selected articles, 25 records only provided an abstract without public access to the paper. In addition, 34 articles did not propose a NTBF definition or the description of its fundamental characteristics. We thus excluded these articles from the analysis. In the end, 75 articles comprised the basis of our analysis (Figure 1).

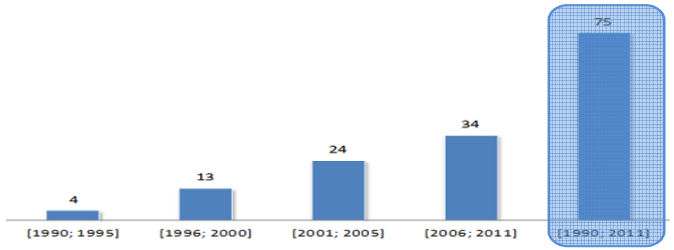

Figure 1: Number of articles analyzed on the definition of NTBFs, 1990-2011

By comparing the number of analyzed NTBFs papers with all the papers gathered from Scopus, over the same time period, and based on the search keyword ‘innovation’, we found that NTBF studies rose significantly in the period from 1996 to 2000. In fact, whilst total publications on the general subject of ‘innovation’ increased by 191%, publications

[1] SCOPUS is considered to be the largest abstract and citation electronic database of peer-reviewed literature and quality web resources. It contains nearly 19.500 titles from 5.000 publishers worldwide. (Source: http://www.info.sciverse.com/scopus/about, accessed on 10 September 2011).

concerning NBTFs increased by 225%. However, since 2001, this research topic lost momentum when compared with total records on 'innovation' (see Table 2).

Table 2: Evolution of the bibliographic database of SciVerse Scopus Publications

Periods	NTBFs (*)	Average Growth	Innovation	Average Growth
1990-1995	4	-	2.275	-
1996-2000	13	225%	6.610	191%
2001-2005	24	85%	10.953	66%
2006-2011	34	42%	20.214	85%
All_Periods	75	-	40.052	-

(*) We consider NTBF publications until 30_Sep_2011.

The bibliometric exercise served to assess the relevance of five key dimensions over time and for the whole period considered, which, according to the literature surveyed (Section 2.1), are directly associated with NTBF definitions: 1) technology newness and industry emergence; 2) youth of the firm; 3) size of the firm; 4) independence of the firm; and 5) founding team's capabilities.

1) Technology newness and industry emergence

Several definitions of NTBFs focus on the "exploitation of new technical knowledge" (Cooper, 1971: 5), or "exploiting advanced technological knowledge" (Autio and Yli-Renko, 1998a: 975), or mention the "development and/or diffusion of new technologies" (Fontes and Coombs, 1995: 499; 2001: 83). Thus, one might argue that the dynamics of NTBFs are directly linked to technology. Nevertheless, there is a problem as to how to define 'technology-based' firms.

Generally, authors define a technology-based firm as a firm that depends on technology to survive and grow. This perspective, however, does not mean that the technology has to be new (Dahlstrand, 2007); the key factor is that the firm depends on technology.

Some authors have employed the concept 'high-technology' in order to reflect technological newness. The operationalization of the concept, following Butchard's proposal (1987), involves measures of resource inputs to high technology, like investment in Research and Development (R&D) and proportion of employees in R&D (Löfsten and Lindelöf, 2001, 2003, 2005a, 2005b; Lindelöf and Löfsten, 2002, 2004, 2006; Aaboen et al., 2006; Ganotakis and Love, 2011).

The most frequent indicator of high-tech is based on the OECD classification (cf. Table 3). Accordingly, industries are classified as high-tech when the R&D intensity ratio (R&D expenditures by value-added, turn-over or sales) is above 5% (Godin, 2004).

Table 3: OECD taxonomical categories

CATEGORIES	R&D intensity (R&D expenditures/value added)
Low-tech industries	0 to 0.9%
Medium low-tech industries	0.9% to 3%
Medium high-tech industries	3% to 5%
High-tech industries	More than 5%

Source: Smith (2005).

An analysis of the articles confirms a growing association between NTBFs and 'high-tech' sectors. Although some authors consider the classification of sectors into 'high' and 'low' tech simplistic, because they fail to capture the dynamics of innovation which are relevant in sectors other than 'high tech' (Laestadius, 1998; Dahlstrand and Jacobsson, 2003), this association to NTBFs gained relevance throughout the 2000s, with almost three quarters of the papers published in this period mentioning this as a key identifying dimension of NTBFs.

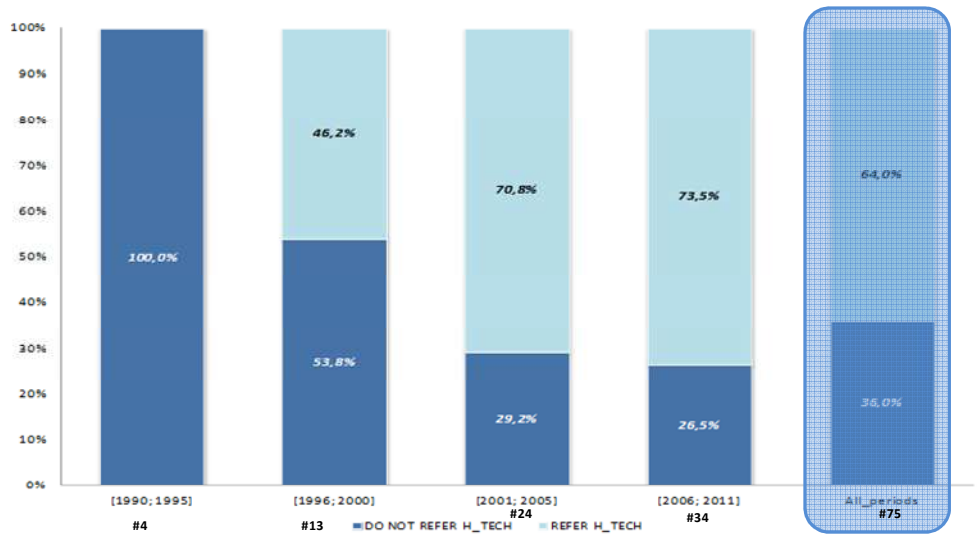

Figure 2: Distribution (%) of articles by the 'high-tech' criterion, 1990-2011

As observed in Figure 2, 'high-tech' is increasingly used as a criterion for characterizing NTBFs. In the period 1990-1995, no article expressly associated NTBFs to high-tech intensity, whereas in the 2006-2011 period this association represents 73.5% of the analyzed papers.

Another operationalization of the 'technology-based' characteristic of NTBFs is the definition by sector, materialized by aggregating the samples into manufacturing and/or services.

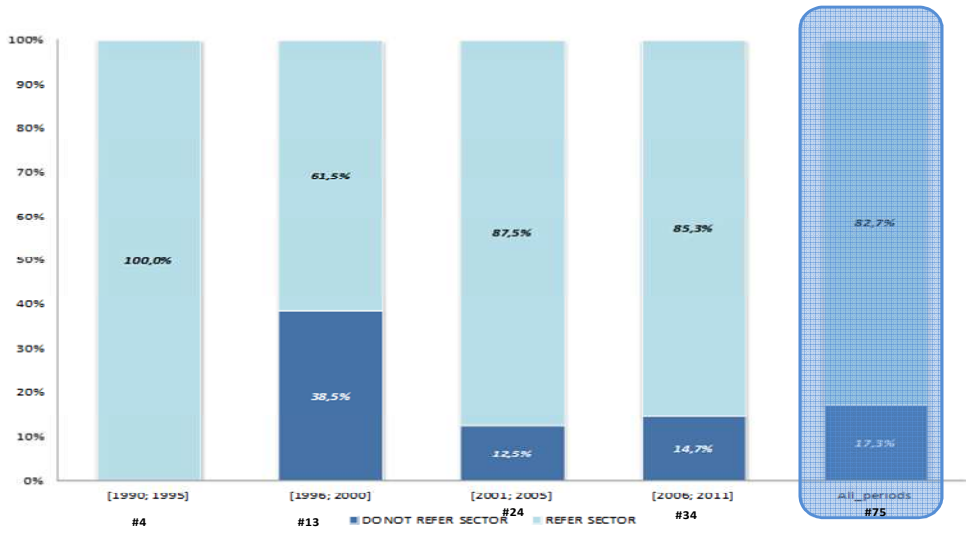

Figure 3: Distribution (%) of articles by the 'Sector definition' criterion, 1990-2011

Excluding the initial period which encompasses only 4 papers, in the subsequent periods the percentage of articles that associate NTBFs to a sectoral categorization of activities is quite high, observing a quite stable figure (around 85%).

Analyzing Figures 2 and 3, we can argue that the 'high-tech' criterion is linked to the 'sector categorization'. The analysis confirmed that period after period several articles relate and link these two dimensions for the study and selection of NTBF samples.

The first exercise, concerning sector identification, comprised the analysis of the number of publications that identified manufacturing or services (cf. Table 4). Overall, 'manufacturing' and 'services' yielded 56 and 47 publications, respectively.

Table 4: Evolution in terms of manufacturing and services identification

Sector Identification	[1990; 1995]	[1996; 2000]	[2001; 2005]	[2006; 2011]	All Periods
Manufacturing	4	8	19	25	56
Services	0	6	17	24	47

Then, the authors' choices in terms of sector criterion were identified and systematized, quantifying those articles that focus on economic activities in manufacturing and services (cf. Figures 4 and 5).

Some authors, such as Shearman and Burrell (1988), relate NTBFs with new industries. This relation seems too simplistic, to the extent that it can only be used for emerging industries (like the medical laser industry) but it does not consider new firms operating in consolidated industries.

Analyzing this particular matter, our bibliometric review confirms that authors identify a wide range of sectors normally considered as 'high-tech' (and 'medium high-tech'), like 'Pharmaceuticals', 'Aerospace', 'ICT' industries',[2] 'Electrical Machinery and Apparatus', 'Robotics and Process Automation', and 'Chemistry'.

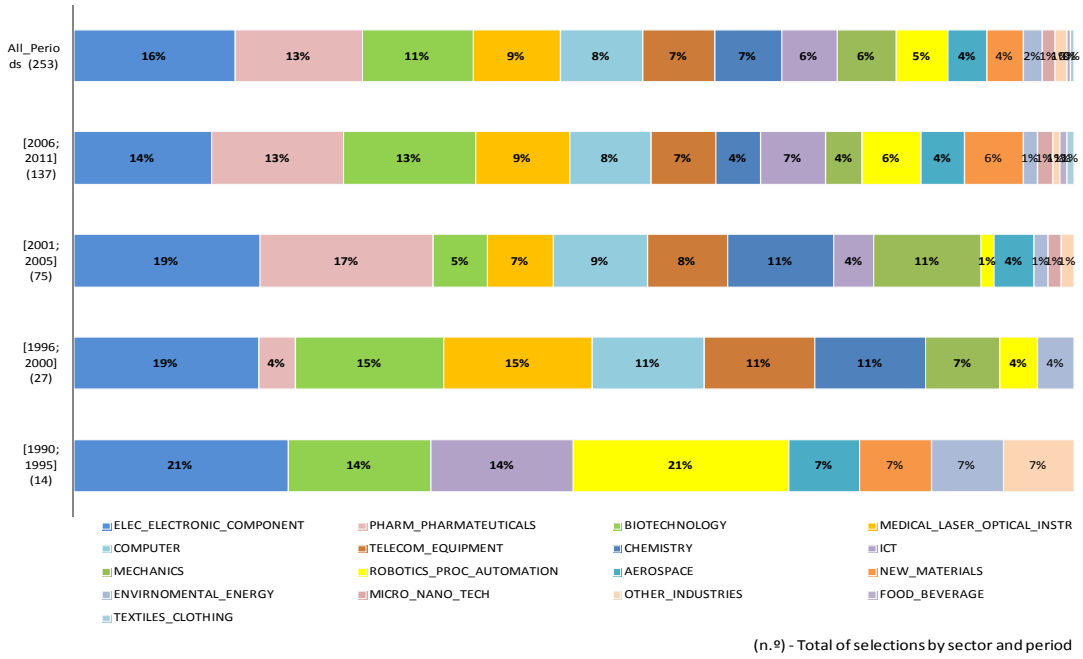

Figure 4: Distribution (%) of articles by manufacturing sectors, 1990-2011

Over the analyzed periods, the manufacturing sectors can be aggregated into two distinct groups. The first group gathers the most frequently identified industries for the overall period, 1990-2011, like 'Electric and Electronics', 'Pharmaceutical and Biotechnology', 'Medical and Optical instrumentation', 'Computer' or 'Telecommunications'. This group seems to be the most consensual in the NTBF studies, in the last fifteen years, although their weight is decreasing. Specifically, the 'Electric and Electronic Components' sector corresponded to 19% in 1996-2000 and to 14%, in 2006-2011, being considered in 41 studies over total period. 'Biotechnology' encompassed 15% in the 1996-2000 period and dropped to 13% in the last period of analysis, being associated globally with 28 studies.

The 'Pharmacology and Pharmaceutical', 'Medical, laser and optical instruments', 'Computer', and 'Telecommunications equipments' sectors present stable figures all round, 13%, 9%, 8% and 7%, respectively.

[2] The ICT classification includes a large number of economic activities, according to the Frascatti Manual (2002), which describes a list of industries both in manufacturing and related services belonging to the Information and Communication Technology Sector in ISIC Rev.3: for example, computer, electronic components, telecommunications equipment, optical, medical and electronic instruments.

Our bibliometric exercise served to identify a second group of NTBFs associated with more recent industries, such as 'Micro and Nanotechnologies', and 'Environment and Energy'. However, in the last period of analysis, some authors also associate NTBFs with firms that introduce new technologies in less high-tech sectors such as 'Textiles and Clothing' or 'Food and Beverages'.

Hence, the industries' distribution over the analyzed periods confirms that NTBFs are important not only for the introduction of new technologies and new industries but also for technological acquisition, transformation and diffusion, in the sense that authors identify NTBFs not only in 'new' sectors but also in 'old' sectors, confirming several conclusions from the relevant literature (Fontes and Coombs, 1995, 2001; Laranja and Fontes, 1998).

It is interesting to note that during the five-year periods in analysis, the number of sectors identified as being associated with the NBTF label increased continually. In the 1990-1996 period, NTBF samples associated with 8 different sectors were identified, whereas in the 2006-2011 period, 17 distinct sectors were mentioned.

The literature commonly associates NTBFs with firms operating in high-tech sectors, which is in line with Butchard's conceptualization proposed in 1987 (see Table 1), related with both manufacturing and services. In quantitative terms, the analysis of the articles confirms that NTBF samples from high-tech services started to be studied in the 1996-2000 period, whereas NTBFs operating in the 'Internet-based services' and 'Multimedia' sectors gathered greater interest in the 2000s (cf. Figure 5).

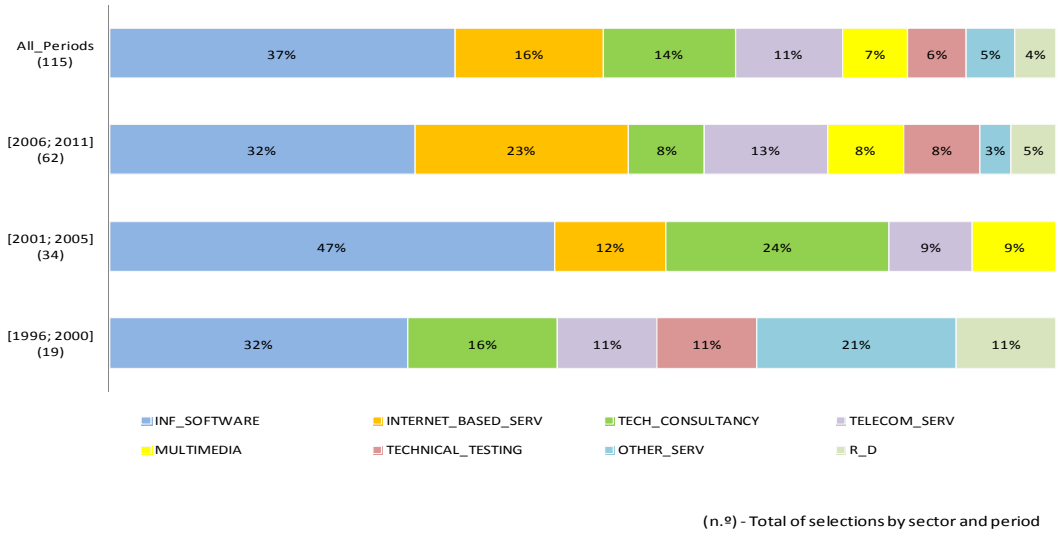

Figure 5: Distribution (%) of articles on NTBFs in services, 1996-2011

Although the analysis reveals ups and downs in the selection of some activities across the periods, 'Information and Software' had a relative weight of 32% in 2006-2011, whereas 'Telecommunications services' reached 13%. Although 'Information and Software' was the most cited sector in the high-tech services (42 studies identified NTBFs operating in this area), 'Internet-based Services' recorded an impressive second position (18 studies overall), with 23% of the total published papers in the 2006-2011 period.

2) Youth of the Firms

A quantitative analysis of our database reveals that the 'Youth of the firms' seems to be the most important dimension in what concerns the operationalization of the NTBF concept.

Indeed, almost all the papers in our database refer to the founding period in their definition of NTBFs. Only twelve papers (of the 75) do not explicitly define the founding period or age of the firm. Nevertheless, although the founding date/age of the firm is the most recurrent dimension in the studies surveyed, the age interval considered in each study differs – see Figure 6.

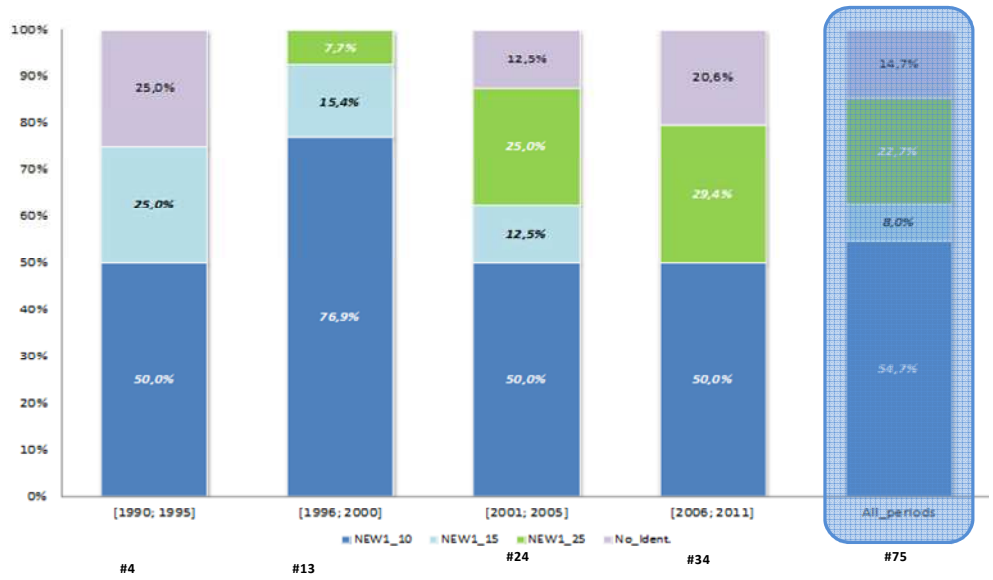

Figure 6: Distribution (%) of articles by 'firms' newness' criterion, 1990-2011

Three distinct options in terms of time intervals for NTBF age were identified: 'one to ten', 'one to fifteen' and 'one to twenty-five' years.

The analysis of the articles reveals that 41 papers define NTBFs based on a 'one to ten' year period.[3] For the total period in study (1990 to 2011), 54.7% of the total papers define NTBFs

[3] The database categorization was particularly difficult for this criterion. In the analyzed articles, NTBF samples were obtained from specific databases or from particular case studies, covering distinct founding dates. We

based on this particular time span (cf. Figure 6). Despite this general conclusion, the evolution is not regular, registering a peak in the 1996-2000 period, when it accounted for 76.9% of the papers employing this characteristic with reference to that period. The 'one to ten' year time interval lost some importance from the 1990s to 2000s.

The only argument sustaining the choice of the 'one to ten' year period is explicitly referred to by Yli-Renko et al. (2001: 539), who argue that "the ten year upper limit is consistent with previous research on entrepreneurial firms (e.g., Covin and Slevin, 1990; Ostgaard and Birley, 1994)".

Our bibliometric analysis also confirms that some authors associate the NTBF concept with the definition of start-up (Lynskey, 2004; Colombo and Grilli, 2005a; Aspelung et al., 2005; Fukugawa, 2006; Colombo et al., 2010; West and Noel, 2009; Gao et al., 2010; Piva et al., 2011). But once more, the definition of start-up seems to differ across authors. Despite some vagueness that still remains, the term start-up is usually associated with a business at an initial stage of life. Almeida et al. (2003, in Teixeira and Tavares-Lehmann, 2007) and Oliveira and Teixeira (2011) associate this initial stage to a firm with 10 years or less.

Although the 'one to ten' year span gathers the authors' preferences globally, it is important to highlight that the 'newness' criterion encompasses distinct time approaches, as noted previously.

It is possible to identify a second group of studies (e.g., Hogan and Hutson, 2005, 2006; Colombo et al., 2006; Colombo and Grilli, 2005a, 2005b, 2006, 2007, 2010; Bertoni et al., 2010, Bertoni et al., 2010, Bertoni et al. 2011; Ganotakis and Love, 2011) that base their definition on Little's proposal (1977), which defines a "NTBF as a business established for not more than 25 years" (Lindelöf and Löfsten, 2002: 145). This option seems to be increasingly chosen by researchers: the associated weight increased almost four times from the 1996-2000 period to 2006-2011, from 7.7% to 29.4%. On the whole, this time interval was used in 22.7% of the total articles.

The studies based on the RITA (Research on Entrepreneurship in Advanced Technologies) database, developed at the *Politecnico di Milano*, includes firms established in the 1980s and 1990s.

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decided to systematize the firm's age into 'one to ten', 'one to fifteen' and 'one to twenty-five' years (following Little's proposal), in terms of mean or absolute values.

Finally, a third category of papers was identified which focus on the NTBFs defined according to the 'one to fifteen' year criterion (see Figure 6). Fontes and Coombs (1995, 2001) use this criterion, as well as by Pfirrmann (1999: 652), who mention that "the survey comprised firms which were no older than 15 years", and Aspelund et al. (2005). In the early 1990s, there seems to have been some interest in the ‘one to fifteen’ option, but it lost importance in the following two periods, in 1996-2000 and 2001-2005, decreasing to 15.4% and 12.5%, respectively. In the last period, no reference to this 'New 1_15' was found. For the whole period, this time interval was used in 8% of the articles, representing 6 items.

Summing up, although Little's proposal has obtained increasing attention from authors, being the only definition that clearly defines the age criterion, the bibliometric analysis highlights that the 'one to ten' year period is the most frequently employed basis for firm age, meaning that NTBFs are mostly considered ‘start-ups’.

3) Size of the firms

NTBFs are often defined as small and medium firms (Butchart, 1987; Oakey et al., 1988) or initially small firms (Maine et al., 2010), linking two important aspects - youth and smallness. Storey and Tether (1998b: 1057) clearly assume NTBFs as "new and small technology-based firms".

We consider the European Commission (EC) (2003) categorization which encompasses micro, small and medium-sized enterprises, comprising firms that employ fewer than 250 workers. Within this SME category, a small firm employs fewer than 50 people and a medium one employs (more than 50 but) fewer than 250 people.

Around forty papers (54.7% of the total) refer to the size of the NTBFs, measured by the number of employees (cf. Figure 7).

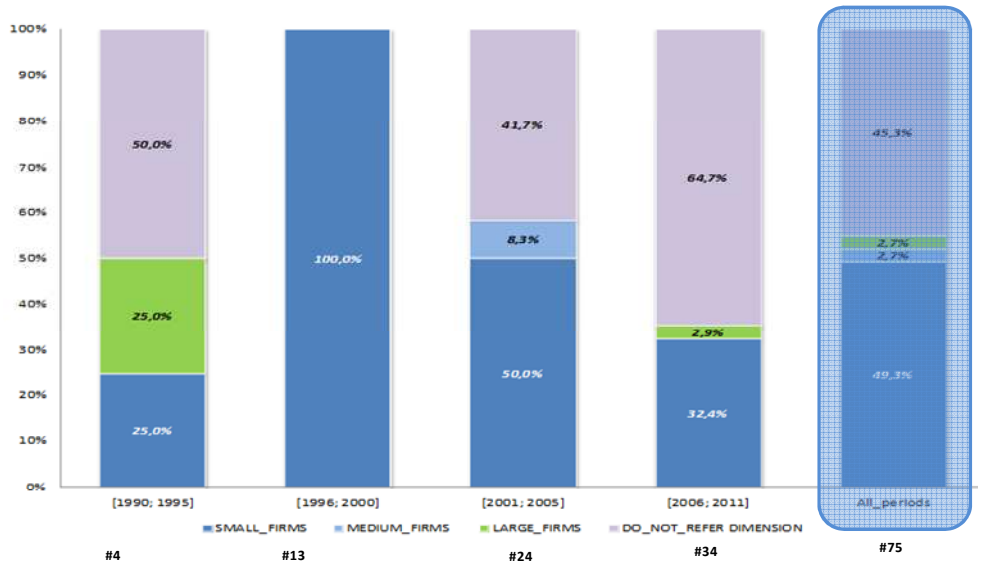

Figure 7: Distribution (%) of articles by size (number of employees), 1990-2011

The existing empirical studies comprise samples of firms that are mostly small (37), representing 49.3% of the total, and about 90% of the studies mention firm size; only two studies mention 'medium' firms and another two studies 'large' firms.

In dynamic terms, there was a relative tendency to neglect the size dimension – the weight of the studies that do not use this particular dimension increased drastically over time, from 0% in the 1996-2000 period, to 64.7% in the most recent period.

Size can also be operationalized by total annual turnover (EC, 2003). According to the EC (2003), the category of micro, small and medium-sized firms (SMEs) is composed of firms which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.

Only a marginal fraction of the records on NTBFs considers size in terms of turnover - such a dimension is present in only 7 studies (Autio, 1997b; Autio and Yli-Renko 1998a, 1998b; Autio and Lumme, 1998; Kollmer and Dowling, 2004; Hogan and Hutson, 2005 and Maine et al., 2010), representing 9.3% of the total (cf. Figure 8).

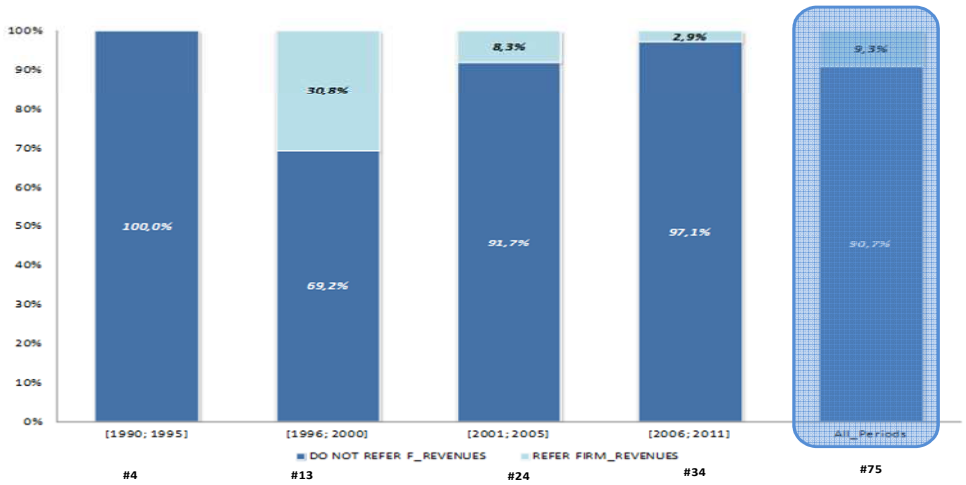

Figure 8: Distribution (%) by size (turnover), 1990-2011

4) Independence of the firm

Another matter the authors pay particular attention to in the sample identification concerning NBTFs is the independence of the firm. Little (1977) explicitly identified this characteristic when he proposed the definition of NTBF.

The Bolton Committee (1971) defined a (small) firm as an independent socio-economic unit in the sense "that it does not form part of a larger enterprise and owner-managers are free from outside control in taking their principal decisions" (Stanworth and Curran, 1976: 96).

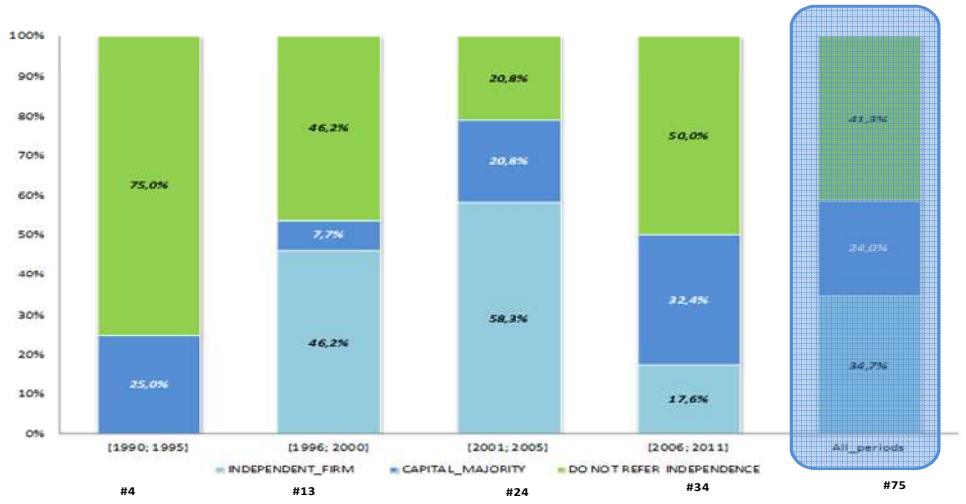

Figure 9: Distribution (%) by Independence criterion, 1990-2011

Following Little's definition (1977) of NTBF as an independently-owned business, it is critical to guarantee that they do not belong to a larger enterprise.

The independence criterion emerges as a fundamental dimension in 44 of the 75 records in our database. Following the literature in the area, this dimension was measured in two ways:

1) independence as a single branch, which does not belong to a group or is not a subsidiary of multinational or larger firms (e.g., Autio and Lumme, 1998; Almus and Nerlinger, 1999; Lindelöf and Löfsten, 2003; Dettwiler et al., 2006; Fukugawa, 2006; Coeurderoy and Murray, 2008), and

2) the majority of the capital structure belongs to the founding team (e.g., Fontes and Coombs, 1995, 2001; Igel and Islam, 2001; Colombo and Piva, 2008; Colombo et al., 2010; Brinckmann et al., 2011; Ganotakis and Love, 2011).

It is important to note that some difficulties are observed when measuring this dimension since, although independence might be guaranteed at the date of establishment, it is difficult to ensure that the same remains true by the end of the observation period (Fontes and Coombs, 1995, 2001; Laranja and Fontes, 1998).

Our bibliometric exercise confirms the association of the NTBFs' independence criterion with distinct groups of firms. Studies which include samples from Finland, Sweden or Germany, choose the single branch dimension, whereas Italian or Portuguese samples are associated with Little's proposal.

Figure 9 shows that the independence criterion associated with the single branch condition gathers 34.7% of total articles, although the relevance of this categorization changes over the period considered: 46.2 % in the initial period (1996-2000) down to 17.6% in the last period (2006-2011). In contrast, the criterion for independence, focused on capital majority, observes an increasing trend, with 7.7% in the 1996-2000 period, and 32.4% in 2006-2011.

5) Founders characteristics

Many authors sustain that perhaps more important than technological knowledge for the success of NTBF businesses, are their capabilities and human capital (Löfsten and Lindelöf, 2001; Colombo and Delmastro, 2002; Oakey, 2003; Coster and Butler, 2005; Roskos and Klandt, 2007; Brinckmann et al. 2011), particularly, the knowledge and experience that enable firms to adapt successfully to changes in technology and markets (Colombo and Grilli, 2006, 2010; Ganotakis, 2010; Taheri and Geenhuizen, 2011).

The human perspective encompasses different dimensions and may include endowed abilities, experience, trained skills, attitudes and behaviors (Davenport, 1999), or highlight new features such as individual motivation, ambition and leadership (Mayo, 2001; O'Regan and Ghobadian, 2006).

Several studies (e.g., Colombo and Grilli, 2005b; Bianchi et al., 2011; Brinckmann et al., 2011) emphasize the characteristics related to a high level of education and know-how associated with NTBFs founders. In this perspective, firms are bundles of unique, difficult-to-imitate capabilities that are the main source of their sustainable competitive advantages (Grant, 1996). These distinctive capabilities of NTBFs are closely linked to the knowledge and skills of their founders, and thus to their human capital endowments (e.g., Colombo and Grilli, 2010; Ganotakis, 2010; Taheri and Geenhuizen, 2011).

In terms of the operationalization of the NTBF concept, we confirmed that although many authors reinforce and study the linkage between the technological base of the firm and the scientific background of its founders (e.g., Donckels and Segers, 1990; Pfirmann, 1999 and Igel and Islam, 2001), human capital traits and capabilities of NTBF founders are seldom incorporated in the proposed definitions (cf. Figure 10).

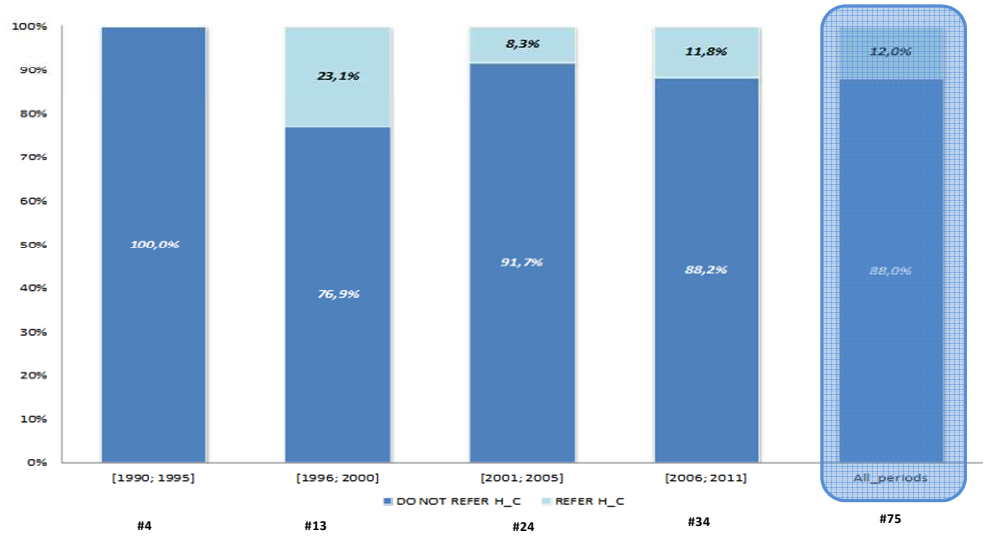

Figure 10: Distribution (%) of articles referring to the human capital dimension, 1990-2011

Only 9 papers (12% of the total) in our database incorporate this specific dimension in the NTBF definition.

Although a large number of studies have indeed documented that skilled human capital is a *sine qua non* condition for NTBF creation (Baptista and Mendonça, 2010; Piva et al., 2011), the inclusion of the human dimension in the NTBF definition is scarce.

∴

A large number of NTBF definitions exist and are not consensual on which dimensions should be included. Based on the NTBF literature review and on the bibliometric analysis, we confirm the specificity of the concept of NTBF and the difficulty in its operationalization.

According to the bibliometric exercise undertaken, the criteria associated with the concept of NTBF are the following:

1) Technology newness and industry emergence operationalized in terms of sector definition and high-tech measures;
2) Youth of the firm defined in terms of newness of NTBFs (mean age of the firms);
3) Size of the firm in terms of number of employees and sales;
4) Independence of the firm reflected by the fact that the majority of capital belongs to the NTBF teams;
5) Human capital of the founding team.

Within this list, as Table 5 shows, the most frequently used criteria in empirical studies in the area are 'newness', 'sector' definition and 'high-tech' association, each recording relative values above 70% in the 2000s.

Table 5: Different dimensions of the NTBF conceptualization – Systematization by number (and %) of articles

NTBFs Dimensions	[1996; 2000]	*%*	[2001; 2005]	%	[2006; 2011]	%	All Periods (number of articles)
Newness	13	***100%***	21	***87,5%***	27	***79,4%***	64
Sector	8	***61,5%***	21	***87,5%***	29	***85,3%***	62
High-Tech	6	***46,3%***	17	***70,8%***	25	***73,5%***	48
Independence	7	***53,9%***	19	***79,2%***	17	***50,0%***	44
Size Employees	13	***100%***	14	***58,3%***	12	***35,3%***	41
Human Capital	3	***23,1%***	2	***8,3%***	4	***11,8%***	9
Size Sales	4	***30,8%***	2	***8,3%***	1	***2,9%***	7

Note - % defined by weighting the value obtained in each criterion and the absolute no. of publications.

The bibliometric review also identified a second group of NTBF characteristics, 'independence' and 'size' (measured in terms of number of employees), that had lost relative relevance over the period in analysis.

A third group of characteristics, 'human capital' and 'size', measured in terms of NTBF turnover/sales, reveals low representativeness in the operationalization of the NTBF concept. Concerning this latter group, 'human capital' has been nevertheless gaining some relevance in defining NTBFs in practice, especially in the periods 2001-2005 to 2006-2011.

In Section 4, we assess whether a group of university spin offs can be considered NTBFs according to the criteria found above and establish the main differences between academic

spin-offs classified as NTBFs and non-NTBFs. But first, the next section describes the methodology.

3. Methodological underpinnings

The expression ‘New technology-based firm’ (NTBFs) is commonly used in economics, but it is also supported by different conceptual understandings (Autio, 1997a; Storey and Tether, 1998a), as the analysis presented in Section 2 confirms. The bibliometric exercise undertaken previously allowed us to arrive at a pragmatic concept of NTBFs based on a set of criteria put forward by the studies surveyed.

Based on the set of criteria identified, we classify a group of firms which are likely to be considered as NTBFs: the firms ('academic spin-offs’) located in UPTEC, an incubator and science park of the Universidade do Porto (UP).

The UP manages four different incubation centers (U. Porto Science and Technology Park - UPTEC Incubation Centers), each of them operating in specific economic areas:

1) Sea Incubation Center - UPTEC MAR;
2) Creative Industries Incubation Center - UPTEC PINC;
3) Technological Incubation Center - UPTEC TECH;
4) Biotechnological Incubation Center - UPTEC BIO.

Sixty-six firms constituted the universe of incubated firms at the end of 2010, encompassing a wide diversity of industries and technological fields. This is a suitable set for our exercise. As mentioned earlier, the aim of this paper consists in assessing the extent to which this group of firms might be categorized as NTBFs or not, according to the set of criteria that emerged from the literature review on NTBFs.

For this purpose, we constructed a questionnaire, which was tested with a firm incubated at the UPTEC Centers. The purpose was to evaluate the clarity of the questions and to introduce improvements in the initial proposal. An interview with the founding team served to confirm some problems related with specific questions and to introduce additional questions in order to gather information that would be interesting for our study.

The questionnaire was composed of 4 groups of questions, detailing the main proxies to operationalize the NTBF characteristics.

The first group intended to identify the firm, containing questions regarding year of establishment, social capital structure, founding team and number of employees, activity and

financial data, covering turnover, R&D, exports and patents. All these questions aimed to compare the firm's evolution between the establishment date and the end of 2010, except for the financial data, which compared figures obtained in the first year of sales with the final year (2010).

In order to assess the firm's technological skills, the second group of questions focused on the initial founding team in terms of qualifications and scientific knowledge, and the third group proposed to evaluate the resources brought to the business by each founder and to analyze the impact of professional experience on the team's constitution. The fourth part of the questionnaire aimed at understanding the origin of the technology and knowledge underlying the firm's sustainability.

After the pilot phase, the final questionnaire was sent to 58 firms by email between 15th and 30th June 2011.

The firms were chosen following a prior selection, which excluded projects in a pre-incubation phase (3 projects), associations (2 projects), specific projects to support R&D in partnership (2 projects) and a branch in Portugal of a multinational in the biopharmaceutical research field. During July 2011, the data gathering process entered a final phase and all the firms were contacted again by email and then by phone. At the end of the process, 30 responses were obtained, representing 51.7% of the target population.

The responses were quantitatively analyzed and two groups were created: those categorized as NTBFs and those that were not considered NTBFs. Afterwards, we assessed which were the key factors that distinguished these groups and proceeded with an in-depth study of these two groups of firms.

4. Empirical results

4.1. Discovering NTBFs in practice

The respondent sample comprises 30 firms, founded between 1994 and 2010, with 99 founders at the date of establishment. Analyzing the initial founding team, 92 of the founders are individuals and the other 7 are venture capital societies (3), a university, one R&D institution and firms (2).

By the end of 2010, these firms employed 152 workers, meaning that the firm's average size is around 5 employees. About 89% of the total employees are university graduates.

The respondent sample includes only small firms and, within this particular category, 29 of them are micro firms.[4] Although four firms employ more than 10 people, only one of them obtains simultaneously an annual turnover above EUR 2 Million.

A significant proportion of the respondent firms belong to the 'Information and Software services' sector (33.3%), followed by the 'Environmental technologies and energy' (20.0%), 'Internet-based services' (13.3%) and 'Multimedia' (10.0%) sectors. The 'Biotechnology' and 'Telecommunications services' sectors represent 6.7% each. Finally, sectors such as 'New materials', 'Medical devices and instrumentation', 'R&D' and 'Edition' have residual positions, with 3.3% each. Hence, the UPTEC sample is in line with the information gathered in the bibliometric exercise (Section 2), regarding the activity sector. Indeed, the 'Information and Software services', 'Internet-based services' and 'Multimedia' sectors emerge as prominent. Notwithstanding, the 'Environmental technologies and energy' sector holds a more important position in the UPTEC sample that it did in the bibliometric exercise, and the 'Biotechnology' sector has a less relevant position. Globally, the sample is composed of 10 different sectors.

As mentioned previously, all the firms in our sample are small, with the majority being microenterprises, according with the double criteria proposed by the EC (2003) – see Table 6.

Table 6: Sample classification according to NTBF characteristics

Sample Classification	*Newness [1_10]*	*High-Tech Sector*	*R&D Ratio*	*Independence*	*Size (n.º Employees)*	*Size (Sales)*	*Human Capital_ Dimension*
Criterion	29	29	17	28	30	30	29

Almost all the respondent firms are start-ups (less than 10 years in business) belonging to 'high-tech' sectors/industries.

Taking into account of the 'Independence' criterion excludes two firms from the category of NTBF, whereas the 'Human capital criterion' cuts off one firm from the NTBF classification.

Summing up, we found that the criterion that impacts the most on the final classification of the NTBFs is the 'High-Tech' definition, applying the OECD categories (cf. Table 2).

Taking all the criteria into account, we conclude that only 14 of the 30 firms in the sample could be classified as NTBFs.

[4] According to the EC (2003), a microenterprise is defined as an enterprise which employs less than 10 people and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million.

In what follows, the categorization of the firms as NTBFs is explained and detailed for each criterion: Newness; High-Tech Sector and R&D ratio; Independence; Size (number of employees and sales); Human Capital.

1) Youth of the firm (Newness)

Using the same time reference as in the bibliometric exercise (Chapter 2), we distributed the UPTEC sample using five-year periods (cf. Figure 11).

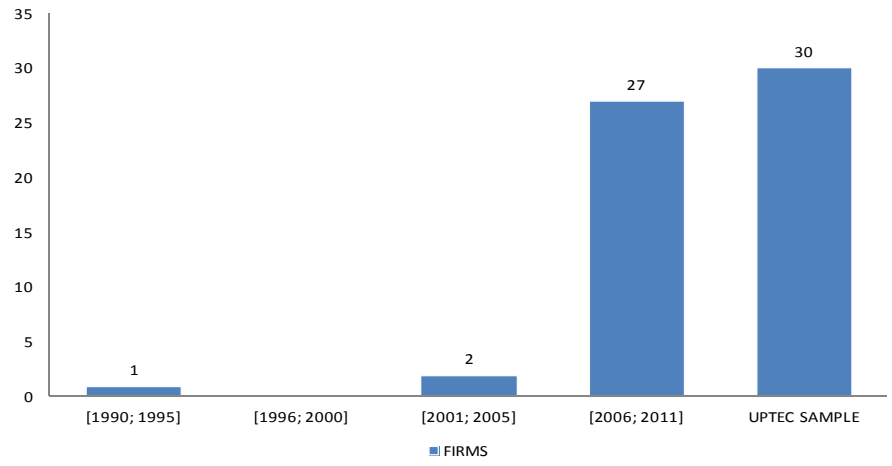

Figure 11: Number of firms by establishment date, 1990-2011

The sample is constituted by start-ups, the majority of which were established in the last five-year period. The firms in the sample are, on average, 3.7 years old.

Hence, the 'Newness' criterion is confirmed in this particular sample.

2) High-Tech Sector and R&D intensity

Our bibliometric review confirmed the difficulty of operationalizing the criterion of technology intensity and also the fact that authors apply similar indicators that fall into two distinct groups, as noted by Monck et al. (1988, in Löfsten and Lindelöf, 2011: 312): "measures of resource inputs to high-technology activity, such as R&D effort, R&D expenditure and employment of qualified personnel and secondly measures of output or performance of high technology firms, such as growth rates, patent records and technological innovations".

12 of the 30 firms in the sample do not have investments in R&D and, in one case R&D expenditures represent less than 5% of sales. Using the OECD taxonomy (cf. Table 2), NTBFs should have a R&D ratio above 5%, that is, they are ‘High-Tech’ in the OECD

nomenclature. 7 of the 18 firms that perform R&D activities present an atypical R&D ratio (well above 100%), as they do not (yet) have sales or record insignificant sales.

Analyzing the sample and their core-business activities, 29 firms are classified as NTBFs when looking at their sector characteristics. Many authors who studied the NTBF concept (e.g., Laestadius, 1998; Dahlstrand and Jacobsson, 2003) find this particular classification too narrow.

3) Size of the firm

NTBFs are often defined as small (Storey and Tether, 1998b), medium-sized firms (Butchart, 1987; Oakey et al., 1988), or initially small firms (Maine et al., 2010).

Although this characteristic has lost relevance over the five-year periods in study, all the firms in the UPTEC sample are small, in terms of both number of employees and sales, being most of them microenterprises.

4) Independence of the firm

Little's NTBF definition was the most referred to in our bibliometric exercise when we analyzed the firms' independence since several authors refer to NTBFs as an independently owned business (Löfsten and Lindelöf, 2001, 2002; Lindelöf and Löfsten, 2002; Hogan and Hutson, 2005, 2006; Aaboen et al., 2006; Colombo et al., 2010 and Ganotakis and Love, 2011). This definition encompasses two dimensions: the group independence and the importance of capital majority.

The Bolton Committee Report (1971) and the Le Cornu et al. (1996) study, both cited in Hogan and Hutson (2005: 372), conclude that "the managerial independence is an important characteristic in small businesses". Under this perspective, "independence was found to be the most important non-financial objective, (...), and critical to understanding the observed capital structure of SMEs".

The sample was then analyzed under these two distinct perspectives and it was found that no firm belongs to a large firm or multinational. In terms of structures of social capital, two companies had partners but with minority participation.

Participations in the capital structure of the firms by venture capital societies were identified in the UPTEC sample. The participations guarantee that companies do not belong to a group or multinational, but do not guarantee the capital majority, because the venture capital investors do have representatives in the firms, confirming that the managerial independence

concept is not fulfilled. In fact, when NTBFs obtain venture capital equity, the founding teams should accept the loss of some control of the business (Minola and Giorgino, 2008). However, since venture capital participations are understood to be temporary, we considered the two firms that were participated by venture capital societies as NTBFs.

5) Human capital

The founders' human capital is recognized as a primary asset for the competitive advantage of a NTBF (Cooper and Bruno, 1977; Colombo and Grilli, 2006, 2010), "as it is believed that only individuals who hold technical qualifications at the highest academic level will be able to form NTBFs, with the ability to exploit leading-edge technologies and therefore introduce radically new and technologically complex, innovative products to a market" (Ganotakis, 2010: 4).

Nevertheless, several authors argue that the technological advantage may not be sufficient to successfully direct products or services to the market; in certain cases, the so-called 'technological myopia' emerges, progressively considered as a critical key to the success of firms (Miller, 2002; Antoniou and Ansoff, 2004). This occurs because the strategic direction of NTBFs must be determined by anticipating the future needs of the environment and markets, not only by identifying technological trends.

Hence, in order to have success in exploiting new business opportunities, complementary context-specific knowledge (e.g., marketing, management, strategy or property rights), that is generally dispersed among different individuals, needs to be combined and integrated (Colombo and Grilli, 2010; Bianchi et al., 2011).

In this line of reasoning, we analyzed the initial teams and identified the elements with strong connections to engineering and science. Although, as noted previously, the technological dimension may not be sufficient, in general, authors agree that it is necessary to exploit leading-edge technologies (Colombo and Delmastro, 2002; Ganotakis, 2010; Piva et al., 2011). Under this criterion definition, 29 firms are considered NTBFs.

4.2. Distinguishing NTBFs from non NTBFs in a sample of academic spin-offs

In the previous section, based on the criteria gathered in the literature review and bibliometric exercise, we classified the academic spin-offs located in UPTEC into two main groups: NTBFs and non NTBFs. At the end of the process, 14 firms were classified as NTBFs and 16 were not.

In the present section, we intend to identify the main characteristics of the two groups.

Given the small sample size, the Kruskal-Wallis nonparametric test was used to examine the differences in mean of a set of relevant variables (e.g., Maroco, 2010).[5]

The incubation phenomenon is recent in the University of Porto and the UPTEC incubation centers exist since February 2007.

As mentioned earlier, the incubated firms are, in general, start-ups. No statistical difference emerged in this regard between the NTBFs (3.4 years in business) and non NTBFs (4.2 years in business) (cf. Table 7).

Regarding the general characteristics of the academic spin-offs located at UPTEC, the only two characteristics that emerged as distinctive (statistically, at 5% significance) is the amount of capital both at the beginning of the business and at the end of 2010. Indeed, the Kruskal Wallis test shows that the NTBF founders invested a substantially higher amount of capital that their non NTBF counterparts – about 4 times higher.

The size of the founding team (about 3 individuals in the beginning and in December 2010) and the size of the firms (almost no employees in the business's starting phase and 5 by December 2010) are similar between the two groups. This is also the case with the number of employees with tertiary (or higher) formal qualifications.

Table 7: General characteristics of the categories of firms

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Age	3,4	4,2	0,898
Capital _Constitution_Date	42.100 €	10.996 €	***0,038***
Capital_Dec_2010	96.824 €	26.179 €	***0,018***
Founding_Team_Constitution_Date	3,5	3,1	0,332
Founding_Team_Dec_2010	3,3	2,9	0,564
Employees_Constitution_Date	0,6	0,8	0,850
Employees_December_2010	4,5	5,7	0,600
Undergraduate_or_Higher_Constitution_Date	0,5	0,7	0,784
Undergraduate_or_Higher_December_2010	4,2	4,9	0,614

[5] Formally the hypotheses under study could be written as (considering the subgroups X1 = NTBFs and X2 = non NTBFs): ***H0***: F(X1) = F(X2) (The Kruskal-Wallis tests if the sample comes from a population with the same distribution) vs. ***H1***: ∃ 1,2 F(X1) ≠ F(X2) (The Kruskal-Wallis tests if the sample comes from a population with a different distribution).

The background and complementarities of the top management team is usually understood as a competitive factor in NTBFs' survival and development (Colombo and Grilli, 2005b, 2010; Bianchi et al. 2011; Brinckmann et al., 2011).

Regarding the founding team's characteristics (Table 8), a set of indicators were gathered - level and type of education in the initial founding teams, and number of years of experience in the specific business sector (Oliveira and Teixeira, 2011). Only in one indicator does the Kruskal Wallis test reveal differences (at 10% significance) between NTBFs and non NTBFs: weight of individuals in the founding team that possess advanced managerial knowledge (44% against 14% in NTBFs and non NTBFs, respectively).

Table 8: Founding team's characteristics

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Majority Founding Team Undergraduate	0,44	0,29	0,397
Majority Founding Team Master Degree	0,19	0,21	0,857
At least One Phd	0,31	0,36	0,799
Majority Founding Team Technological K-How	0,87	0,71	0,280
Multidisciplinary Teams	0,56	0,36	0,269
Management Knowledge	***0,44***	***0,14***	***0,084***
Founding Team Experience	0,88	1,00	0,178
Founding Team Business Experience	0,50	0,71	0,240
Founding Team Experience More 10 Years	0,63	0,86	0,158
Founding Team Business Exp More 10 Years	0,25	0,29	0,828

This result seems to convey the idea that in order to for NTBFs to successfully exploit technology (Berry, 1996; Ganotakis, 2010; Becker (1993) in Taheri and Geenhuizen, 2011), they also need market, long-term strategy and management knowledge (March-Chorda and Yagüe-Perales, 1999).

Educational level and the technological know-how did not emerged as statistically different between NTBFs and non NTBFs.

The literature sustains that NTBFs form strong relations with the economic environment and innovation systems (Dahlstrand, 1997; Autio and Parkahangas, 1998; Druilhe and Garnsey, 2000). They are understood as an organic part of them (Autio, 1997a; Yli-Renko and Autio, 1998), through networking and linkages with universities and research institutions (Reitan, 1997; Malecki, 1981), incubators (Sternberg, 1990; Mian, 1996 Studdard, 2006; Yang et al., 2009; Scillitoe and Chakrabarti, 2010), business angels and venture capital societies (Madill et al., 2005) and large firms (Segers, 1993), in order to respond to the limitations in financial

and organizational assets (Kelley and Nakoesteen, 2005) and to minimize their lack of resources. This perspective means that it is possible to assume that a NTBF can increase its effectiveness by accessing knowledge outside the organization (Kelley and Rice, 2002), brought by personal contacts and networking.

Our results seem to be at odds with the previous reasoning, since contacts (and capital & contacts) emerge as significantly more important for the non NTBF group (with more than half of the founders indicating these reasons) than for the NTBFs (only 13% indicated such reasons for starting or joining the business in its early phase).

Table 9: Reasons to start a business

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Majority Fteam Entering Reasons_Capital	0,81	0,71	0,533
Majority Fteam Entering Reasons_Contacts	***0,13***	***0,57***	***0,011***
Majority Fteam Entering Reasons_Knowledge	0,56	0,64	0,659
Majority Fteam Entering Reasons_Patents	0,00	0,00	1,000
Majority Fteam Entering Reasons_Capital & Contacts	***0,13***	***0,50***	***0,028***
Majority Fteam Entering Reasons Cap.&Contacts&Know	0,13	0,29	0,280

Regarding innovation and technology acquisition traits (cf. Table 10), the statistical results revealed homogeneity in the technological processes of transfer, development and acquisition between NTBFs and non NTBFs.

Table 10: Businesses innovation and technology acquisition traits

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Product	***0,25***	***0,00***	***0,048***
Service	***0,19***	***0,50***	***0,075***
Product_Service	0,56	0,50	0,736
R&D Ratio_1.st Year_Sales	***0,07***	***0,00***	***0,010***
R&D Ratio_2010	***8,17***	***0,04***	***0,000***
Export/Sales Ratio_1.st_Year_Sales	***0,07***	***0,00***	***0,094***
Export/Sales Ratio_2010	***0,18***	***0,02***	***0,012***
Registered_Patents_Constitution_Date	0,00	0,07	0,285
Registered_Patents_2010	0,31	0,21	0,972
Technology Transference_UP_Department	0,38	0,43	0,769
Technology Transference Investigation_Center	0,19	0,14	0,748
Technology Development_Consortium	0,13	0,07	0,631
Technology In-House_Development	0,81	0,71	0,533
Technology Acquisition_Portugal	0,19	0,36	0,303
Technology Acquisition_Importation	0,06	0,29	0,108

In contrast, significant differences emerged in the firms' business type, where NTBFs are much more exclusively product-based firms (25% vs. 0% in the case of non NTBFs) and non NTBFs relatively more service-based (50% vs. 19% in the case of NTBFs).

NTBFs emerged as much more R&D and export intensive than non NTBFs, both at the beginning and in December 2010.

Interestingly, some studies argue (e.g., Coeurderoy and Murray, 2008; Ganotakis and Love, 2011; Taheri and Geenhuizen, 2011) that the international activities of NTBFs have become an additional opportunity to explore a competitive advantage in foreign markets (Sapienza et al., 2006), specially to open economies such as Portugal (Silva et al., 2010; Oliveira and Teixeira, 2011).

5. Conclusions

NTBFs drive profound technological changes, economic growth and competitiveness, and depend "not only on the work of scientists and engineers, but also on a wider range of economic and societal factors" (Teixeira and Lopes, 2012 in Teixeira, 2012: 8).

Although the related literature has revealed awareness of the relevance of NTBFs, it is somewhat diffuse and vague in the sense that it proposes several, alternative definitions of NTBFs, the main purpose of this paper was to clarify and operationalize the concept,

preventing "the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based", Coase (1937: 386).

The bibliometric exercise developed in Section 2 served to study the characteristics of NTBFs in an integrated and systematic manner, since information on a vast set of definitions of NTBFs was collected. Based on 75 articles which put forward distinct definitions for NTBFs, we built a database through which it was possible to define a set of criteria to clarify the concept of NTBF. Based on a quantitative analysis of the several definitions, we identified the relevant characteristics and proposed criteria to identify NTBFs.

To the best of our knowledge, no similar methodological exercise has been conducted before, so this effort was intended to provide a new perspective on the conceptualization of NTBFs. The second phase of this paper consisted in applying the above set of criteria to a specific sample of firms – the academic spin-offs (ASOs). Since ASOs are usually interchangeably identified as NTBFs, considered to be important drivers of economic change and growth, that contribute to the transformation of university knowledge into successful businesses (e.g., Taheri and Geenhuizen, 2011), we decided to use these firms as a unit of analysis.

The empirical data was gathered through a direct questionnaire targeting 58 new firms incubated in the UPTEC (Universidade do Porto Science Park). We managed to get 30 valid responses, which corresponded to an effective response rate of 51.7%.

By using the NTBF criteria obtained through the bibliometric exercise, it was possible to conclude that, contrary to common wisdom, not all ASOs are NTBFs. Indeed, only 46.7% of the ASOs were classified as NTBFs.

Additionally, the academic spin-offs classified as NTBFs according to our criteria differ significantly from the other ASOs, in terms of higher level of capital invested, higher R&D and internationalization intensity, and founding teams with a higher concentration of individuals with management capabilities.

The present work poses some challenging questions, namely to what extent do academic spin-offs that are NTBFs perform better than the non NTBFs, and whether NTBFs located in other science parks would behave or possess distinct characteristics than those found in our limited sample. This would require broadening the target population to more universities and their science parks and incubators, as well as the need to employ more sophisticated statistical and econometric tools.

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