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The contribution of university research to the growth of academic start-ups: an empirical analysis

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Abstract The aim of this paper is to analyze empirically under which circumstances the universities located in a geographical area contribute to the growth of a special category of local new technology-based firms (NTBFs), those established by academic personnel (academic start-ups, ASUs). We examine the effects of a series of characteristics of local universities on the growth rates of ASUs and we compare them with the effects of the same university characteristics on the growth of other (i.e., non-academic) NTBFs. In the empirical part of the paper, we estimate an augmented Gibrat law panel data model using a longitudinal dataset composed of 487 Italian NTBFs observed from 1994 to 2003. Out of these NTBFs 48 are ASUs. The results of the econometric estimates suggest that universities do influence the growth rates of local ASUs, while the effects on the growth rates of other NTBFs are negligible. In particular, the scientific quality of the research performed by universities has a positive effect on the growth rates of ASUs; conversely the commercial orientation of research has a negative effect. These results indicate that universities producing high-quality scientific research have a beneficial impact on the growth of local high-tech start-ups, but only if these firms are able to detect, absorb, and use this knowledge. In this perspective, a greater commercial orientation of university research leading to a reduction of the knowledge available for absorption by these companies, can be detrimental.

Keywords Academic start-ups · New technology-based firms · University research · Growth

JEL Classification L25 · M13 · O30

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1 Introduction

Since the seminal works by Nelson (1959) and Arrow (1962), it is widely accepted that the geographical proximity of universities to knowledge-intensive companies generates positive knowledge externalities for technological innovation and productivity within the private sector. In fact, spatial proximity allows knowledge transmission from universities to companies through the local networks of university staff and industry professionals (local labor market of graduates, faculty consulting, university seminars, conferences, student internships, continuing education of employees), formal business relations (university spin-off companies, technology licensing), and externalities engendered by university physical facilities (libraries, scientific laboratories, computer facilities) (Varga 2000).

The literature on the contribution of universities to local industry has focused on three major issues. Many studies have examined the relation across geographical areas between university research expenditures and private innovation outputs, measured in terms of either patent counts (Anselin et al. 1997; Del Barrio-Castro and García-Quevedo 2005; Fischer and Varga 2003; Jaffe 1989; Jaffe et al. 1993; Piergiovanni et al. 1997) or the number of innovations introduced into the market (Acs et al. 1992; 1994; Feldman and Florida 1994). All these works found a strong and positive relation between local innovative activity and university research and concluded that innovation in the private sector is positively affected by knowledge spillovers from universities, i.e., intentional or unintentional knowledge flows to the private sector, that tend to be geographically bounded within the area (either the state or the region/province) where the universities are located.

More recent empirical studies focused on the impact of university research on firms' localization (Audretsch et al. 2004; Audretsch and Lehmann 2005a; Bade and Nerlinger 2000; Rodríguez-Pose and Refolo 2003; Varga 2000). These works found a significant positive correlation between firms' local concentration and university location and deduced that the existence of localized knowledge spillovers leads to greater concentration of companies in the proximity of universities. Such effect is more evident the greater the quantity and quality of university research output.

Finally, a few studies examined how knowledge externalities affect regional economic growth (Goldstein and Drucker 2006; Goldstein and Renault 2004; for a survey see Drucker and Goldstein 2007). These works showed that knowledge produced by universities is captured within the regional environment and results in enhanced economic development measured by average annual earnings (i.e., annual income excluding dividends, rent, interest, and transfer payments) per worker.

All the above mentioned studies have neglected the analysis of the effects of university research on the growth of individual local firms (Audretsch et al. 2005). Nonetheless, we believe that this is an important avenue for research. In particular, in the present work we examine the relations between university research and the growth of local new technology-based firms (NTBFs), that we define as independent high-tech firms established within the last 25 years (Little 1977). This is an ideal unit of analysis for this research because, as we discuss in the following section, access to external scientific knowledge is particularly relevant for the development of new firms in high-tech sectors. Moreover, for these firms rapid growth is an unequivocal signal of wide market acceptance of their products/services and it is thus generally associated with business success (Barringer et al. 2005; Fischer and Reuber 2003; Feeser and Willard 1990).

To the best of our knowledge, only Audretsch and Lehmann (2005b) explored the connection between university knowledge production and the growth of individual companies. They used a dataset of 281 German IPO firms to empirically analyze the impact of knowledge spillovers from local universities on the growth rates of the number of employees in the sample firms 1 year after the IPO. They found that, with all else equal, the closer the next university and the higher the number of academic papers published by its researchers, the higher the growth rates of sample firms. Here we diverge from this study in two directions.

First, one of the limits of the work by Audretsch and Lehmann (2005b) is that, even though they are interested in the effects of knowledge spillovers to the private sector they do not measure the flows of knowledge. It is fair to acknowledge that finding an appropriate proxy for knowledge spillovers has proved to be a challenging exercise and the lack of a proper operationalization of this concept is a weakness common to many other studies. Hence we do not set the ambitious aim of studying the impact of knowledge flows from universities on firms' growth, conversely we limit our analysis to testing the effects of a series of organization-specific characteristics of universities.

Second, we adhere to the argument set forth by prior studies that the ability of firms to get access to and assimilate the knowledge produced by local universities depends on firms' absorptive capacity (Fischer and Varga 2003) and the presence of academic researchers in the board (Audretsch and Lehmann 2006). In accordance with this view, we argue that the impact of the characteristics of local universities on individual firm growth is affected by the specificities of focal NTBFs. Accordingly we distinguish new high-tech ventures established by academics and/or researchers[1] that were previously employed by public research organizations (academic start-ups, ASUs), from other (i.e., non-academic) NTBFs. We contend that ASUs are in an ideal position to take advantage of university research as a consequence of both their science-orientation and the social contacts and collaborative linkages of their founders with the research personnel of public research organizations.

To sum up, in order to extend our understanding of the contribution of universities to the growth of individual firms, we address the following research questions: which characteristics of local universities enhance or hinder the growth rates of ASUs? Do the alleged effects of local universities on firm growth differ between ASUs and other NTBFs?

In the theoretical part of the paper we rely on prior studies on the contribution of academic research to firms' performances and on the peculiarities of ASUs and we formulate a series of hypotheses on both the effects of selected characteristics of local universities on the growth of ASUs and the different impact of such characteristics on ASUs and other NTBFs. In the empirical part, we compare the determinants of the growth rates of ASUs with those of other NTBFs through the estimation of an augmented Gibrat law panel data model. We devote specific attention to the impact on the growth rates of the two types of firms of the amount, quality, and commercial orientation of the scientific knowledge produced by the universities located in the same provinces as focal companies. For this purpose we take advantage of a unique longitudinal dataset including 487 Italian young firms that operate in high-tech industries in both manufacturing and services and are observed over the period 1994–2003. Out of these firms 48 are ASUs.

The remainder of the paper is structured as follows. In Sect. 2, we first describe how the characteristics of academic institutions influence the knowledge externalities arising from the proximity of universities to NTBFs and, thus, how they affect the growth potential of

[1] Researchers are defined as individuals who perform research activities in public research organizations, regardless of the contractual link with the parent institution. They include the research staff of parent organizations (both full time and part time) and also Ph.D. students.

these companies. Then we examine to what extent this growth potential is realized depending on the specificities of local firms. More specifically, we formulate a series of hypotheses concerning the effects of the characteristics of local universities on ASUs' growth rates and the differences with respect to the effects on the growth of non-academic NTBFs. In Sect. 4, we describe the dataset. Then we illustrate the specification of the econometric model and the explanatory variables. In Sect. 5, we report the results of the econometric estimates. A discussion of the main findings and limitations of the study in Sect. 6 concludes the paper.

2 From the extant literature to the theoretical hypotheses

2.1 The conceptual framework

Our hypotheses are based on the resource- and competence-based theories of the firm. Such theories postulate that the growth of individual companies depends on their ability to develop internally and/or acquire rare and difficult to reproduce resources and competencies. In the high-tech industries where NTBFs operate new scientific knowledge is particularly valuable (Fischer and Varga 2003). As universities are key sources of new scientific knowledge, we expect the NTBFs that succeed in having access to and absorbing the knowledge produced by universities to achieve greater growth performances.

Any firm finds it easier to have access to the knowledge produced by a university when it is located nearby. In fact, spatial proximity allows the dissemination of academic knowledge through channels such as the local personal networks of university researchers or fresh graduates. Hence, ceteris paribus, being located close to universities should facilitate also knowledge absorption and thus it should positively affect the growth potential of NTBFs.

However, as prior studies have shown, knowledge externalities from university research are influenced by several characteristics of the universities located in the same area of focal firms. As we will show in Sect. 2.2, such characteristics of local universities also influence firms' growth potential.

As we will better show in Sect. 2.3, to what extent this growth potential is realized will depend on the characteristics of focal NTBFs. Recent studies on the role of firms' characteristics in university-to-industry knowledge transfer (for a review see Agrawal 2001) suggest that the mere availability of scientific knowledge as a consequence of the presence of a university in a given geographical area is not enough to enable the firms located in the same area to assimilate such knowledge. Conversely, one can identify a number of firm-specific characteristics that facilitate the absorption of university knowledge. In this paper we focus on a special group of NTBFs: the high-tech start-ups established by academic personnel (ASUs). In particular, in Sect. 2.3 we contend that these firms have some "genetic" characteristics that facilitate detection, absorption, and exploitation of academic knowledge (Colombo and Piva 2008a). Then we discuss how the characteristics of local universities affect the growth rates of these firms. We also compare the effects on the growth rates of ASUs to those on the growth of non-academic NTBFs, i.e., firms that do not exhibit the genetic characteristics of ASUs. In Fig. 1 we graphically illustrate the effects of both the characteristics of local universities and the status of ASU on firms' growth rates.

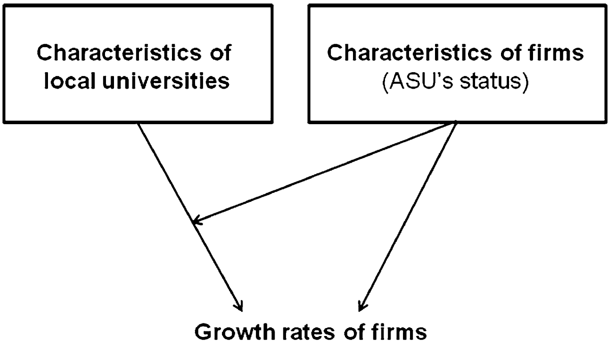

Fig. 1 The conceptual model

2.2 The influence of the characteristics of local universities on the growth potential of NTBFs

In this section we consider (some of) the characteristics of universities that are likely to influence the growth potential of local NTBFs.[2]

First, the size of the university research staff in a particular domain determines the amount of knowledge that local firms may have access to. Ceteris paribus, the greater the number of scientists within a university, the greater the skills and knowledge available for transfer to the private sector (O'Shea et al. 2005), and the higher the growth potential of the NTBFs located in the same area. Second, the growth potential of NTBFs is likely to be affected by the quality of the research performed in local universities. In fact, the more advanced the knowledge produced within universities, the more relevant its alleged contribution to the generation of competitive advantages for local NTBFs and thus to firm growth potential. The development of cutting-edge scientific knowledge requires universities to hire skilled and talented individuals (Powers and McDougall 2005). Hence, the higher the quality of university research staff, the greater the growth potential of local NTBFs (this argument is consistent with the findings of Anselin et al. 1997; Rodríguez-Pose and Refolo 2003).

Finally, the contribution of universities to the growth potential of local NTBFs may depend on the commercial orientation of university research, i.e., the degree to which researchers focus on industrial needs and problems. This is reflected in the source of funding of research: the research activity of universities that receive a greater share of their research budget from industry is likely to be more commercially oriented (Rosenberg and Nelson 1994). The effect of commercial orientation on firms' growth potential is not straightforward.

[2] It is fair to acknowledge that, following the extant literature, we may expect a number of traits of universities additional to those analyzed in this paper to influence the growth potential of local NTBFs. In particular, prior studies have shown that university policies regarding intellectual property, licensing strategies and characteristics of technology transfer offices may affect university-to-industry knowledge transfer (for a review of these studies see again Agrawal 2001). Hence, we may expect these characteristics to influence firms' growth potential too; however we decided not to consider them in this work. In Italy policies and support infrastructures for technology transfer have started spreading after 2000 and have proliferated only in the last couple of years. Therefore, very few universities already exhibited such properties over the period 1994–2003 that we consider in this work. As a consequence, we could not capture the effect of these characteristics through the estimation of econometric models over this time horizon. Thus we excluded the study of these characteristics from both the empirical analysis and the development of the theoretical hypotheses.

On the one hand, greater commercial orientation may facilitate the absorption of the knowledge produced by universities on the part of local firms. The tendency of a university to conduct commercially oriented research should increase the likelihood of discovering technologies and producing knowledge that have commercial value (Di Gregorio and Shane 2003). We expect that firms find it easier to absorb this knowledge rather than abstract scientific knowledge. In addition, institutions performing research that is closer to industrial needs exhibit more entrepreneurial activity, such as faculty consulting within industry, faculty involvement in new firms and faculty and university equity participation in start-ups (Cohen et al. 1998; Roberts and Malone 1996). These activities enhance the contacts between academic researchers and practitioners and encourage the knowledge flows from academia to industry.

On the other hand, greater commercial orientation of university research may inhibit knowledge transfer to local NTBFs. As Argyres and Liebeskind (1998) suggest, universities interested in attracting private research sponsorship might offer sponsoring firms privileged access to the results of academic research. Universities could even assign intellectual property (IP) rights to the firms that funded the research that produced such IP. As firms are more motivated than universities to protect IP from public disclosure and secure exploitation rights of research results (Dasgupta and David 1994; Stern 2004), we expect firms to be anxious to ensure that knowledge leakages do not take place until a patent application is filled or the research results are exploited commercially. To achieve this, firms may try to inhibit premature publication or dissemination of research results by requiring the right to delay or, at least, to approve any proposed scientific publication or further university initiative to disseminate the research results in advance. This clearly hinders the generation of positive externalities to other firms from university research and, consequently, has negative effects on the growth potential of local NTBFs.

2.3 The role of ASU's status

As we have pointed out in Sect. 2.2, the characteristics of universities affect the growth potential of local firms. Whether this growth potential is translated into realized growth depends on the characteristics of focal firms. In this section we focus on the status of ASU as an enabling factor of the exploitation of academic knowledge. Hence, we expect that there are considerable differences between ASUs and other NTBFs as to the effect on firms' growth of the above mentioned characteristics of local universities.

In order to capture and deploy knowledge from external sources firms must be endowed with adequate "absorptive capacity" (Cohen and Levinthal 1989; 1990). Absorptive capacity is "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal 1990, 128). It largely depends on the level of prior related knowledge within the firm. This in turn is a function of firms' internal investments in R&D. Hence, the higher firms' R&D intensity in the fields where local universities are active, the easier the exploitation of academic knowledge and thus the greater its effects on firm growth.

Following this argument, we claim that ASUs should enjoy significant advantages in exploiting university knowledge as they are endowed with greater absorptive capacity than other NTBFs. In fact, ASUs' founding teams exhibit greater scientific education and prior research experience than those of other NTBFs (Colombo and Piva 2008b). Furthermore, ASUs are likely to invest greater resources in R&D activities than other NTBFs. On the one hand, due to the genetic characteristics of their founding teams, the marginal returns of the investments of ASUs in these activities allegedly are greater than those of other

NTBFs. On the other hand, due to their science orientation, ASUs encounter smaller obstacles in hiring qualified technical personnel. As a consequence of the larger initial scientific knowledge base and the higher R&D intensity, ASUs should find it easier than other NTBFs to evaluate the research of local universities, identify interesting results and utilize them in their own activities.

Second, more recent studies concerning the firm-specific characteristics that influence the ability of companies to use scientific knowledge transferred from universities have shown that investments in R&D are not the only mechanism to develop absorptive capacity (Cockburn and Henderson 1998; Lim 2000; Zucker et al. 2000). In particular, firm "connectedness" in the scientific community plays a key role in facilitating the evaluation and utilization of academic knowledge. In fact, when researchers employed in a company co-author papers with academics, a firm participates in research consortia with universities and cultivates university relationships by sponsoring university research or collaborating with faculty members, acquiring knowledge from academia is easier. As to ASUs, the network of social contacts of academic entrepreneurs in the public research sector is wider than that of the founders of other NTBFs, making ASUs more embedded within the scientific community (Murray 2004). Furthermore, academic founders often keep their position in the parent research organization even after the foundation of the new venture (Roberts 1991), so it is easier for them to maintain and enlarge this social network. These links in the research environment give ASUs privileged access to the results of university research and make it easier to detect potentially valuable knowledge and skilled academic researchers that could actively participate in firms' activities.

Nonetheless it has been argued that under specific circumstances, connectedness in the scientific community is not enough to enable the utilization of external knowledge produced by universities (Audretsch and Lehmann 2006; Audretsch and Stephan 1996; Mowery and Ziedonis 2001; Zucker et al. 1998; 1999). In particular, in the fields where knowledge is embodied in human capital it is crucial to involve university scientists in the company as principals, consultants, employees, or members of scientific advisory boards. In this respect, ASUs should clearly enjoy advantages in comparison with other NTBFs as, by definition, their founding teams always include academic researchers.

To sum up, the above arguments suggest that ASUs are better equipped than other NTBFs to detect and absorb useful knowledge produced by local universities. Hence, they can more easily attract ideas from academia and thus benefit from a positive impact of these ideas on firm growth. By combining these arguments with those reported in the previous section we conclude that the number and quality of scientists of local universities will have a positive impact on the growth of ASUs, as these firms are in an ideal situation to absorb and exploit scientific knowledge. Such effect should be greater for ASUs than for other NTBFs. This leads to the following hypotheses.

Hypothesis H1a The number of researchers in local universities has a positive effect on the growth rates of ASUs.

Hypothesis H1b The number of researchers in local universities has a more positive effect on the growth rates of ASUs than on those of other NTBFs.

Hypothesis H2a The quality of the scientific knowledge produced by local universities has a positive effect on the growth rates of ASUs.

Hypothesis H2b The quality of the scientific knowledge produced by local universities has a more positive effect on the growth rates of ASUs than on those of other NTBFs.

Let us now consider the effects of the commercial orientation of academic research. First of all, commercial orientation might act as a substitute for the above mentioned characteristics of firms that facilitate the absorption of academic knowledge. Commercially-oriented universities are more likely to produce knowledge that has immediate commercial value. This knowledge can be easily exploited also by non-academic NTBFs that exhibit low absorptive capacity and are otherwise unable to absorb more abstract scientific knowledge. Similarly, the greater entrepreneurial attitude of researchers in commercially-oriented universities should compensate for the weaker ties of non-academic NTBFs within the public research sector thus having a clear positive effect on the ability of these NTBFs to absorb academic knowledge. Conversely, commercial orientation should not increase the already well-developed ability of ASUs to take advantage of scientific knowledge (see Fig. 2, Graph 1). This suggests that the more commercially-oriented the research performed by universities, the less relevant the advantages that local ASUs enjoy with respect to other NTBFs in detecting, absorbing, and utilizing academic knowledge. Conversely, the limited amount of knowledge freely flowing from commercially-oriented universities should have negative consequences for both ASUs and other NTBFs (Figure 2, Graph 2). The result of these overlapping forces is that commercial orientation should have negative consequences for ASUs (Fig. 2, Graph 3), while the effect on other NTBFs is questionable (Fig. 2, Graph 4).

We synthesize such arguments in the following hypotheses.

Hypothesis H3a The commercial orientation of local universities has a negative effect on the growth rates of ASUs.

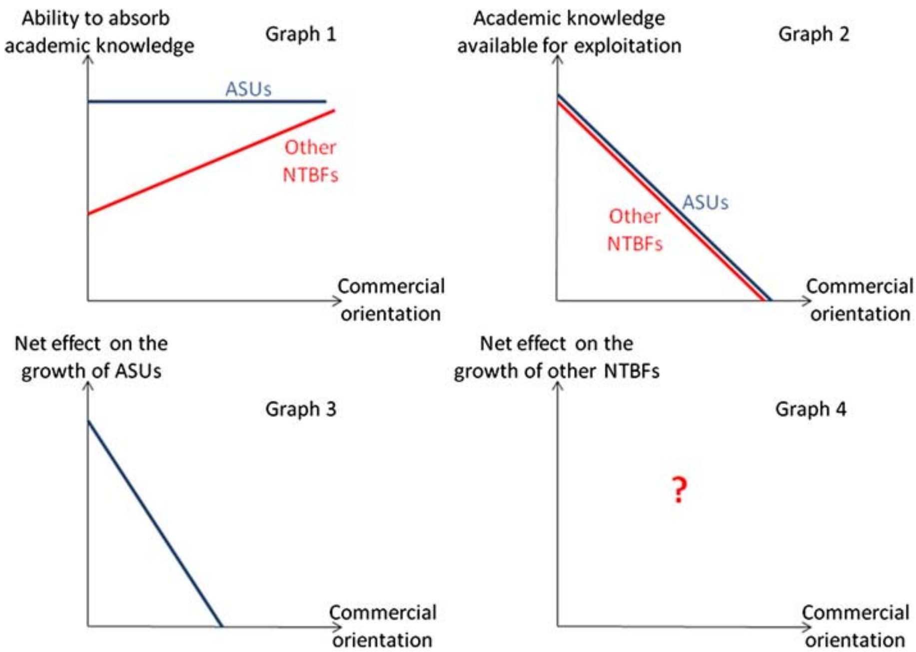

Fig. 2 The effect of commercial orientation of university research on ASUs and other NTBFs

Hypothesis H3b The commercial orientation of local universities has a more negative effect on the growth rates of ASUs than on those of other NTBFs.

3 The dataset

This section has purely illustrative purposes. Here we describe the dataset we use to test our hypotheses. This dataset includes both survey data on a sample of 487 Italian NTBFs and public information on the characteristics of the universities located in the same provinces as the sample firms.

3.1 The sample of NTBFs

In this paper we use a unique dataset of Italian NTBFs that operate in high-tech manufacturing and services sectors. These firms are extracted from the RITA (Research on Entrepreneurship in Advanced Technologies) database developed by the Department of Management, Economics and Industrial Engineering of Politecnico di Milano. The RITA dataset was created in 2000 and it was updated and extended in 2002 and 2004. The development of the 2004 release of the database went through a series of steps. First, Italian firms that were established after 1980, remained independent (i.e., not controlled by other organizations) up to the end of 2003 and operated in high-tech sectors, both in manufacturing and services, were identified. For the construction of the target population a number of sources were used.[3] These included 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, specialized magazines, other sectoral studies, and regional Chambers of Commerce was also considered. Altogether, 1,974 firms were selected for inclusion in the database. Among these firms there were 123 ASUs. For each firm, a contact person (i.e., one of the owner-managers) was also identified. Second, a questionnaire was sent to the contact person of target firms either by fax or by e-mail in the first semester of 2004. The questionnaire provided detailed information on the characteristics of the firms including the human capital characteristics of their founders, their financing strategies and their growth performances.

Lastly, answers to the questionnaire were checked for internal coherence by educated personnel and were compared with published data (basically data provided by firms' annual reports and websites). In many cases, phone or face-to-face follow-up interviews were made with firms' owner-managers. This final step was crucial in order to obtain missing data and ensure that data were reliable.[4]

The sample used in the present work consists of all RITA firms for which we were able to create a complete data set including data on size, measured by the logarithm of the number of employees (including owner-managers), for at least three consecutive years (on

[3] Unfortunately, data provided by official national statistics do not allow to obtain a reliable description of the universe of Italian NTBFs. The main problem is that in Italy most individuals who are defined as "self-employed" by official statistics actually are salaried workers with atypical employment contracts. Unfortunately, on the basis of official data such individuals cannot be distinguished from entrepreneurs who created a new firm.

[4] Note that for only three firms the set of owner-managers at survey date did not include at least one of the founders of the firm. For these firms information relating to the human capital characteristics of the founders was checked through interviews with firms' personnel so as to be sure that it did not relate to current owner-managers.

this issue see footnote 12). It is composed of 487 NTBFs. 48 of these firms are ASUs. χ^2 tests show that there are no statistically significant differences between the distributions of sample firms across industries and regions and the corresponding distribution of the 1,974 RITA NTBFs from which the sample was drawn ($\chi^2(4) = 4.01$ and $\chi^2(3) = 6.10$, respectively). Sample firms are observed during the period 1994–2003.

Of course, there is no presumption here to have a random sample. First, in this domain representativeness is a slippery notion as new ventures may be defined in different ways (see for instance Aldrich et al. 1989; Birley 1984; Gimeno et al. 1997). Second, absent reliable official statistics, it is very difficult to identify unambiguously the universe of Italian NTBFs and that of Italian ASUs. Therefore, one cannot check ex-post whether the sample used in this work is representative of the population. Third, the analysis presented in this paper is based on survey data; so it might suffer from a sample selection bias. First and foremost, only firms having survived up to the survey date could be considered: this generates a survivorship bias. As in most survey-based studies, it is impossible to properly control for the survivorship bias. What we can do is to check its extent.

For this purpose, we focused attention on the RITA 2000 sample. This sample is composed of 401 NTBFs identified when the RITA database was created; it includes 25 ASUs and 376 other NTBFs. Out of the 25 ASUs only four ceased operations or were acquired by/merged with other firms in the period 2000–2003. Therefore, we could not test whether there was any difference between the ASUs that exited the sample and those that did not. The likelihood of exit was greater among non-academic NTBFs; in fact, 83 of these firms exited the sample, corresponding to a 22.1% share. As the likelihood of exit was very low among ASUs, the survivorship bias, if there were any, would be driven by the exit of non-academic NTBFs. We then run a probit model of the likelihood of these latter firms having survived in the 2000–2003 period, conditional on survival up to 2000. In addition to firm- and industry-specific controls, the explanatory variables included all the measures of the characteristics of local universities that are likely to affect firm growth and hence will be considered in the analysis reported in Sect. 5. The econometric estimates show that these variables have no effects on the likelihood of survival of non-academic NTBFs. Hence, even though this check is very partial, we have no indication suggesting that the results of the estimates that will be illustrated in Sect. 5 are driven by a survivorship bias.

The distribution of sample firms across industries, geographic areas and periods of foundation is highlighted in Table 1.

Differences across industries in the number of ASUs and other NTBFs are fairly limited. Both ASUs and other NTBFs mainly operate in Software (29.2% vs. 29.8% of the sample, respectively) and Internet and telecommunication services (35.4% vs. 28.7%). ASUs are less numerous than NTBFs in the ICT manufacturing sector (18.8% vs. 22.6%).

As to the geographical distribution, sample firms are mainly located in the North–West (47.6% of the total sample), conversely they are seldom founded in southern regions (13.6%). As to the distribution across provinces, the 487 NTBFs are located in 78 out of the 103 Italian provinces that existed in the period under scrutiny with greater concentration in the provinces of Milan, Turin, and Rome. It is interesting to compare the geographical distributions of ASUs and other NTBFs as the pattern of localization of ASUs differs quite remarkably from that of other NTBFs. The percentages of ASUs located both in the regions of the North-West and in the less developed regions of the South are lower than those of other NTBFs (41.7% vs. 48.3% and 6.3% vs. 14.4%, respectively), conversely the percentage of ASUs is higher in the remaining areas (29.2% vs. 22.6% in the North–East and 22.9% vs. 14.8% in the Centre). As to the distribution across provinces, we encounter ASUs in 24 out of the 78 provinces where sample NTBFs are located.

Table 1 Distribution of sample ASUs and other NTBFs by industry, geographic area and year of foundation

	ASUs		Other NTBFs		Total	
	N	%	N	%	N	%
Industry						
ICT manufacturing	9	18.8	99	22.6	108	22.2
Automation & Robotics	4	8.3	41	9.3	45	9.2
Biotechnologies, pharmaceutics and advanced materials	2	4.2	19	4.3	21	4.3
Software	14	29.2	131	29.8	145	29.8
Internet & TLC services	17	35.4	126	28.7	143	29.4
Multimedia content	2	4.2	23	5.2	25	5.1
Total	48	100.0	439	100.0	487	100.0
Geographical area						
North–West	20	41.7	212	48.3	232	47.6
North–East	14	29.2	99	22.6	113	23.2
Centre	11	22.9	65	14.8	76	15.6
South	3	6.3	63	14.4	66	13.6
Total	48	100.0	439	100.0	487	100.0
Year of foundation						
1980–1984	6	12.5	50	11.4	56	11.5
1985–1989	3	6.3	81	18.5	84	17.2
1990–1994	4	8.3	98	22.3	102	20.9
1995–1999	24	50.0	167	38.0	191	39.2
2000–2003	11	22.9	43	9.8	54	11.1
Total	48	100.0	439	100.0	487	100.0

As to the year of foundation, sample NTBFs have been mainly founded since the mid Nineties (50.3% of sample firms have been founded between 1995 and 2003). This is particularly evident for ASUs. A total of 72.9% of sample ASUs were founded after 1994 and 22.9% after 1999. Conversely, the number of other NTBFs established in the same periods is 47.8% and 9.8%, respectively.

3.2 Italian universities

Table 2 shows the geographical distribution of Italian universities. At the end of 2003 in Italy there were 77 universities located in 49 out of the 103 Italian provinces.[5] The number

[5] Following prior studies on the Italian case (Piergiovanni et al. 1997; Rodríguez-Pose and Refolo 2003) we use the province as the geographic unit of analysis. Although some of the largest Italian universities have campuses in different provinces (for instance, Politecnico di Milano has six campuses over the Lombardy region in five provinces and one campus in Emilia Romagna), in Table 2 for each university we consider the location of the main campus only. This allows us be consistent with the data reported in the following. In fact, all the data on the characteristics of Italian universities are available at university level only (i.e., they are not disaggregated by provinces). Hence, in order to measure the number of researchers, the quality of the knowledge produced and the commercial orientation of local universities for Italian provinces, for each university we have attributed all the researchers and, coherently, all the research activities to the main campus. As faculty members are mainly located in the main campus, this approximation can be considered reasonably accurate.

Table 2 Geographical distribution of Italian universities at the end of 2003

Geographical area	Universities	
	N	%
North–West	17	22.1
North–East	13	16.9
Centre	22	28.6
South	25	32.5
Total	77	100.0
Number of universities per province	Italian provinces	
None	54	52.4
1	37	35.9
2	7	6.8
3	2	1.9
>3	3	2.9

of universities per province was low: only 11 out of the 49 provinces had more than one university. Exceptions were the provinces of Naples, Milan, and Rome with respectively 5, 7, and 8 universities. Italian universities were mainly located in the South (32.5%) and in the Centre (28.7%).

In Table 3 we report some figures on Italian universities focusing on the three characteristics that we consider in the present article: number of researchers, quality of the scientific knowledge produced (called research quality in the following) and commercial orientation. The main aim of this table is to show whether and to what extent Italian universities (and accordingly Italian provinces) differ along these three dimensions.

Let us first consider university size. At the end of 2003 the mean of the total number of researchers across the 77 Italian universities was 730. If we focus only on economic and technical faculties, the ones that are more likely to produce knowledge that may be commercially exploited by NTBFs, the mean number of researchers at the end of 2003 drops to 534. In both cases the standard deviations are high (843 and 644, respectively). This suggests that there are considerable size differences among Italian universities.

We measure the research quality of each university by the ratio of the number of citations obtained till year 2001 by articles published in the international journals monitored by the Institute for Scientific Information (ISI) in the 1995–1999 period by researchers employed by the university to the number of these researchers. Data on

Table 3 Number of researchers, quality of the scientific knowledge produced and share of privately funded research of Italian universities

	Number of universities	Mean	Standard deviation
Number of researchers	77	730	843
Number of researchers in economic or technical faculties	77	534	644
Quality of research in medical field	69	23.5	48.0
Quality of research in engineering field	69	5.0	18.5
Quality of research in other scientific fields	69	17.7	24.2
Share of privately funded research	77	0.25	0.19

publications (and thus citations) per researcher are not comparable across scientific areas, scientific disciplines may differ in terms of technological opportunity and commercial potential (Wright et al. 2004). Therefore, in measuring the research quality we distinguished medical, engineering, and other scientific fields. The mean ranges from five citations per researcher in the engineering field to more than 23 in the medical field, and the standard deviations again are high in every field. Hence, we conclude that Italian universities exhibit large variety also as to research quality.

Finally, we measured the commercial orientation of universities as the share of university research funded by private companies out of the total research budget of the university in 2003. The mean share is 25%, with a minimum of 0% and a maximum of 86%. Again the differences among Italian universities are remarkable.

4 The methodology of the econometric analysis

4.1 The specification of the econometric model

In order to capture the differences between ASUs and other NTBFs, we estimate the following augmented Gibrat law dynamic growth model:

$$\begin{aligned} LSize_{i,t} = {} & \beta_0 + \beta_1 LSize_{i,t-1} + \beta_2 LAge_{i,t-1} + \beta_3 \left(LSize_{i,t-1}\right)^2 + \beta_4 \left(LAge_{i,t-1}\right)^2 \\ & + \beta_5 (LSize_{i,t-1} * LAge_{i,t-1}) + \beta_6 U_{i,t-1} + \beta_7 CV_{i,t-1} \\ & + \beta_8 * DASU_i + \beta_9 LSize_{i,t-1} * DASU_i + \beta_{10} LAge_{i,t-1} * DASU_i \\ & + \beta_{11} \left(LSize_{i,t-1}\right)^2 * DASU_i + \beta_{12} \left(LAge_{i,t-1}\right)^2 * DASU_i \\ & + \beta_{13} \left(LSize_{i,t-1} * LAge_{i,t-1}\right) * DASU_i \\ & + \beta_{14} U_{i,t-1} * DASU_i + \beta_{15} CV_{i,t-1} * DASU_i + \varepsilon_{i,t} \end{aligned} \quad (1)$$

In Eq. 1 $LSize_{i,t}$ indicates the size of sample firms measured by the logarithm of the number of employees (including owners-managers) at time t, and $LAge_{i,t-1}$ is the logarithm of firms' age at $t-1$. Here we adopt the approach of Evans (1987a, b), thus we include in the model specification also the squared values of $LSize_{i,t-1}$ and $LAge_{i,t-1}$, and the interactive term between $LSize_{i,t-1}$ and $LAge_{i,t-1}$. $U_{i,t-1}$ is a group of variables describing the characteristics of the universities located in the same province as sample NTBFs. $CV_{i,t-1}$ is a group of control variables including measures of (i) the human capital of firms' founders, (ii) firms' obtainment of venture capital (VC), (iii) the level of economic development of the provinces where firms are located, and (iv) firms' sector of activity (for an in depth description of the $U_{i,t}$ and $CV_{i,t}$ variables see Sect. 4.2). Finally, $DASU_i$ is a dummy variable equal to one if the firm is an academic start-up and $\varepsilon_{i,t}$ are i.i.d. disturbance terms.

The inclusion in Eq. 1 of the lagged dependent variable as one of the covariates and the possible endogenous nature of the relationship between VC financing and firm size require the use of appropriate estimation techniques. In fact, as long as regressors are correlated with disturbance terms, both pooled ordinary least squares and random effects estimators are likely to produce biased estimates. Therefore, following the recent literature on dynamic panel data models (see Arellano and Bond 1991; Blundell and Bond 1998; Bond 2002), we resort to the generalized method of moments (GMM) procedure and estimate model (1) by the GMM-System estimator. This approach, originally proposed by Blundell and Bond (1998), extends the GMM-DIF estimator (first differenced), and additional moment conditions are used in order to obtain more efficient estimates. In particular, in addition to using lagged levels of the series as instruments for first differences (as in GMM-DIF), additional information is extracted using first differences as instruments for variables in levels.[6] This augmented GMM estimator requires the assumption of mean stationary of the series and is particularly appropriate where series are highly persistent (see Bond 2002).

Finally, since we perform the analysis on micro units using several aggregate variables at the province level as covariates, we need to control for the potential downward bias in the estimated errors (see Moulton 1990). We do so by clustering the standard errors at firm level.

4.2 The explanatory variables of the econometric model

The explanatory variables used in the estimation of model (1) are presented in Table 4. They include measures of the characteristics of the universities located in the same provinces as sample NTBFs and a series of control variables measuring founder-, firm-, and industry-specific characteristics.

Let us first consider the variables measuring the characteristics of local universities. Faculty size is measured by $ResearcherDensity_{t-1}$ that we calculated as the sum of the researchers employed in either economic or technical faculties[7] in the universities located in the same provinces as sample start-ups at time $t-1$, $t-2$, and $t-3$ divided by the population (in thousands of residents) of the province at $t-1$ to control for the size of the area.

We measured the research quality of universities located in a given province by the ratio of the number of citations obtained till year 2001 by articles published in the international journals monitored by the ISI in the 1995–1999 period by researchers employed by these universities to the number of these researchers (Breno et al. 2002). Consistently with the descriptive statistics on the Italian university system provided in Sect. 3.2, we distinguished the citation indexes in engineering (*EngQuality*), medical (*MedQuality*), and other scientific fields (*ScienceQuality*). For each scientific field the effects of the research quality of universities on the growth of local NTBFs may differ according to the sector of activity of recipient companies; hence, in the model we include the interactive terms between the indexes of citations and the industry dummies *DBio* and *DNoBio*. *DBio* is equal to 1 for companies operating in biotechnology, pharmaceutics, and advanced materials, conversely *DNoBio* equals 1 for companies in other industries. We do not include in the model $DBio \times EngQuality$ as university research in engineering fields is likely to have negligible effects on biotech companies. For similar reasons we exclude also $DNoBio \times MedQuality$.

The variables measuring the research quality are time-invariant. This clearly is a limitation of our study. However, as the citation ratio is unlikely to have varied substantially in the period under scrutiny, differences across provinces are likely to have remained quite constant over time. Therefore we are confident that considering the research quality as a constant between 1994 and 2003 is unlikely to lead to biased results.

Finally, the commercial orientation of local universities (*%PrivateBudget*) has been calculated through a two-step procedure. First for each province we computed the share of

[6] In particular, considering $LSize_{i,t-1}$ as endogenous implies the use of instruments dated $t-3$ for the equation in first differences and instruments dated $t-2$ for the equation in level.

[7] The economic faculties include economics, management, and political sciences, while the technical faculties are engineering, chemistry, physics, geology, mathematics, biology, medicine, pharmaceutics, and computer science.

Table 4 Definition of the explanatory variables

Variable	Description
DASU	One for academic start-ups
Gibrat variables	
$LSize_{t-1}$	Logarithm of the size of the firm at $t-1$ measured by the number of employees
$LAge_{t-1}$	Logarithm of the number of years since firm's foundation at $t-1$
$LSize\text{^}2_{t-1}$	Squared logarithm of the size of the firm at $t-1$ measured by the number of employees
$LAge\text{^}2_{t-1}$	Squared logarithm of the number of years since firm's foundation at $t-1$
$LAge_{t-1} \times LSize_{t-1}$	Product of *LAge* and *LSize*
Characteristics of local universities	
$ResearcherDensity_{t-1}$	Average number of researchers (i.e., professors, lecturers, Ph.D. students) employed in local universities in either economic or technical faculties at $t-1$, $t-2$ and $t-3$, divided by the population of the province (in thousands of residents) in $t-1$
DBio × *MedQuality*	Ratio of the number of citations obtained till 2001 by articles published in the 1995–1999 period in medical fields to the number of researchers in the province multiplied by a dummy equal to one for firms operating in biotechnology, pharmaceutics, and advanced materials
DNoBio × *EngQuality*	Ratio of the number of citations obtained till 2001 by articles published in the 1995–1999 period in engineering fields to the number of researchers in the province multiplied by a dummy equal to one for firms not operating in biotechnology, pharmaceutics, and advanced materials
DBio × *ScienceQuality*	Ratio of the number of citations obtained till 2001 by articles published in the 1995–1999 period in other scientific fields to the number of researchers in the province multiplied by a dummy equal to one for firms operating in biotechnology, pharmaceutics, and advanced materials
DNoBio × *ScienceQuality*	Ratio of the number of citations obtained till 2001 by articles published in the 1995–1999 period in other scientific fields to the number of researchers in the province multiplied by a dummy equal to one for firms not operating in biotechnology, pharmaceutics, and advanced materials
%PrivateBudget	Average share over the fiscal years 2002 and 2003 of privately funded research out of the total research budget of local universities
Founder-specific variables	
WorkExp	Average number of years of industrial work experience gained by founders before firm's foundation
Education	Average number of years of founders' education
DManager	One for companies with one or more founders with a prior management position in a large or medium company (i.e., number of employees greater than 100)
Firm-specific variables	
DVC_{t-1}	One for companies that obtained VC financing at $t-1$
DVC_{t-2}	One for companies that obtained VC financing at $t-2$
DVC_{t-3}	One for companies that obtained VC financing at $t-3$
Geographical and industry controls	
Infrastructure	Value of the index measuring regional infrastructures in 1989 (mean value among Italian regions = 100; source: Centro Studi Confindustria, 1991)
DICTManufacturing	One for companies that operate in aerospace and ICT manufacturing
DBiotech	One for companies that operate in biotechnology, pharmaceutics, and advanced materials

Table 4 continued

Variable	Description
DSoftware	One for companies that operate in software
DInternet	One for companies that operate in internet and TLC services
DMultimediaContent	One for companies that operate in the multimedia content sector

the research performed by local universities and funded by private companies out of the total research budget of these universities both in 2002 and in 2003.[8] Then we assigned *%PrivateBudget* the average value over this 2 year period for the province where the focal NTBF is located.[9]

In this paper we are interested in (i) examining the effects of the characteristics of local universities on the growth rates of ASUs and (ii) assessing whether such characteristics differently affect the growth rates of ASUs and those of other NTBFs. Hence, the explanatory variables in Eq. 1 also include the interactive terms between the dummy *DASU* which equals 1 for academic start-ups, and the above mentioned measures of the characteristics of local universities. According to hypotheses H1a,b and H2a,b, we expect the coefficients of $ResearcherDensity_{t-1} + DASU \times ResearcherDensity_{t-1}$, $DASU \times ResearcherDensity_{t-1}$, $DNoBio \times EngQuality + DASU \times DNoBio \times EngQuality$, $DBio \times MedQuality + DASU \times DBio \times MedQuality$, $DNoBio \times ScienceQuality + DASU \times DNoBio \times ScienceQuality$, $DBio \times ScienceQuality + DASU \times DBio \times ScienceQuality$, $DASU \times DNoBio \times EngQuality$, $DASU \times DBio \times MedQuality$, $DASU \times DNoBio \times ScienceQuality$, and $DASU \times DBio \times ScienceQuality$ to be positive. Conversely, following hypotheses H3a,b, we predict that the coefficients of $\%PrivateBudget + DASU \times \%PrivateBudget$ and $DASU \times \%PrivateBudget$ are negative.

[8] The first available data on the amount of financing of Italian universities refer to the fiscal year 2000. In fact, it was only in 2001 that the National Committee for the Evaluation of the Academic System (Comitato Nazionale per la Valutazione del Sistema Universitario, CNVSU) started collecting the financial accounts of Italian universities and making available aggregated data. The reports of the CNVSU on the fiscal years 2000 and 2001 classified the revenues of Italian universities in three categories: financing from MIUR (the Italian Ministry of University and Research), university internal funds and financing from external sources. Since the publication of the report on the fiscal year 2002, three subcategories have been distinguished within the "external sources" category: financing from the European Union, from other public research organizations and from other organizations. As we are interested in the share of research funded by the private sector, we have to focus on the last subcategory. Hence, in calculating *%PrivateBudget*, we could not use data on the fiscal years 2000 and 2001. Note that the category "financing from other organizations" includes both financing from firms and financing from other sources (e.g., foundations). However, the role of foundations in financing academic research in Italy was fairly limited in the observation period. Hence, even though *%PrivateBudget* is likely to overestimate financing from firms, absent more fine grained data, it can be considered as a reasonably good proxy.

[9] *%PrivateBudget* was calculated as the average value over two subsequent years in order to reduce random fluctuations. We are aware that this variable, being time-invariant, might generate biases that may distort the estimates. In particular, as financing to universities from the Italian Central Government has decreased during the last decade, universities have started looking for additional sources of income thus probably raising the share of funds from private sources out of the total budget. This increase might have been more relevant for northern provinces as the industrial system of this area is more developed and local companies are likely to be more prone to finance academic research. Therefore, our measure of *%PrivateBudget* might overestimate the commercial orientation of universities located in northern provinces in the first years of the period under scrutiny. As a consequence, if in this period the growth rates of NTBFs located in northern provinces were higher (lower) than those of the companies located elsewhere because of unobserved effects, the estimates of the coefficient of *%PrivateBudget* might reveal a upward (downward) bias.

As to the control variables, we first introduce into the model measures of founder-specific characteristics of sample firms. These variables allow to control for the alleged positive impact on firm growth of the human capital of the founding team (for a survey see Colombo and Grilli 2005; Storey 1994). We consider the level of education measured by the mean number of years of university education of founders (*Education*) and the mean number of years of prior industrial work experience (*WorkExp*). We also add a dummy (*DManager*) equal to 1 if prior to the establishment of the new venture, one (or more) founder(s) had a managerial position in a medium or large company (i.e., number of employees greater than 100).[10]

As to firm-specific controls, we first control for the obtainment of VC financing which according to the financial literature has a positive effect on firm growth (for a survey see Bertoni et al. 2007). In order to do so we include in our estimates three dummy variables, DVC_{t-1}, DVC_{t-2}, and DVC_{t-3}, which are equal to 1 if, respectively, at time $t-1$, $t-2$, and $t-3$ sample NTBFs got access to VC financing. We also control for firm location: being located in a developed area is likely to positively influence growth as it enables NTBFs to benefit from positive externalities that may arise from external assets with public good nature (e.g., transport system, telecommunication infrastructure, efficient market for support services). Hence, in the model we include the variable *Infrastructure*, that reflects the level of economic development in 1989 of the province where firms are located (source: Centro Studi Confindustria 1991). It is calculated as the average of the following indexes: per capita value added, share of manufacturing out of total value added, employment index, per capita bank deposits, automobile-population ratio, and consumption of electric power per head.[11] We also allowed firm- and founder-specific control variables to differ according to the status (ASU or non-ASU) of firms. For this purpose we inserted in the model specification a series of interactive terms between the control variables and the dummy *DASU*.

Finally, the industry-specific controls are five sectoral dummies: DInternet, DSoftware, DMultimediaContent, DICTManufacturing, and DBiotech. These variables equal 1 for firms in the internet and telecommunication services, software, multimedia content, ICT manufacturing, and biotechnology and pharmaceutics industry, respectively. The baseline of the estimates is the robotics and automation industry. As to these latter variables we have no specific predictions.

5 Results of the econometric analysis

The results of the econometric analysis are illustrated in Tables 5 and 6.[12] In Table 5 we present the estimates of the equation including the control variables only (Model 1) and the

[10] In small family-owned Italian companies decision authority is often centralized in the owner-managers' hands (see Colombo and Delmastro 1999), while salaried managers are assigned execution tasks. So, entrepreneurial learning associated with such managerial positions generally is fairly limited.

[11] We also controlled for other characteristics of the provinces where sample NTBFs are located, namely provincial deflated GDP per capita, provincial deflated GDP per capita rescaled on a national basis and provincial population or provincial density of population. The results are almost unchanged. They are available from the authors upon request.

[12] As we mentioned in footnote 6, GMM-SYS estimate requires the use of instruments for $LSize_{i,t-1}$, $(LSize_{i,t-1})^2$ and $LSize_{i,t-1} \times LAge_{i,t-1}$ dated $t-3$ for the equation in first differences. Hence, the sample used for the estimates presented in Tables 5 and 6 excludes all RITA NTBFs for which data on size were available for less than three consecutive years.

Table 5 The determinants of the growth of NTBFs: a GMM-system model

	$LSize_t$	Model 1	Model 2
a_0	*Constant*	0.553(0.269)*	−0.422(0.652)
a_1	$ResearcherDensity_{t-1}$	–	−0.033(0.020)
a_2	$DBio \times ScienceQuality$	–	0.041(0.044)
a_3	$DBio \times MedQuality$	–	0.005(0.011)
a_4	$DNoBio \times ScienceQuality$	–	0.003(0.005)
a_5	$DNoBio \times EngQuality$	–	0.000(0.008)
a_6	*%PrivateBudget*	–	−0.102(0.209)
a_7	$LSize_{t-1}$	0.696(0.086)**	0.639(0.089)**
a_8	$LSize\hat{}2_{t-1}$	0.045(0.022)*	0.059(0.023)**
a_9	$LAge_{t-1}$	−0.011(0.142)	0.061(0.142)
a_{10}	$LAge\hat{}2_{t-1}$	−0.004(0.043)	−0.018(0.043)
a_{11}	$LAge_{\ t-1} \times LSize_{\ t-1}$	0.000(0.056)	−0.008(0.061)
a_{12}	*DManager*	−0.112(0.155)	−0.097(0.163)
a_{13}	*WorkExp*	−0.005(0.007)	−0.005(0.007)
a_{14}	*Education*	−0.012(0.010)	0.003(0.013)
a_{15}	DVC_{t-1}	0.330(0.140)*	0.366(0.147)*
a_{16}	DVC_{t-2}	0.299(0.069)**	0.293(0.069)**
a_{17}	DVC_{t-3}	0.154(0.071)*	0.157(0.071)*
a_{18}	*Infrastructure*	0.002(0.002)	0.003(0.002)
Industry controls		Yes	Yes
Wald χ^2 *test*			
$a_1 = a_2 = a_3 = a_4 = a_5 = a_6 = 0$		–	6.13(6)
$a_7 = a_8 = a_9 = a_{10} = a_{11} = 0$		3814.63(5)**	3835.92(5)**
$a_{12} = a_{13} = a_{14} = 0$		2.30(3)	1.22(3)
$a_{15} = a_{16} = a_{17} = 0$		25.00(3)**	22.20(3)**
Number of observations		3201	3201
Number of groups		487	487
AR(1)		−9.56 **	−9.28**
AR(2)		−1.02	−1.02
Sargan		150.25(139)	144.65(133)
Hansen		144.30(139)	137.38(133)

Legend: * Significance level greater than 5%; ** Significance level greater than 1%

AR(1) and AR(2) are tests of the null hypothesis of respectively no first- or second-order serial correlation. Sargan and Hansen are tests of the validity of the overidentifying restrictions based on the efficient two-step GMM estimator. Standard deviations in round brackets. Standard errors clustered at firm level

control variables plus the independent variables (Model 2), but the model specification does not make any distinction between ASUs and other NTBFs. In Table 6 we present the estimates of the equation including also the interactive terms between the independent and control variables and *DASU*.

As to the control variables, the estimates of Model 1 in Table 5 show that the coefficient of firm size ($LSize_{t-1}$) is significantly smaller than 1 (and higher than 0) while the coefficient of $LSize\hat{}2_{t-1}$ is positive and significant. Hence, we may conclude that the relation

Table 6 The determinants of the growth of ASUs and other NTBFs: a GMM-system model

		$LSize_t$			
a_0	*Constant*	−0.433(0.928)	a_{19}	*DASU*	0.412(0.996)
a_1	$ResearcherDensity_{t-1}$	−0.037(0.043)	a_{20}	$DASU \times ResearcherDensity_{t-1}$	0.091(0.063)
a_2	$DBio \times ScienceQuality$	0.028(0.054)	a_{21}	$DASU \times DBio \times ScienceQuality$	0.135(0.100)
a_3	$DBio \times MedQuality$	0.012(0.016)	a_{22}	$DASU \times DBio \times MedQuality$	dropped
a_4	$DNoBio \times ScienceQuality$	−0.023(0.014)*	a_{23}	$DASU \times DNoBio \times ScienceQuality$	0.018(0.021)
a_5	$DNoBio \times EngQuality$	−0.009(0.013)	a_{24}	$DASU \times DNoBio \times EngQuality$	0.107(0.052)**
a_6	*%PrivateBudget*	0.749(0.531)	a_{25}	$DASU \times$ *%PrivateBudget*	−2.066(0.834)**
a_7	$LSize_{t-1}$	0.600(0.144)***	a_{26}	$DASU \times LSize_{t-1}$	0.531(0.385)
a_8	$LSize\hat{}2_{t-1}$	0.073(0.033)**	a_{27}	$DASU \times LSize\hat{}2_{t-1}$	−0.106(0.084)
a_9	$LAge_{t-1}$	0.174(0.175)	a_{28}	$DASU \times LAge_{t-1}$	−0.993(0.414)**
a_{10}	$LAge\hat{}2_{t-1}$	−0.039(0.064)	a_{29}	$DASU \times LAge\hat{}2_{t-1}$	0.294(0.126)**
a_{11}	$LAge_{t-1} \times LSize_{t-1}$	−0.025(0.098)	a_{30}	$DASU \times (LAge_{t-1} \times LSize_{t-1})$	−0.044(0.174)
a_{12}	*DManager*	−0.367(0.359)	a_{31}	$DASU \times DManager$	0.502(0.468)
a_{13}	*WorkExp*	0.013(0.015)	a_{32}	$DASU \times WorkExp$	−0.015(0.025)
a_{14}	*Education*	0.029(0.047)	a_{33}	$DASU \times Education$	−0.024(0.054)
a_{15}	DVC_{t-1}	0.470(0.197)**	a_{34}	$DASU \times DVC_{t-1}$	−0.102(0.296)
a_{16}	DVC_{t-2}	0.269(0.090)***	a_{35}	$DASU \times DVC_{t-2}$	−0.054(0.181)
a_{17}	DVC_{t-3}	0.143(0.087)	a_{36}	$DASU \times DVC_{t-3}$	0.010(0.227)
a_{18}	*Infrastructure*	0.006(0.003)*			
Industry controls		YES			
Wald χ^2 test on the effects of the characteristics of local universities					
$a_1 = a_2 = a_3 = a_4 = a_5 = a_6 = 0$		6.22(6)			
$a_{20} = a_{21} = a_{23} = a_{24} = a_{25} = 0$		15.25(5)***			
$a_1 + a_{20} = a_2 + a_{21} = a_4 + a_{23} = a_5 + a_{24} = a_6 + a_{25} = 0$		16.08(5)***			

Table 6 continued

	$LSize_t$
Wald χ^2 test − hypotheses testing	
H1a: $a_1 + a_{20} = 0$	1.48(1)
H2a: $a_2 + a_{21} = 0$	2.15(1)
H2a: $a_4 + a_{23} = 0$	0.10(1)
H2a: $a_5 + a_{24} = 0$	3.86(1)**
H3a: $a_6 + a_{25} = 0$	4.56(1)**
Wald χ^2 test on the control variables	
$a_7 = a_8 = a_9 = a_{10} = a_{11} = 0$	1267.95(5)***
$a_{26} = a_{27} = a_{28} = a_{29} = a_{30} = 0$	11.02(5)*
$a_8 = a_{10} = a_{11} = 0$	9.06(3)**
$a_{27} = a_{29} = a_{30} = 0$	8.23(3)**
$a_{12} = a_{13} = a_{14} = 0$	1.33(3)
$a_{31} = a_{32} = a_{33} = 0$	1.15(3)
$a_{15} = a_{16} = a_{17} = 0$	11.05(3)**
$a_{34} = a_{35} = a_{36} = 0$	0.36(3)
Number of groups	487
AR(1)	−8.97***
AR(2)	−0.97
Sargan	122.81(116)
Hansen	112.93(116)

Legend: * Significance level greater than 10%; ** Significance level greater than 5%; *** Significance level greater than 1%

AR(1) and AR(2) are tests of the null hypothesis of respectively no first- or second-order serial correlation. Sargan and Hansen are tests of the validity of the overidentifying restrictions based on the efficient two-step GMM estimator. Standard deviations in round brackets. Standard errors clustered at firm level between firm size and firm growth is U-shaped. That is, firm growth decreases with firm size up to a size corresponding to about 29 employees and then it increases when firm size grows larger. Conversely, firm's age ($LAge_{t-1}$ and $LAge\text{^}2_{t-1}$) and its interactive term with firm size ($LAge_{t-1} \times LSize_{t-1}$) do not significantly affect growth.

In line with prior studies, VC financing has a positive impact on the growth of NTBFs. The coefficients of the three lagged VC variables are all positive and significant. Conversely, the variables measuring the human capital of NTBFs' founding teams, the index measuring regional infrastructures and the five sectoral dummies are not statistically significant at conventional confidence levels.

In Model 2 we insert the independent variables in the model specification. The impact of the size of the research staff of local universities, and the quality and commercial orientation of the knowledge produced by these universities on the growth of NTBFs is negligible. In fact, the null hypothesis that the corresponding variables have no effect on firm growth cannot be rejected at conventional confidence level ($\chi^2(6) = 6.13$).

Table 6 presents the estimates of the equation including the interactive terms of all the variables listed in the first column of Table 5 with *DASU*. Even though the findings are somewhat weaker than expected, they suggest that, consistently with our predictions, the characteristics of local universities have different effects on the growth of ASUs and other NTBFs. In fact, as is apparent from the first Wald tests at the bottom of Table 6, while the null hypothesis that the characteristics of local universities jointly have no effects on the growth rates of non-academic NTBFs cannot be rejected ($\chi^2(6) = 6.22$), the same hypothesis indeed is rejected for ASUs ($\chi^2(5) = 15.25$). Similarly the null hypothesis that the coefficients of the corresponding interactive terms be null is also rejected ($\chi^2(5) = 16.08$).

Let us now consider in detail the theoretical hypotheses developed in Sect. 2.3. Hypothesis H1a is not supported by our results. In fact, the coefficient of $ResearcherDensity_{t-1} + DASU \times ResearcherDensity_{t-1}$ is positive, as we hypothesized, but not significant. The results regarding research quality are mixed. On the one hand the estimates suggest that, consistently with hypothesis H2a, ASUs greatly benefit from the quality of the scientific knowledge produced by local universities in engineering fields, with the coefficient of $DNoBio \times EngQuality + DASU \times DNoBio \times EngQuality$ being positive and significant at 5%. On the other hand, the coefficient of $DBio \times ScienceQuality + DASU \times DBio \times ScienceQuality$ is positive, but insignificant, while the one of $DNoBio \times ScienceQuality + DASU \times DNoBio \times ScienceQuality$, in contrast with H2a, is negative, but again not significant. Lastly, the results regarding commercial orientation confirm our expectations. Consistently with H3a, the greater the commercial orientation of university research, the lower the growth rates of local ASUs, as is apparent from the negative coefficient of $\%PrivateBudget + DASU \times \%PrivateBudget$, significant at 5%. Conversely, as to non-academic NTBFs, *%PrivateBudget* exhibits a positive (though not significant) coefficient. We interpret this result as a signal that the commercial orientation of local academic institutions prevents ASUs from having access to the results of university research thus negatively affecting the growth of these firms. Conversely, the estimates provide some (admittedly weak) indication that the greater the share of research funded by private organizations out of the total research budget of local universities, the more positive might the impact of this research be on the growth of non-academic NTBFs. We also inserted two squared terms ($Sq\%PrivateBudget$ and $DASU \times Sq\%PrivateBudget$) into the model specification so as to check whether a curvilinear specification better fits the data. The corresponding coefficients were insignificants (the estimates are available from the authors upon request).

Let us now consider the hypotheses on the differences between ASUs and other NTBFs. First, the argument that the size of the research staff of local universities has a more positive effect on the growth rates of ASUs than on those of other NTBFs (H1b) is not supported: the coefficient of $DASU \times ResearcherDensity_{t-1}$ is positive but not significant. Second, the coefficients of $DASU \times DNoBio \times ScienceQuality$, $DASU \times DBio \times ScienceQuality$, and $DASU \times DNoBio \times EngQuality$ are positive as was predicted by hypothesis H2b, but only the latter one is significant (at 5%). Altogether these results provide an admittedly weak indication that ASUs' superior ability to detect, absorb, and effectively use the knowledge produced within local universities strengthen the contribution of university research to firm growth. Third, the coefficient of $DASU \times \%PrivateBudget$ is negative and significant at 5%. In line with hypothesis H3b, the commercial orientation of university research has a more negative effect on the growth rates of ASUs than on those of other NTBFs.[13]

In order to evaluate the magnitude of the effects of these characteristics of local universities on the growth of ASUs and other NTBFs we performed the following simple exercise. First, we calculated the predicted size at the fifth year of existence of an ASU and a non-academic NTBF located in a province where the research quality and commercial orientation of local universities were equal to the means across our sample. For this purpose we used the coefficients reported in Table 6 and we set all the dummy variables to their median and all the remaining variables to their mean. We used these values as the benchmark and compared them respectively with the estimated size at the fifth year of existence of an ASU and a non-academic NTBF located in a province where the research quality of local universities is high (i.e., equal to the 90th percentile; again all the remaining continuous variables were set to their mean and the dummy variables to their median). The difference with respect to the benchmark appears large for the ASU and marginal for the other NTBF: the size results 171% greater than the benchmark for the ASU, and just 6% smaller for the other NTBF. Finally we compared the benchmark with the estimated size of an ASU and a non-academic NTBF located in a province where the commercial orientation of local universities is low (i.e., equal to the 10th percentile). In this latter case the size resulted 56% greater than the benchmark for the ASU, and 13% lower for the other NTBF. This calculation suggests that the effects of both research quality and commercial orientation on the growth of ASUs are of great economic magnitude.

Let us now briefly consider the control variables. As to the five Gibrat's law variables, a Wald test on the coefficients of the five interactive terms which include the dummy *DASU* rejects the null hypothesis that the dependence of the growth rates of ASUs and other NTBFs on firms' size and age be the same ($\chi^2(5) = 1267.95$). As to non-academic NTBFs, the coefficient of $LSize_{t-1}$ is significantly smaller than 1 (and higher than 0) while the coefficient of $LSize\^2_{t-1}$ is positive and significant. Hence, the relation between firm size and firm growth is U-shaped for these firms. Conversely, the coefficient of $LSize_{t-1} + DASU \times LSize_{t-1}$ is significant and above unity, while the one of $LSize\^2_{t-1} + DASU \times LSize\^2_{t-1}$ is not significant. This finding is opposed to the stylized fact highlighted by the empirical literature on Gibrat's law (see Evans 1987a, b; Hart and Oulton

[13] It is fair to acknowledge that 95 out of the 487 NTBFs included in our sample are located in provinces where there were no universities in the period under consideration. For these firms all the variables measuring the characteristics of local universities are always equal to zero over the time horizon 1994–2003. As a check for robustness, we reestimated the models using only the data on the 392 firms located in provinces where at least one university existed. The results are almost unchanged. They are available from the authors upon request.

1996; Sutton 1997; Caves 1998) that smaller firms tend to grow faster than larger ones. Second, while age seems to have no effects on the growth rates of non-academic NTBFs (neither $LAge_{t-1}$ nor $LAge\text{^}2_{t-1}$ are significant), it significantly affects those of ASUs. More specifically, the coefficient of $LAge_{t-1} + DASU \times LAge_{t-1}$ is negative while the one of $LAge\text{^}2_{t-1} + DASU \times LAge\text{^}2_{t-1}$ is positive and both are significant at 5%. So, the growth rates of ASUs first decrease and then increase with firm age.

As to the other controls, the coefficients of the interactive terms relating to: (i) the variables capturing VC financing, (ii) the variables measuring the human capital of firms' founding teams, (iii) the measure of the level of economic development of the province where sample firms are located, and (iv) the sectoral dummies are not statistically significant at conventional levels as is shown by the Wald tests at the bottom of Table 6. In other words, we were not able to detect any significant differences in the impact of these variables on the growth rates of ASUs and other NTBFs. Therefore, we simplified the specification of the model dropping the interactive terms between *DASU* and these control variables. Of course we could not exclude the Gibrat's law variables as is shown by the Wald test at the bottom of Table 6. The results of these estimates do not differ from those discussed above (they are available from the authors upon request).

6 Concluding remarks

In this paper we aimed at examining empirically the impact of university research on the growth of individual local firms. More specifically, we analyzed the effects on academic start-ups' growth rates of the characteristics of local universities (i.e., universities located in the same provinces as focal firms); we also examined the differences with other NTBFs. We argued that the characteristics of local universities influence firms' growth potential. To what extent this potential is realized depends on firm-specific characteristics. ASUs exhibit stronger ties in the research environment than other NTBFs, and are better able to detect and absorb academic knowledge; hence, we expected the growth rates of ASUs to be more sensitive to the characteristics of local universities than those of other NTBFs. In the empirical part of the work, we studied the determinants of firm growth within a sample composed of 48 ASUs and 439 non-academic NTBFs that operate in Italy in both manufacturing and service high-tech sectors. Sample firms were observed from 1994 to 2003. Their growth rates were analyzed through the estimation of an augmented Gibrat law dynamic panel data model.

The results of the econometric estimates provide evidence of a substantial impact of university research on the development of local ASUs. In particular, higher research quality in the engineering field positively contributes to the growth of ASUs. This result is in line with the view that ASUs are endowed with sufficient absorptive capacity and social contacts in the research environment so as to be able to benefit from academic knowledge. Instead, research quality does not influence the growth of non-academic NTBFs. Quite interestingly, the estimates also suggest that the commercial orientation of university research may have negative consequences on the growth of local companies as it may reduce the knowledge available for absorption by the companies better able to exploit it. In particular, the commercial orientation of university research has a clear negative impact on the growth of ASUs, while the effect is negligible for non-academic NTBFs. Conversely, faculty size has a negligible impact on the growth of both ASUs and non-academic NTBFs.

While describing the results of the study, a number of limitations are to be noted as they open up interesting avenues for future research. The main limitations of the study come from the characteristics of the dataset. The most serious problem of this work is the failure to control for possible unobserved heterogeneity. In particular, the positive impact of university quality on the growth of ASUs may depend on unobserved factors. Academic founders are assumed to learn from their experiences within their parent research organizations, and to exploit such knowledge in their own firms. It is also natural to assume that higher quality universities produce more valuable knowledge, thus researchers from these organizations can more effectively draw on their experiences to enhance the growth of the ASUs they found. Hence, ASUs from higher quality universities are likely to exhibit higher growth rates than the remaining ASUs.[14] In this work we cannot disentangle this latter effect from the one of the quality of the research performed in local universities. In order to properly distinguish the two effects we would need for each ASU both a measure of the quality of the parent university at firm foundation and one of the quality of local universities in subsequent years. Unfortunately these data were not available at a suitable aggregation level.

Second, as we mentioned above, the findings are weaker than expected. This possibly is a consequence of the low number of ASUs included in our sample. Thus in order to strengthen our conclusions extending the dataset seems warranted. One may also wonder whether the results illustrated in this paper can be generalized. These results might clearly be influenced by the specific institutional setting in which Italian NTBFs are embedded. Similarly, the 10-year period under consideration might exhibit specific characteristics relating to such aspects as the policy of research organizations towards knowledge diffusion. Therefore, these results wait for further corroboration from replications of this study in different countries and time periods.

A third limitation possibly regards the geographic unit of analysis. Even though the extant studies on the effects of university research on Italian companies usually use the province as the unit of observation (Piergiovanni et al. 1997; Rodríguez-Pose and Refolo 2003), it would be interesting to extend this analysis to understand what scale of geographic aggregation is the most appropriate to investigate the contribution of university research on local firm growth.

Besides the limitations of this study we think that altogether these results both contribute to the extant literature and have interesting policy implications. In terms of literature development, we extend previous empirical works on the effects of university research on local companies by showing that, besides contributing to firms' innovation performances and influencing firms' localization choices, university research may also affect the growth of individual local firms. However, the mere presence of a university in a province is not sufficient to stimulate the growth of the companies located in the same province. Our results clearly indicate that the effect on growth depends on the characteristics of both local universities and recipient firms.

Prior research had already recognized that knowledge externalities from university research and their effects within the private sector are influenced by several characteristics of the universities close to focal firms. Conversely, the role of the specificities of recipient firms had not been explored yet. In accordance with the "absorptive capacity" literature (Cohen and Levinthal 1989, 1990; Zahra and George 2002), we documented that ASUs because of their "genetic characteristics" (Colombo and Piva 2008a), are better positioned than other NTBFs to detect, absorb, and utilize the scientific knowledge generated by local universities. It would be interesting to highlight whether and how NTBFs that are not endowed with favorable genetic characteristics can exploit this knowledge. For instance,

[14] For a similar argument in a different context see Klepper (2007).

one may wonder whether the establishment of long-term collaborative relations with local universities may have similar beneficial effect on firm growth.

Let us now focus on the policy implications of this study. First, as was said above, our findings suggest that ASUs are better equipped than other NTBFs to exploit the results of academic research. This makes them appealing alliance partners or acquisition targets. As a corollary, ASUs may favor the circulation in the private sector of valuable knowledge generated within universities, playing a crucial bridging role (for a similar view see Stuart et al. 2007). In fact, ASUs can easily detect the source of this knowledge, translate it, and transfer it to their customers, alliance partners and to the firms that may acquire them, thus allowing the successful exploitation of university research results by other companies. Through this indirect mechanism, academic knowledge would affect also the growth of companies that are endowed with smaller absorptive capacity and thus are unable to directly profit from the proximity of universities. Hence, in order to enable more widespread exploitation of the knowledge produced within universities, university managers should not only encourage academic personnel to create new ventures, but help these new ventures to establish collaborations with other companies.

Second, our study suggests that although university cooperation with private companies through contract research agreements may be an effective mechanism to commercialise research results, it could inhibit knowledge transfer to other local companies and thus hinder the generation of positive externalities from university research. This negative consequence of commercial orientation needs to be duly taken in consideration by university managers while designing and assessing the effectiveness of policy instruments aimed at regulating the interactions between university and the private sector.

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