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Technology transfer offices and academic spin-off creation: the case of Italy

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Abstract Over the past decades, university-industry relationships have become an important subject due to the essential role played by technological progress in the economic development of countries. From a theoretical point of view, several studies have shown the close relationship between investments in research and innovative activities of universities and the economic growth of specific territories. Indeed, the strong linkages between universities and a country's production system encourage the process of technology transfer and the commercial use of the research results. For this reason, the European Union has implemented a series of measures to promote the adoption of research findings in the real economic and social context, strengthening the linkages between universities, industries and government. As a starting point for enhancing this link, specific mechanisms have been devised by universities. In particular, technology transfer offices (TTOs) have been created to stimulate and encourage the dissemination of the research outcomes, translate them into practise, and facilitate their interrelations with the other two agents of the innovation systems: industries and government. Within this context, the present paper aims to gain knowledge on the determinants of spin-off creation in Italy with special attention to the role played by university TTOs. Specifically, an econometric probability model has been built merging the extant literature into four distinct strands. The analysis, based on the NetVal indicators and primary data survey, has allowed us to assess the Italian experience at an aggregate and disaggregate level.

Keywords Technology transfer · Spin-offs · Academic entrepreneurship

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1 Introduction

Technology transfer, i.e., a transfer of knowledge from universities to industry, has gained considerable attention in recent years because knowledge produced in universities can spur business innovation, foster competitiveness, and promote economic and social development. Over the past decade, there has been increasing political pressure in many European countries to transfer research findings to the market and to strengthen the linkage among universities, industries and governments. In this context, several European universities have added a new mission to their agenda. In addition to the traditional teaching and research activities, they are pursuing a higher interaction with society by bringing research results to business. This novel mission and the increased integration between researchers and industry have led to the term "entrepreneurial university" (Branscomb et al. 1999). Technology transfer and cooperation between universities, industries and the government generate benefits by representing a source of funding for universities (Etzkowitz et al. 2000; Miyata 2000; Martin 2003; Mustar et al. 2008; Mustar and Wright 2010), a source of innovation for industries, and a source of economic development for policy makers (Guldbrandsen and Smeby 2005; Muscio 2008, 2010). Cohen et al. (1998), for instance, hypothesised that universities are primarily motivated to collaborate with industry because of their need to raise additional financial resources to support their research and other activities. This is particularly important in light of the present context of limited public funds as indicated by the European Commission (2009).

In order to diffuse an entrepreneurial culture of research, encourage the dissemination of scientific outcomes and support scientists through the stages of commercialisation of the results of their study, several universities have established technology transfer offices (TTOs). The first TTOs were set up in the US, as a consequence of the Bayh-Dole Act in 1980. The act gave universities that conducted federally funded research the right to take title to any resulting patents as long as they were willing to patent and commercialise them. Thereafter, TTOs spread in several European countries.

In this context, the present study aims to analyse the TTO experience in Italian universities by investigating their role in promoting the economic valorisation of research and their contribution to the creation of spin-offs, defined as "new companies founded to exploit a piece of intellectual property created in an academic institution"[1] (Shane 2004, p. 4). Italy is an interesting case to study for two main reasons. Firstly, the country has a dual economy that presents special traits compared to other industrialised countries, namely that productive specialisation is more oriented towards traditional sectors than high-tech sectors, which generally characterise worldwide academic spin-offs. Therefore, the understanding of factors behind spin-off formation could help policy makers better address their interventions, in order to stimulate investments towards technology-based entrepreneurship and foster international competitiveness. Secondly, few studies have analysed the links between Italian technology transfer offices and spin-off creation. To our knowledge, Fini et al. (2009) have investigated the factors that influence the creation of

[1] There is no standard definition of a spin-off. A narrow definition considers a spin-off as any new firm that includes a public sector or university employee as a founder. A broader meaning includes employee founders, licensees and firms in which the institution holds equity. The broadest definition comprises employees, licensees, equity, students/alumni, incubator firms, and other.

new companies in a specific Italian region, Emilia-Romagna. They found that “environmental influences”, “university support mechanisms” and “individual level related factors” affect the creation of new companies in the region. There are another two fields of study on Italy that have considered a different perspective of analysis, focusing mainly on spin-off growth or TTOs activities and performance. The work by Colombo et al. (2010), which belongs to the first type of analysis, investigated how the characteristics of local universities affect the growth of academic high-tech companies, measured in terms of variation in the number of employees, and how the growth rate of these academic firms differs from the growth rate of other non-academic firms. In particular, Colombo et al. (2010) have evaluated how a group of explanatory variables, including a dummy—which stands for academic start-ups—has impacted the firm’s size. Conversely, we focus on the drivers that are likely to push the establishment of new firms. Therefore, differently from Colombo et al. (2010), spin-offs are our dependent variable and not an explicative variable of firm dimension. The studies by Piccaluga et al. (2007) and Balderi et al. (2010), which belong to the second group of analysis, have discussed the strategies and actions of TTOs by evaluating their role in terms of several indicators, such as patenting activities and licensing commercialisation. Along this line, Muscio (2010) has investigated the extent of TTO involvement in university-industry research collaborations by estimating the effects of the presence of a TTO in a university on the frequency of collaboration and identifying the factors that determine university collaboration with industry.

The present study thus takes a step forward in the analysis of Italian TTOs and spin-off creation, merging different strands of the empirical literature that is strongly focused on the US case, and providing a broader view on the drivers of new entrepreneurial activities at national and regional levels. Moreover, the study is based on a wider availability of data collected through a direct survey carried out in March–April 2011.

Specifically, the existing literature identifies several factors explaining the creation of new academic start-ups. We distinguish four main strands that comprise different arrays of variables affecting spin-off formation.

A first set of variables refers to knowledge externalities and geographical location. In particular, Arrow (1962), Romer (1990), Jaffe (1989) and Acs et al. (1992, 1994) have shown that knowledge generated by R&D in universities and in private corporations spills over to other firms and stimulates innovative activities. The spatial pattern of knowledge, i.e. the importance of geographical location, plays a relevant role. Studies on the US by Jaffe (1989), Krugman (1991), Feldman (1999), among others, have demonstrated that innovation in private sectors is strongly and positively affected by proximity to universities. This knowledge-flow tends to be geographically bound within the area where universities are located. Similar evidence has been found for the Euro Area countries, such as France (Piergiovanni and Santarelli 2001), Germany (Herrigel 1993) and Italy (Piergiovanni et al. 1997). In this framework, works by Audretsch and Lehmann (2005), Varga (2000), and Rodriguez-Pose and Refolo (2003) have highlighted that firms tend to concentrate in proximity of universities, as they find it easier to have access to the knowledge generated by the university.

A second array of factors that influences the creation of academic spin-offs is related to the specific characteristics of the universities (O’Shea et al. 2005; Powers and Mc Dougall 2005; Rodriguez-Pose and Refolo 2003; Colombo et al. 2010; Mustar and Wright 2010). Explicitly, the greater the skills, and the number of scientists within a university, and the higher the funding—which includes government support mechanisms and policy initiatives to develop venture capital—the greater the growth potential of new start-ups. For example, Lockett and Wright (2005) found the number of spin-off companies created from UK universities to be positively associated with R&D expenditure, i.e. funding for R&D activities within the university. Belong to this stream, also the quality of university researchers and/or the reputation of a given university. According to Deeds et al. (1998) and Zucker et al. (1998) both elements have an important impact on spin-off creation.

A further group of factors prone to foster academic spin-offs are linked to local economic and social environment characteristics, including the opportunities offered by the local industrial sector, the degree of infrastructure, and the entrepreneurial and business environment, including the influence of business incubators (Bahrami and Evans 1995; Di Gregorio and Shane 2003; O'Shea et al. 2005; Fini et al. 2009). For instance, Kenney (2000) has shown that Silicon Valley continues to be successful because it has all the "regional infrastructure elements" needed to create new industries. Feldman and Francis (2003) argued that the weak entrepreneurial infrastructure of a region significantly hampers the promotion of academic entrepreneurship.

A final set of academic spin-off determinants refers to the resources and capabilities of TTOs (Hague and Oakley 2000; Carlsson and Fridh 2002; Gómez Gras et al. 2008). In this perspective, O'Shea et al. (2005) and Markman et al. (2005) have suggested that the years of experience of a given university or TTO facilitate spin-off creation. This is because more years of experience can lead to an accumulation of heterogeneous knowledge, generating improved results related to spin-off creation in the present and in the future (Gómez Gras et al. 2008). O'Shea et al. (2005) also find a positive and statistically significant correlation between the number of TTO employees and the spin-off creation rate. Conversely, Lockett and Wright (2005) and Di Gregorio and Shane (2003) find only partial evidence of O'Shea's outcomes.

Taking into account these different strands of the literature, the present study builds a novel probability econometric model with the scope to identify the determinants of academic spin-offs and the probability of the success or failure of new academic companies for the whole country, with emphasis on the Northern-Central and Southern parts of Italy.

The rest of the paper is organised as follows. Section 2 provides the outlook on the main characteristics of Italian technology transfer offices. Section 3 focuses on the creation of public research-based spin-offs. Section 4 offers an econometric analysis of the contribution of TTOs and other variables to the creation of new companies and discusses the results. Section 5 concludes the paper.

2 Main features of the Italian technology transfer offices

Historically universities have transferred technology using classical methods such as publications, student education, conferences, and workshops. Technology transfer through intellectual properties, licensing, patenting, the creation of start-up companies, business incubators, and technological parks added a new educative dimension and offered additional research opportunities for academicians and students (COGR 2000). Therefore, technology transfer offices have been included in the university organisational structure or have been established as an independent structure outside a university, but operating in its name, in order to facilitate the passage of knowledge and know-how from academia to business. Formally, TTOs in Italy were established by national law D.L. 27/7/1999 n. 297 and then regulated by the D.M. 8/8/2000. Based on data extracted from the annual survey by NetVal[2] (2009) that collected data from 58 universities covering 62.9% of the total

[2] Netval is the Italian University Network for the Valorisation of Research (see http://www.netval.it).

number of Italian universities, 79.6% of the total number of students and 83.3% of researchers and professors, it is possible to analyse the evolution of TTOs in the past decade. Specifically, Italian universities have progressively increased the number of TTOs over time: in 2008 their number rose to 58 TTOs from 5 TTOs in 2000. The highest year-on-year percentage changes were recorded in 2001 and 2005, when the number of offices grew by 100 and 60% respectively from the previous year. The lowest percentage raise was registered in 2008 (+3.6%).

The specific policies of technology transfer set out by TTOs mainly address the creation of spin-offs (31.39% in 2008 vs. 30.18% in 2004), patenting (28.47% in 2008 vs. 31.03% in 2004), and cooperation activities with industries (25.55% in 2008 vs. 24.99% in 2004), less importance is given to the resolution of controversies (10.94% in 2008 vs. 6.90% in 2004) and copyright properties (3.66% in 2008 vs. 6.90% in 2004). The percentage quota of policies devoted to the creation of spin-offs, cooperation activities with industries, and resolution of controversies increased from 2004 to 2008.

Likewise, between 2003 and 2008, the university's investments via TTOs in techno-science parks and business incubators soared notably. Specifically, while in 2004 only 44.6% of the sample ($TTOs_{2003} = 56$) was taking part to scientific parks, in 2008 this value reached 62.5% ($TTOs_{2008} = 57$); similarly the contribution to the creation of business incubators was 23.3% in 2004 against 41.5% in 2008. These values show that Italian universities are becoming more entrepreneurial than they used to be.

3 The creation of public research-based spin-offs

As mentioned, the main policy programmes carried out by TTOs are devoted to creating spin-offs. Spin-offs act as a significant medium in the technology transfer process between public and private sectors. Public research-based spin-offs are generally understood to be small, new technology-based firms whose intellectual capital originated in universities or other public research organisations. These firms are thought to contribute to innovation, growth, employment, and revenues. They are perceived as flexible and dynamic, giving rise to novel fields and markets, and playing a critical role in the development of high-technology clusters (OECD 2001). Since spin-offs are considered an important driving force in renewing industrial structures, and a way of modernising industry, TTOs are helping their creation. Table 1 shows the number of research-based spin-offs created by universities and other public institutes. Before 2000, there were only 89 spin-offs in Italy. This number increased to 806 in 2009, a 524% increase between 2000 and 2009.

Regarding the geographical location of the spin-offs in 2009, 190 were located in the northwest (23.6%), 214 in the northeast (26.6%), 226 in the central part of Italy (28%) and 176 in the south, including the isles (21.8%) (Netval 2010). The region of Emilia-Romagna recorded the highest percentage of active start-ups (14%), followed by Lombardy (12.3%), Tuscany (11%) and Piedmont (8.1%).

In 2004, approximately 41% of spin-offs was created by the most efficient university's TTOs (top 5) (Table 2). This percentage has decreased over time to reach 32% in 2008. By calculating the linear trend of the top 5 quota,[3] this descending tendency is plain. Specifically, the negative trend should indicate a process of relative convergence between the

[3] The linear trend has an equation $y = -0.0267x + 0.4476$ with a $R^2 = 0.8986$.

Table 1 Public research-based spin-offs in Italy

	Before 1979	1980–1989	1990–1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N. of spin-offs	5	18	89	129	159	189	244	325	411	527	665	779	806
% Quota	0.62	2.23	11.04	16.00	19.73	23.45	30.27	40.32	50.99	65.38	82.51	96.65	100

Source: Own elaborations on NetVal data

Table 2 Number of spin-offs: top 5 vs. total number of TTOs

	Top 5	All
2004	31	76
2005	32	77
2006	39	106
2007	42	128
2008	35	110

Source: Own elaborations on NetVal data

top 5 group and the rest of the Italian TTOs. Put differently, a process of "catching-up" from the less efficient TTOs toward the most efficient ones has started.[4]

Italian research-based spin-offs are more widespread in ITC, energy and environment, and life science sectors. The aero-spatial engineering and the cultural heritage sectors have the lowest percentage quota.[5]

It is not clear whether the fact that spin-offs are mainly in the information technology and life science fields is due to the low costs of entry, small scale economies, the closeness of industry to research, or the fact that it is possible for firms to act as research consultants while developing new products and services. Clearly, not all academic disciplines are equally able to generate new firms. Considering only the spin-offs created by universities with a formal and established TTO, 716 firms were registered by 31.12.2009. This means that 88.83% of the public research based spin-offs have originated by universities' activities. The Polytechnic University of Turin has set the record for the number of spin-off companies it helped to establish. Specifically, it facilitated the formation of 49 new businesses, covering approximately 6% of total spin-offs. The University of Bologna, and the University of Perugia follow soon behind (Table 3).

4 Empirical evidences of technology transfer and spin-offs: the case of the Italian TTOs

To better evaluate the contribution of the Italian TTOs and other factors to the creation of spin-offs, a logit analysis has been pursued using data collected through a direct survey carried out in March–April 2011. The logistic regression technique allows us to specify the probability that the number of spin-offs increases as a function of a set of explanatory variables. Specifically, the dependent variable, the total variation in the number of

[4] Making an international comparison, Italy shows nearly the same performance in terms of new spin-offs (110 spin-offs created in 2008) as Spain (102) and Japan (140), but its policy of creating new firms from the public research base has been less active than China, the U.S. and the U.K. By 2008, excluding China, whose statistics are not directly comparable due to aggregation problems, the U.S. is the leader in establishing new research spin-offs (555). Among these 555 spin-offs, several have developed a very high-profile and have become very successful; for instance, Silicon Graphics, Genentech, Hewlett Packard, Polaroid and the Internet search engine Google—many of which originated at Stanford University—are all examples of university start-ups, which have helped to attract new students, faculty, and funding (OECD 2009). Trailing the U.S. is the U.K with 256 spin-offs.

[5] In detail, the analysis of the percentage quotas of sector activities shows that in 2009, 33% of research-based spin-offs are devoted to ITC, 16% to energy and environment, 15% to life science, 10% to electronics, 7% to bio-medical research, 7% to innovation services, 6% to factory automation, 5% to nanotechnology, 3% to cultural heritage goods and 1% to aero spatial engineering (own elaborations on NetVal data).

Table 3 University spin-off companies in Italy (31.12.2009)

	N	%		N	%		N	%
Polytechnic University of Turin	49	6.84	University of Salento	13	1.82	University of Molise	4	0.56
University of Bologna	42	5.87	University of Florence	13	1.82	University of Messina	4	0.56
University of Perugia	35	4.89	University of Parma	12	1.68	University of Foggia	4	0.56
University of Padua	31	4.33	Polytechnic University of Bari	12	1.68	University of Verona	3	0.42
University of Udine	30	4.19	University of L'Aquila	11	1.54	University of Trento	3	0.42
University of Cagliari	30	4.19	University of Milan-Bicocca	11	1.54	Catholic University	3	0.42
Sant'Anna School of Advanced Studies of Pisa	29	4.05	University of Oriental Piedmont	10	1.40	University of Bergamo	3	0.42
Polytechnic University of Milan	28	3.91	University of Catania	10	1.40	University of Salerno	3	0.42
University of Milan	27	3.77	University of Naples "Fed. II"	10	1.40	University of Catanzaro	3	0.42
University of Pisa	26	3.63	University of Palermo	9	1.26	University of Tuscia Viterbo	2	0.28
Marche Polytechnic University	24	3.35	University of Brescia	8	1.12	University of Cassino	2	0.28
University of Calabria	23	3.21	University of Sassari	7	0.98	University of Basilicata	2	0.28
University of Ferrara	22	3.07	University of Sannio	7	0.98	Ca' Foscari University of Venice	1	0.14
University of Bari	17	2.37	University of Pavia	7	0.98	University of Teramo	1	0.14
University of Siena	16	2.23	University of Camerino	7	0.98	Second University of Naples	1	0.14
University of Modena and Reggio-Emilia	16	2.23	University of Urbino	6	0.84	University of Chieti-Pescara	1	0.14
University of Rome "Tor Vergata"	15	2.09	University of Milan "San Raffaele"	5	0.70	Free University of Bozen	1	0.14
University of Genoa	15	2.09	SISSA Trieste	5	0.70	The University of Insubria	1	0.14
University of Trieste	14	1.96	University of Turin	4	0.56			
University of Rome "La Sapienza"	14	1.96	University of Rome 3	4	0.56	Tot. Univ Spin-offs	716	100

Source: Elaborations on NetVal Survey (2009)

spin-offs between 2008 and 2009 (ΔYi), is a dichotomous variable that takes the value of 1 if the total number of spin-offs rise compared to the previous year, 0 if it is less than or equal to the previous year. In formal terms:

$$p_i = \Pr(Y_i = 1) = F(x_i\beta)$$

where p_i is the probability that the dependent variable $Y = 1$ for individual i (i.e. TTO), $F(\cdot)$ is the logistic cumulative distribution function, x_i is the set of explanatory variables thought to affect p_{i}, and β are the regression coefficients. The explanatory variables are divided into four groups, merging the different strands of the extant literature as identified in the introduction, and expressed as follows:

$$\Pr(Y_i = 1) = F(\beta_0 + \beta_1\, BUD_i + \beta_2\, AGE_i + \beta_3\, EMPL_i + \beta_4\, X\_UNIV_i + \beta_5 Z\_REG_i + \beta_6\, Y\_ENV_i)$$

$i = 1 \ldots n$ where i is the ith TTO, $N = 58$.

In particular, the first set of explanatory variables takes into account the characteristics of TTOs and includes the variables BUD_i, AGE_i and $EMPL_i$. The variable BUD_i indicates the annual budget available for each TTO in 2008 in hundred thousands of Euros. It measures the total financial resources available for each TTO and includes university funds explicitly designed for the office management, self-financing from patents, research projects and cooperation contracts with industry. The variable AGE_i is the age of a TTO since its foundation. As previously mentioned, technology transfer is a relatively recent experience in Italy and all TTOs are very young. The variable $EMPL_i$ indicates the total number of full-time workers employed at TTO's.[6]

The second group of explanatory variables included in the vector X controls for a university's characteristics. It considers the size of each institution measured by the total number of enrolled students and the ratio between the number of researchers and the number of professors employed in scientific areas.

The third group Z controls for the specific regional variables. Explicitly, two dummy variables (D_{North} and D_{Centre}) identify the location of the university or TTOs into three levels (north, centre, south). D_{North} takes a value of 1 if the office is located in the north, 0 otherwise; D_{Centre} takes a value of 1 if the office is located in the centre, 0 otherwise. The south is, therefore, the reference category, i.e., setting both D_{North} and D_{Centre} to 0 indicates the presence of a university or TTO in southern Italy. In this way, the south serves as the baseline or reference level for the north and the centre.

The fourth group, the vector Y, identifies the economic and social environment, specifically, it includes the number of workers employed in R&D per 1,000 residents in the region where the TTO is located; public expenditures in R&D as a percentage of GDP, and social cohesion measured by a legality and security index. The descriptive statistics and all data sources are reported in the Appendix.

Table 4 shows the estimation results of the logistic regression[7] parameters, the standard errors, the Wald[8] statistic, the p-values and the odds ratio of the logistic regression, which

[6] The number of national and international patents, indicating formal technology transfer, was initially considered as an additional explanatory variable. However, it has not been included in the final model since the correlation matrix showed high correlation between the number of patents and the number of students and the number of patents and age.

[7] The logistic regression has been expressed in its exponential form, since there is a disadvantage in using a linear form. Namely in the latter case the maximum likelihood estimates are expressed in a logit scale and therefore are not directly interpretable as probability.

[8] The Wald test, which calculates a statistic $z = \beta\text{^}/SE$, is used to test the significance of each coefficient in the model. The squared value of z provides the Wald statistic with a Chi-square distribution.

Table 4 Econometric estimates—logistic regression

	β	SE	Wald	p value	Odds ratio e^{β}
Budget	1.000	0.558	3.20	0.073	2.71
Age	−0.003	0.165	0.00	0.985	0.99
Employees	1.018	0.426	5.71	0.017	2.77
Size	−0.988	2.122	0.22	0.641	0.37
Research./prof.	0.147	0.089	2.72	0.100	1.16
D_{North}	5.806	3.557	2.65	0.100	
D_{Centre}	2.378	2.348	1.02	0.311	
R&D workers	1.606	0.854	3.53	0.060	4.98
Public exp	1.030	0.456	5.10	0.024	2.80
Social cohesion	0.019	0.084	0.05	0.816	1.02
Constant	−11.445	5.428	4.45	0.035	
Log-likelihood: −20.497	Pseudo $R^2 = 0.46$				
LR Chi-square(10) = 35.03	$N = 58$				
Prob > Chi-square = 0.000					

coincides with the exponential value of estimated parameters.[9] Given the non-linearity of the first-order conditions with respect to parameters, a solution of numerical approximation is adopted that reaches the convergence after six reiterations. The maximised value of the log-likelihood function is −20.497.

LR Chi-square (10) is the asymptotic version of the F test for zero slopes.[10] The p-value allows the rejection of the null hypothesis that all the model coefficients are simultaneously equal to zero. Therefore, the model as a whole is statistically significant. To avoid the risk of multicollinearity among variables, the computed bivariate correlation test has been carried out. It does not reveal any linear relation among variables. To further corroborate this result we computed two additional measures, namely the “tolerance” (an indicator of how much collinearity a regression analysis can tolerate) and the VIF (variance inflation factor-an indicator of how much of the inflation of the standard error could be caused by collinearity) (Tables 13 and 14 Appendix). Since both measures were close to 1 for the considered variables, we can exclude any multicollinearity.

Turning to the analysis of the estimates, given that the parameters of the logistic regression are not directly interpretable as marginal effects, these have been explicitly calculated.[11] The results are reported in Table 5.

In line with the studies by O’Shea et al. (2005) and Lockett and Wright (2005), our empirical findings show that, with respect to TTO characteristics, both the budget and the

[9] We have also considered non-linear effects associated with AGE, EMPLOYEES and SIZE by including the quadratic form of the mentioned variables. When we run the logit regression, only $EMPLOYEES^2$ was significant at 1% level, while neither AGE^2 nor $SIZE^2$ were significant. However, when we computed the marginal effects after logit, none of the three quadratic explanatory variables was significant.

[10] This is the likelihood ratio Chi-square with 10 degrees of freedom. One degree of freedom is used for each predictor variable in the logistic regression model. The likelihood ratio Chi-square is defined as $2(L_1 - L_0)$, where L_0 represents the log likelihood for the constant-only model and L_1 is the log likelihood for the full model with constant and predictors.

[11] For each explanatory variable the marginal effect has been calculated by computing the difference between the probability of success including all the predictors and the probability of success excluding the considered explanatory variable.

Table 5 Marginal effects—logistic regression

	dy/dx	SE	z	*p*-value
Budget	0.148	0.079	1.88	0.060
Age	−0.000	0.024	−0.02	0.985
Employees	0.151	0.050	2.98	0.003
Size	−0.147	0.327	−0.45	0.651
Research./prof.	0.021	0.015	1.47	0.141
D^{a}_{North}	0.711	0.313	2.27	0.023
D^{a}_{Centre}	0.452	0.242	1.86	0.062
R&D workers	0.238	0.130	1.84	0.066
Public exp	0.153	0.077	1.98	0.048
Social cohesion	0.002	0.012	0.23	0.814

[a] dy/dx is for discrete change of dummy variable from 0 to 1

number of employees are statistically significant at the 10 and 1% level, respectively, with the expected positive sign. The positive marginal effects indicate that a rise in each explanatory variable increases the probability of creating spin-offs. In particular, an increase in the TTO's annual budget by 100,000 Euros (a unit) rises the probability of spin-offs by approximately 0.15; hiring an additional worker increases the probability by 0.15. In terms of the odds ratio, for a budget increase by 100,000 Euros the odds of creating a new start-up increases by 171%, holding the other variables constant. Likewise, a unit increase in qualified employees raises the odds by 177%, i.e., TTOs that are exposed to qualified workers are more than two times ($e^{1.018}$) likely to increase the number of spin-offs than other TTOs. From these results it is clear that a high amount of financial resources and full-time employees well specialised in technology transfer and intellectual property rights are important factors for the growth of spin-offs. It is encouraging to note that both the average budget and the average number of employees per TTO are constantly increasing.[12] The age of the office, on the contrary, does not influence the capacity for creating additional spin-offs.

With reference to explanatory variables controlling for university characteristics, neither the size of the university, measured by the number of students, or the ratio between researchers and professors are significant in explaining the creation of academic spin-offs. This result is likely due to the fact that the nature of the research engaged (science, engineering, biological sciences and computer science) or the faculty quality and reputation (Zucker et al. 1998; Di Gregorio and Shane 2003; Stuart and Ding 2006) could have played a more important effect than just university size.

Nearly all the regional control variables are statistically significant; the only exception is the social cohesion index. Public expenditure in R&D is significant at the 5% level with a marginal effect of 0.153 and an odds ratio of 2.80. This suggests that regions with higher public funds are more than two times ($e^{1.030}$) likely to increase the number of new companies than regions that are not exposed to it, ceteris paribus. This result indicates the great importance of public financial resources for the dissemination of research outcomes and the effective creation of academic spin-offs. This finding is in accordance with the studies by Lenoir and Gianella (2006), O'Shea et al. (2005) and O'Shea et al. (2008), which have analysed the case of the US and demonstrated that federal government funding has a large impact on spin-off foundation. Going back to the Italian case, the reduction of regional public expenditure as a percentage of GDP, as well as the cut of public funds for the Italian

[12] The average number of full-time employees per TTO increased by 36.7% between 2003 and 2008 (Netval Report 2010).

Table 6 Average TTO and probability of increasing the number of spin-offs

TTO	
Means	
Budget	2.30
Age	3.75
Employees	3.26
Size	0.292
Research./prof.	0.403
D_{North}	0.431
D_{Centre}	0.276
R&D workers	3.88
Public exp	0.55
Social cohesion	20.99
$P_i = \Pr(y_i = 1) = 0.79$	

universities and TTOs established by the recent Italian University Reform (law n. 240/2010), should decrease the probability of success in the creation of academic spin-offs. This negative trend could be offset by a significant increase of private funds and a strengthening of cooperation activities with industry which, however, strictly depend on the effectiveness of the TTOs' policies.

The number of workers employed in R&D activities is significant at the 10% level with a positive marginal effect. The presence of R&D workers increases the probability of start-ups approximately five times ($e^{1.606}$) compared to the absence of R&D workers. The probability of increasing the number of spin-offs is higher for TTOs operating in the regions where private and public firms heavily invest in R&D and innovating capability.

Finally, the geographical location in which the office operates influences the probability of success in creating new start-ups. D_{North} is significant at the 5% level with a positive marginal effect. Empirical findings suggest that operating in northern Italy increases the probability of success by 71% compared to the south, while operating in the centre of the country (D_{Centre}) increases the probability of success by 45% over the south (Table 5). This means that TTOs located in southern Italy have less advantages than other TTOs in terms of establishing new companies. This finding confirms Feldman and Desrocher's (2004) study on John Hopkins, which highlighted the difficulties faced by universities in promoting academic entrepreneurship in areas surrounded by weak entrepreneurial infrastructures.

To have a complete picture, we estimated the probability that the number of spin-offs associated to the average values of the characteristics of Italian TTOs will increase in the near future by assuming similar conditions to those of 2008 (Table 6). Finally, we computed the effect of the geographical location on the probability of success of the TTO (Table 7).

Interestingly, the probability that the average Italian TTO increases the number of spin-offs in the future is very high ($p_i = 0.79$). This result would indicate the effectiveness of the past specific policies adopted by the Italian TTOs to create additional spin-offs and increase the cooperation activities with industry. The probability of increasing the number of spin-offs is computed under the assumption of no major changes compared to 2008. However, over the past years the Italian government has reduced the financial resources for Italian research and, as a consequence, for technology transfer (Netval Report 2010). This could invert the positive trend. Given the empirical evidence, the expected effect should be a reduction of the probability of success in the creation of academic spin-offs in the near future, at least if no other factor pushes in the opposite direction.

Table 7 Effect of the geographical localisation on the probability of success

Average technology transfer office	North	$Pr(y_i = 1) = 0.92$
	Centre	$Pr(y_i = 1) = 0.63$
	South and Islands	$Pr(y_i = 1) = 0.15$

Table 8 Prediction of the model

Classified	D	~D	Total
+	32	5	37
–	3	17	20
Total	35	22	57
Correctly classified			85.96%

Classified + if predicted $Pr(D) \geq 0.5$

True D

The econometric analysis also shows significant differences among the probabilities of success of the average TTO operating in the northern ($p_i = 0.92$), central ($p_i = 0.63$) and southern part of the country ($p_i = 0.15$). This indicates, in agreement with previous empirical results, the importance of the economic context in which each TTO operates (Table 7).

To evaluate the model we computed the percent of correct classifications, which gives us the percent of correct predictions of our model. Table 8 shows that positive responses were predicted for 37 observations, of which 32 were correctly classified because the observed response was positive ($y = 1$), while the other five were incorrectly classified because the observed response was negative. Likewise, of the 20 observations for which a negative response was predicted, 17 were correctly classified and three were incorrectly classified. In total, 85.96% of predicted probability is correctly classified.

We have further assessed the model's ability to accurately classify observations using a receiver operating characteristic (ROC) curve. A ROC curve is constructed by generating several classification tables for cutoff values ranging from 0 to 1 and calculating the sensitivity and specificity for each value. Sensitivity is plotted against 1, to make a ROC curve. The area under the ROC curve (AUC) is a measure of discrimination; a model with a high area under the ROC curve suggests that the model can accurately predict the value of an observation's response. The model provides outstanding discrimination since the AUC is larger than 0.9 (Fig. 1).

To test the model fit, Hosmer and Lemeshow's test was evaluated. A good fit will yield a large *p*-value. With a *p*-value of 0.45, our model fits the data well (Table 9).

Finally, we have checked the presence of any specification error using the linktest (Table 10). The idea behind linktest is that if the model is properly specified, one should not be able to find any statistically significant additional predictors, except by chance. The linktest uses the linear predicted value (_hat) and linear predicted value squared (_hatsq) as the predictors to rebuild the model. Since the variable _hat is a statistically significant predictor, the model is not misspecified. On the other hand, if our model is properly specified, variable _hatsq should not have much predictive power except by chance. Since, _hatsq is not significant, we have not omitted relevant variables and our equation is correctly specified.

5 Conclusions

Technology transfer has gained considerable attention in recent years because it can spur business innovation, foster competitiveness, generate new job opportunities, and facilitate

Fig. 1 The ROC curve

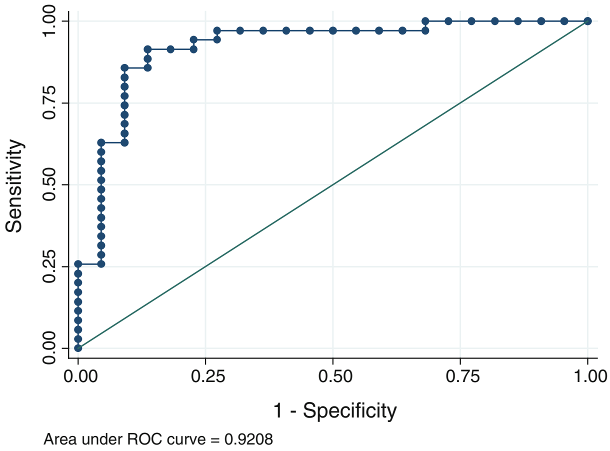

Table 9 Goodness-of-fit test

Number of observations	=58
Number of groups	=8
Hosmer–Lemeshow $Chi^2(6)$	=5.79
Prob > Chi^2	=0.4476

Table 10 Specification error test

Spin	Coef.	Std. Err.	z	$p > z$	95% Conf.	Interval
_hat	1.113753	.3117389	3.57	0.000	0.5027559	1.72475
_hatsq	−0.068002	0.0406428	−1.67	0.094	−0.1476604	0.0116563
_cons	0.1159132	0.4198779	0.28	0.782	−0.7070322	0.9388587

economic and social development. In order to diffuse an entrepreneurial culture of research, encourage the dissemination of research outcomes, and support scientists through the stages of commercialisation of the results of their research, several universities have established technology transfer offices, whose number has progressively increased over time.

The specific policies of technology transfer set out by TTOs mainly address the creation of spin-offs, since they are considered an important driving force in renewing industrial structures, and a way of modernising industry. For this reason, this study contributes to the current analysis on Italian TTOs by investigating their role in promoting the economic valorisation of research and the creation of spin-offs.

We have identified four strands of the existing literature on spin-off creation and built a logit model merging these different streams, in order to shed a light on the determinants of new company foundation. The empirical findings, based on data collected through a direct survey, show that sizeable financial resources and full-time highly-skilled employees are the key factors for increasing spin-offs. However, the age of the office does not influence the capacity to create additional spin-offs. Our findings support previous results derived from studies on European universities (Gómez Gras et al. 2008).

While the explanatory variables controlling for university characteristics are not significant in explaining the creation of academic spin-offs, nearly all the regional control variables are significant, with the exception of the social cohesion index. The econometric results indicate the great importance of public expenditure in R&D for the dissemination of research outcomes and the effective creation of academic spin-offs, consistent with the studies by O'Shea et al. (2005, 2008).

Notwithstanding the limitations of our study, the analysis reveals significant differences in the probability of success of TTOs operating in the northern ($p_i = 0.92$), central ($p_i = 0.63$) and southern Italy ($p_i = 0.15$). This suggests, in agreement with the previous empirical results, the importance of the economic context in which each TTO operates. The economic gap between northern and southern Italy is more significant in explaining technology transfer than differences in terms of legality and public safety.

On the whole, the results of this study point to the effectiveness of the specific policies adopted by the Italian TTOs to create additional spin-offs and increase the cooperation activities with industry. Interestingly, the probability that average Italian TTO increases the number of spin-offs in the future is very high ($p_i = 0.79$), under the assumption that nothing major will change. However, in the past few years, the Italian government has set out real-term reductions in core public funding for the Italian research systems and, as a consequence, for technology transfer. Given the econometric evidence, the expected effect could be a drop in the probability of success in the creation of academic spin-offs in the near future, at least if no other factor acting in the opposite direction will occur. Our expectation is that universities can develop additional expertise and find other dedicated funding in order to maintain the positive trend in the creation of academic spin-offs.

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Appendix

See Tables 11, 12, 13, and 14.

Table 11 Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
Spin-offs	58	0.603	0.493	0	1
Budget	58	2.301	1.446	0	7.45
Age	58	3.758	3.091	0	10
Employees	58	3.263	2.730	0	12
Size	57	0.292	0.235	0.019	1.262
Research./prof.	57	0.403	0.067	0.14	0.52
Localisation	58	1.137	0.847	0	2
R&D workers	58	3.886	1.569	1.2	6.2
Public expenditure	58	0.551	0.223	0.3	1.1
Social cohesion	58	20.99	7.620	11.4	38

Table 12 Data and sources

Data	Sources
TTO	
Spin-offs	Direct Survey carried out through E-mail and telephone interviews in March–April 2011 to 58 TTOs. Netval Survey, several years (2008, 2009, 2010)
Budget	Direct Survey carried out through E-mail and telephone interview in March–April 2011 to 58 TTOs
Age	Direct Survey carried out through E-mail and telephone interview in March–April 2011 to 58 TTOs and TTO website
Patents	TTOs website UIBM, Italian Patent and Trademark Office http://www.uibm.gov.it/
Employees	Direct Survey carried out through E-mail and telephone interview in March–April 2011 to 58 TTOs
University	
Students, researchers and professors	Ministry of University and Research. Statistics Office (University Education Survey)
Region	
Workers employed in R&D	Istat, Territorial Database for Development Policies, Ind. p. 02
Public expenditure in R&D as percentage of GDP	Istat, Territorial Database for Development Policies, Ind. p. 03
Legality and security index	Istat, Territorial Database for Development Policies, Ind. t. 09

Table 13 Correlation matrix

	Budget	Age	Employees	Size	Research/prof	Public expend.	WorkersRD	Social cohesion
Budget	1							
Age	0.0503	1						
Employees	0.1916	0.484	1					
Size	0.1214	0.393	0.2167	1				
Research/prof	−0.1363	−0.0761	−0.0567	−0.2073	1			
Public expend.	0.0714	0.0962	0.004	0.2972	−0.1066	1		
R&D workers	−0.0878	0.0689	−0.1055	0.1426	0.1642	0.1619	1	
Social cohesion	0.0844	0.1072	−0.0372	0.2082	−0.1881	0.3185	−0.1726	1

Table 14 Multicollinearity tests

Variable	VIF	SQRT VIF	Tolerance	R-squared
Budget	1.07	1.04	0.9305	0.0695
Age	1.51	1.23	0.662	0.338
Employees	1.42	1.19	0.7029	0.2971
Size	1.38	1.17	0.726	0.274
Research/prof	1.11	1.06	0.8974	0.1026
Public expend.	1.24	1.11	0.8069	0.1931
R&D workers	1.19	1.09	0.8387	0.1613
Social cohesion	1.25	1.12	0.7991	0.2009
Mean VIF	1.27			

Det(correlation matrix) 0.3753

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