The determinants of academic spin-off creation by Italian universities.

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Abstract

The aim of this work is to investigate the university level determinants of academic spin-off (ASO) firm creation in Italy. We are interested in particular in the relationship between university funding and the university propensity to create spin-offs, and test the effect of public and third party funds on this tendency. We estimate the effect of several variables for the characteristics of the university and the context. In contrast to our expectations, results indicate that third party funding does not exert an effect on the propensity of the university to generate ASO firms. Similarly, and in contrast to what the literature suggests, scientific productivity, context innovativeness and patenting experience also do not have a positive and significant effect on the propensity to generate spin-offs. We find that ASO creation is influenced by the amount of public income, by past experience in creating spin-offs and the presence of a technology transfer office. This work contributes to our understanding of the differences between Italy and the Anglo Saxon countries in relation to the phenomenon of ASO creation, and has some important implications for policy.

Keywords: academic spin-offs, university income, research income, Italy, context

1. Introduction

Academic spin-off (ASO) firms are created to exploit the results of research conducted in academia and are considered important for economic growth because of their positive impact on the processes of technological change and economic development (Vincett 2010). This has prompted numerous studies in economics and management that investigate the factors related to the propensity of universities to generate academic spin-offs (Di Gregorio and Shane 2003, Powers and McDougal 2005, Gomez Gras et al. 2008, Lockett et al. 2003). The factors considered to play a role include the presence of spin-off policies (Di Gregorio and Shane 2003, Baldini 2010), an innovative context (Friedman and Silverman 2003), university research excellence (Di Gregorio and Shane 2003, Powers and McDougall 2005, Baldini 2010), and the university's or Technology Transfer Office's (TTO) previous experience of spin-off activity (Powers and McDougall 2005, Shane 2004, Gomez Gras et al. 2008, Clarysse et al. 2011).

Most work on ASOs focuses on the US and the UK (e.g. Di Gregorio and Shane 2003, Powers and McDougall 2005, O'Shea et al. 2005, Hsu et al. 2007, Lockett and Wright 2005), but investigation of the phenomenon in the context of Europe has begun to attract attention (e.g. Wright et al. 2007). These studies highlight how the phenomenon of ASOs varies across countries (Proton Europe 2012, Wright et al. 2007). It has also been acknowledged that collaborating with industry leads to more patent applications (Lawson 2012, Czarnitzki et al. 2012, Rizzo and Ramaciotti 2014), but only a few studies examine this link in relation to ASOs, and these refer to the Anglo-Saxon countries (Powers and McDougall 2005, Di Gregorio and Shane 2003, Lockett and Wright 2005).

The present work aims to investigate what determines the creation of ASO firms at the university level in Italy, with particular attention to the relationship between university funding and the university propensity to create spin-offs. Although Italy is the fourth largest economy in Europe and a leading country in scientific production by universities (cf. Scimago Journal and Country Rank, www.scimagojr.com), it is considered a peripheral region, not well endowed with the factors associated with a flourishing, high-tech, entrepreneurial context (Benneworth and Charles 2005, GEM 2012). There also appear to be some differences between Italy, and the US and the UK in relation to the ASO phenomenon.

Studies on ASO activity in the US and the UK tend to be based on samples of firms defined as "new ventures that are dependent upon licensing or assignment of the institution's intellectual property for initiation" (Lockett and Wright 2005, p. 1045). In other words, ASOs are

considered as new ventures based on the formal transfer from the academic institute to the new venture, of protected knowledge (e.g. Shane 2004, Djokovic and Souitaris 2008). Most European level studies adopt a broader definition of ASOs as firms that are part owned by the university or were founded by at least one academic staff member (Pirnay et al. 2003, Chiesa and Piccaluga 2000, Netval 2013). The present study is based on the second definition which is the one adopted by Netval – the Italian National Network for the Valorisation of University Research (www.netval.it). Netval has monitored university-industry technology transfer activity in Italy since the early 2000s. The Ministry of Education, University and Research (MIUR) and the National Agency for the Evaluation of Universities and Research Institutes (ANVUR) use Netval data to define the indicators used to evaluate universities' third mission activities (ANVUR 2013).

The scholarly literature on the ASO phenomenon tends to use the US as a benchmark (e.g. Proton Europe 2012) based on the higher incidence of scientific entrepreneurship in the US with respect to European countries (Henrekson and Rosenberg 2001). According to Wright et al. (2007), science based entrepreneurial activity is much more developed in the US than in Europe, especially Continental Europe. The UK is the leader in Europe for university-industry relations and technology transfer activity. According to Proton Europe (2012), UK universities produce, on average and in absolute values compared to other European countries, the highest number of invention disclosures, patent applications and licence agreements and the highest level of licensing revenue. The PraxisUnico Spinouts UK Survey (PraxisUnico 2013) shows that, out of 1,780 UK ASOs broadly defined, 1,225 or around 70%, were generated based on the formal transfer of a protected university invention to the team of founders of the new ASO firm.

The situation is different in Italy. Based on our definition of an ASO, the number of these firms generated per university TTO is significant (Proton Europe 2012); however, according to the Netval surveys (e.g. Netval 2009, Netval 2013), most Italian ASOs are service firms whose market entry costs are relatively low. Only 15% of all the ASO firms active in 2011 in Italy are in the life sciences sectors and only 8% are related to the biomedical industry (Netval 2013). This compares with the UK where 43% of ASOs are based on the life sciences (PraxisUnico 2013).

A recent report by ANVUR (2014) analyses sales trends and sales volume for 443 ASOs, and concludes that the ASO phenomenon is immature in Italy. It suggests that a significant number of Italian ASOs may represent only a means of continuing a particular research project, with

only a few ASOs based on a patented academic invention. In Emilia-Romagna, one of the most active regions for spinning off new ventures in Italy (Netval 2009), only 10% of ASOs were responsible for at least one patent (Aster 2008). Another study of the same region by Rizzo (2014) provides evidence of a well diffused pattern of ASO creation by young scientists keen to continue working in their research area. In addition, Italian scientists tend to be significantly risk averse (Chiesa and Piccaluga 2000), and the ASOs created tend to remain small firms with low growth prospects (Salvador 2006).

Another difference between Continental European and the Anglo Saxon countries is the greater experience of the latter in technology transfer activity (Gibb and Hannon 2006). TTOs and formal technology transfer activities have been in place in the US and the UK since the 1980s, but in Italy ASOs were formally recognized only in 1999 with the enactment of law number 297. For example, average TTO age in the US is 18.5 years and in the UK is 17.5, while in Continental Europe, Spain has some "old" TTOs (18 years), but the average TTO age is 6 years in Italy, 5 years in Ireland and in 13 years in Denmark (Proton Europe 2012).

The recent emergence of the ASO phenomenon in Italy and most other Continental European countries has led to implementation of policies encouraging the establishment of spin off activity, based mostly on evidence from the US context. Our objective is to investigate the determinants of ASO creation in Italy, a country that is less entrepreneurial and high-tech than the US and the UK. Studies of ASOs mostly refer to the Anglo Saxon countries (Wright et al. 2007, Mustar et al. 2008, Stenberg 2014). Our analysis complements these studies contributing to a better understanding of the heterogeneity of the phenomenon across different contexts (Lipinski et al. 2008).

The paper is structured as follows: Section 2 reviews the ASO literature and proposes the hypotheses; Section 3 describes the data and methodology; and Section 4 presents the empirical analysis and its findings. Section 5 concludes the paper and highlights some policy implications.

2. Literature review and hypotheses

Several articles investigate the determinants of ASO creation, at different levels of analysis. The present study focuses on the university level or what O'Shea et al. (2008) would call the organizational level. An analysis at university level is important for two main reasons. First, universities are being encouraged to contribute to economic development and to undertake

technology transfer activities (Etzkowitz and Leydesdorff 2000), and also they represent a main level of policy design and implementation (Nosella and Grimaldi 2009, Chiesa and Piccaluga 2000). Second, the decrease in public funding is increasing the universities' focus on commercially-oriented activities (Geuna 2001), even when this risks undermining the norms of open science (Nelson 2001, Bercovitz and Feldman 2008). The reduction in public funding is putting universities in competition with one another, and technology transfer activities can attract resources, but, more importantly, increase the university's prestige.

The current literature on the US and the UK, identifies some university level factors that may influence the generation of ASO firms. These include: research income, especially from industry (Powers and McDougall 2005, Di Gregorio and Shane 2003, O'Shea et al. 2005, O'Shea et al. 2008, Lockett and Wright 2005); the presence, age and expertise of a TTO (Powers and McDougall 2005, O'Shea et al. 2005, 2008, Lockett and Wright 2005); experience and frequency of technology transfer activity (Powers and McDougall 2005, O'Shea et al. 2005, Lockett and Wright 2005); university quality usually measured as scientific publications and citations (Powers and McDougall 2005, Di Gregorio and Shane 2003, O'Shea et al. 2005, 2008); and contextual characteristics, mostly measured as degree of innovativeness (Powers and McDougall 2005, Lockett and Wright 2005, O'Shea et al. 2005, Di Gregorio and Shane 2003). In order to test for differences with the Italian context, we analyse the factors highlighted in this literature as important: private and public research funding; university policies (e.g. presence of a TTO); university experience measured as patenting activity and ASO activity; university scientific productivity as a proxy for university quality; and contextual characteristics. We explore how each of these factors plays a role in ASO generation.

Research funding

The effect of industry funding on the propensity to undertake technology transfer activities has been investigated in depth by innovation scholars. The literature generally focuses on the effect of this type of research funding on the propensity for individual researchers to apply for patents (e.g. Lawson 2012, Lissoni et al. 2013), and few studies investigate its relationship with technology transfer via ASO activity (e.g. Di Gregorio and Shane 2003, Powers and McDougal 2005).

According to Roberts and Malone (1996), in contexts where levels of industry-university collaboration are high, the number of university spin-off firms is higher than in other contexts.

However, they do not provide clear evidence of this. Similarly, Di Gregorio and Shane (2003) argue that the higher the commercial orientation of the university, the higher will be its propensity to generate ASO firms, but provide only limited empirical support for their claim.

Other studies find a significant and positive relationship: Powers and McDougall (2005) show that receiving research and development funding from industry leads to a greater number of ASOs from US universities. The authors argue that collaborating with industry contributes to building the networking relationships and capabilities needed to motivate scientists to create ASO firms (Colyvas et al. 2002, Wright et al. 2004, O'Shea et al. 2005). Also, Krabel and Muller (2009), in an individual level study, argue that scientists who collaborate with industry are more likely to found an ASO.

Several studies point out that undertaking any type of technology transfer activity, or experience of collaboration with industry, should have a positive effect and motivate individual researchers and universities to engage in ASO firm activity (Lockett and Wright 2005, Lockett et al. 2005, Powers and McDougall 2005). Although the influence of industry funding seems to have a positive effect on the propensity for universities to create ASO firms, with the exception of O'Shea et al. (2005), few works investigate the effect of public funding.

In this context, Blumenthal et al. (1996) suggest that faculty members who collaborate with industry tend to be show greater involvement in commercially-oriented activities compared to those researchers whose work is publicly funded. For example, a study of Spanish scientists shows that public grants do not exert a positive effect on the level of consulting activity (D'Este et al. 2013). At the same time, Muscio et al. (2013) find for Italian universities that funding provided by public organizations is positively correlated to the capability of university departments to raise industry funding. Finally, O'Shea et al. (2005) find that the higher the amount of public funding for science, the greater the university's spin-off activity.

Based on this evidence, we hypothesize that:

H1a: The larger the amount of university funding generated by commercial activity, the higher will be the number of ASO firms;

H1b: The more public funding received by the university, the higher will be the number of ASO firms.

University policies

The literature highlights the influence of policy on the university's propensity to conduct technology transfer activity (Friedman and Silverman 2003), apply for patents (Baldini et al. 2006) and set up ASO firms (Di Gregorio and Shane 2003, Nosella and Grimaldi 2009). One of the main tools used to foster technology transfer activities generally, and ASO activity in particular, is the presence of a TTO (Siegel et al. 2003). It has been argued that TTOs are important for enhancing the technology transfer activities of universities, especially if managed by competent staff and based on accumulated experience in technology transfer activity (Powers and McDougall 2005, Siegel et al. 2003, Muscio 2010).

In the Italian context, Nosella and Grimaldi (2009) studied the interdependence among different kinds of university policies and university propensity to generate ASO firms. Although they do not find a direct link between the establishment of a TTO and a higher number of ASO firms, they find that several factors related to the TTO – for example the number of staff and the services offered – have a positive and significant effect on ASOs. Similarly, Muscio (2010) suggests that TTOs that are managed by skilled and entrepreneurially-oriented and experienced staff, and are integrated in the institutional context, can be an important mechanism for fostering university-industry collaboration. TTOs are a recent phenomenon in Italy and generally were established after 2004 and directed mostly towards management of intellectual property rights and ASOs (Netval 2008). The presence of a TTO could be considered an indication that the university is entrepreneurial. Thus, we can expect that, in the Italian context, establishing a TTO will have a positive impact on the number of ASOs. We hypothesize that:

H2: Establishing a TTO has a positive effect on the number of ASO firms generated by the university.

University experience

Another factor that might be an important determinant of the university's propensity for spin-off firm activity is its past experience. Learning is essential for innovation activity. Experience of firm start-up has been shown to have a positive effect on the propensity to engage in further ASO activity (O'Shea et al. 2005). In line with the innovation persistency (e.g. Peters 2009) and knowledge accumulation literature (Antonelli 2008), the stock of knowledge gained from establishing ASO firms will have an important effect on the propensity of the university to increase its ASO activity. In the present study, we take account of whether past experience is related to current capability to generate ASO firms. The argument applies also to individual

researchers. Several studies show that researchers with experience of creating start-ups will be more likely to establish new ASO firms (Krabel and Mueller 2009, Landry et al. 2006). Also, researchers and universities with patent application experience will be more likely to apply for patents (Lawson 2012, Rizzo and Ramaciotti 2014). Therefore, we hypothesize that:

H3a: The greater the university's experience of ASO, the more likely it will continue to establish spin-off firms.

The process of ASO firm creation is also based on university experience in technology transfer activity and patenting (Shane 2004). There is evidence of a positive relationship between patenting and ASO creation in both the Anglo Saxon countries (Roberts and Malone 1996, Shane 2001) and in Italy (Baldini 2010). We hypothesize that:

H3b: the higher the number of the university's patent applications, the higher will be its number of ASO firms.

Scientific productivity

The complementarity versus substitutive effect of technology transfer activities and traditional academic activities has been widely debated (Chang and Yang 2008). Most work focuses on the relation between patents and scientific productivity rather than ASO firms (Lawson 2012). Although there is some counterfactual evidence (Hottenrott and Thorwarth 2011), most researchers agree about the complementarity between publishing and patent application (Agarwal and Henderson 2002, Fabrizio and Di Minin 2008).

The evidence for ASO firms is similar. Baldini (2010) finds no significant relationship between publication and ASO firm creation at the level of the individual researcher in Italy, but studies in the US context find evidence that universities with higher levels of publication and citations are more active in ASOs (Di Gregorio and Shane 2003, Powers and McDougall 2005).

Number of publications and citations per researcher is strongly skewed to the right and mainly concerns star scientists in specific research fields. Although D'Este et al. (2012) find that scientific excellence is positively correlated with opportunity discovery rather than opportunity exploitation, others show that star scientists are also more active in generating start-ups (Zucker et al. 1998a,b). Several works also find a positive relationship at the level of the single

researcher (Krabel and Muller 2009). Thus, we can expect a positive relationship between scientific productivity and spin-off activity. We hypothesize that:

H4: The higher the university's scientific productivity, the higher will be the number of its ASO firms.

Contextual characteristics

Innovation processes are localized and embedded in the context from which they emerged. Knowledge flows among the various local organizations are crucial for promoting technological change (Zucker et al. 1998a,b, Antonelli 2008). The literature on technology transfer from university to industry shows that universities that operate in contexts where innovation activities are flourishing tend to be involved in more technology transfer activity (Friedman and Silverman 2003).

Given the assumed positive externalities of collaboration with industry for the probability of creating spin-offs, it can be expected also that being embedded in a highly innovative context will have a positive effect on the propensity of the university to create ASO firms. We hypothesize that:

H5: The stronger the innovation performance of firms located in the same region as the university, the greater will be the number of ASO firms generated by the university.

3. Data and method

The empirical analysis consists of an econometric exercise where the dependent variable is the number of ASOs generated by each university in each year from 2005 to 2011. We propose the following model:

$$ASO_{it} = \beta_0 + \beta_1 PUBINC_{it-2} + \beta_2 COMINC_{it-2} + \beta_3 TTO_{it} + \beta_4 ASOSTOCK_i + \beta_5 NOASO_i + + \beta_6 PATUNI_{it-2} + \beta_7 SCIEPROD_{it-2} + \beta_8 PATREG_{it-2} + \beta_9 SIZE_{it-2} + \beta_{10} SOUTH_i + \delta_1 z_i + \gamma_1 x_i + \nu_{it}$$

where ASO_{it} is the number of ASOs created by university i at time t. This information was collected from Netval and is available from 2005 to 2011. The data are extrapolated from the

surveys of university TTOs that Netval conducts annually. Netval was established in 2001 as an informal network, and the first survey was for year 2003 (Netval 2005). While the current survey mostly investigates yearly TTO activities, earlier surveys also included past activities. The information allowed us to collect the number of ASO firms generated by each university before 2005 (*ASOSTOCK*).

The longitudinal dataset on which the exercise is based includes observations of the 53 Italian public universities responding to the Netval questionnaire. The sample consists of 80% of the population of public universities in Italy. Public universities are identified according to MIUR information, and represent 65% of all Italian universities.

The main independent variables tested are related to the university's funding channels. This information is provided by MIUR and is available for 2005 to 2009. We categorized the funding channels into public and third party: *PUBINC* is the total public research income received by university *i* at time *t* (in logarithm); *COMINC* is the commercial income received by university *i* at time *t* (in logarithm).

Since we have information on ASO firms from 2005 to 2011, and on funding channels from 2005 to 2009, and given the usual approach to investigating the effect of funding on technology transfer activity (Lawson 2012, Powers and McDougall 2005, O'Shea et al. 2005), we lag our main independent variables two years. This allows us to control for reverse causality.

TTO is a dummy variable that is equal to 1 if university *i* at time *t* has a TTO, and 0 otherwise. Information on year of establishment of the TTO was collected by matching information from MIUR and the Netval surveys.

We analyse the university's past experience of ASO firm activity. *ASOSTOCK* and *NOASO* are complementary time invariant variables; the former measures the accumulated number of ASOs generated by university *i* before 2005 in logarithm;[1] the latter is valued 1 if the university did not create any ASO firms before 2005, and 0 otherwise.

These two variables measure the university's experience of establishing spin-offs. Several studies that examine the propensity of scientists to apply for patents (Lawson 2012, Meissner 2011) and establish ASOs (O'Shea et al. 2005) take into account past experience. Taking account of the university's past experience allows us to control for the different level of knowledge of the university during the period of analysis. The inclusion of a pre-sample

[1] Unfortunately, we do not know the years of incorporation of these ASOs and cannot create a finer indicator of university experience

measure of the dependent variable allows us to control for unobserved heterogeneity (Blundell et al. 1995, Lawson 2012).

PATUNI measures the number of patents the university applied for in the time interval 2005-2009, extracted by priority date. As explained above, universities heavily involved in patenting are presumed also to be more involved in ASO activity (Shane 2004). The data are from the Espacenet database, and include all the university's patent applications to the European Patent Office (EPO) (Popp 2005).

We check for whether scientific productivity (*SCIEPROD*) has an influence on the propensity of the university to generate more ASOs. This variable is the logarithm of the product of total number of publications by university researchers in a given year (from 2005 to 2009) multiplied by number of citations to these publications in the subsequent three years. These data are from the Thomson Reuters database. The two variables used to build the index are the most widely used to measure scientific productivity (e.g. Lawson 2012, Agarwal and Henderson 2002, Fabrizio and Di Minin 2008, Powers and McDougall 2005).

The literature shows that the reference context has an important effect on our dependent variable. It has been shown that technology transfer activities are more frequent in more innovative contexts (Friedman and Silverman 2003). Therefore, we take the number of patent applications in the region (NUTS 2) in which the university is located as a proxy for regional innovativeness: *PATREG* is the logarithm of the number of patent applications to the EPO in the period 2005-2009 by firms located in the region of the university *i* at time *t*.[2] These data are from Eurostat.

Finally, we include some control variables. First, we control for university size: we include the variable *SIZE* (in logarithm) which measures the number of tenured positions in each university in each year. The data are derived from MIUR which provides data up to 2009. We control also for the presence of a medical school at the university; the literature shows that this is closely related to the propensity to create a spin-off (Shane 2004, O'Shea et al. 2005) (z_i). To account for the different levels of industrial development in the Italian regions, we control for university location (Baldini 2010) by a dummy time invariant variable, *SOUTH*, that takes the value 1 if the university is located in the southern Italian regions, and 0 otherwise. The southern regions

[2] The econometric exercise was conducted using PATREG at the level of NUTS 3 regions; the results were very similar.

are considered less developed compared to the rest of Italy. Finally, we control for time specific effects by including the variable x_i, with v_{it} as the error term.

The characteristics of our dependent variable result in half of our observations reporting a zero value; therefore, we estimate a zero inflated negative binomial model. This methodology allows us to separate the processes that generate positive values from the processes that generate zero values. The model includes a logit equation that tests the probability of observing zero as an outcome, and a negative binomial equation that models the count outcomes.

In the first stage logit model we used as predictors the following variables: *ASOSTOCK* and *NOASO*. In line with innovation persistency literature (e.g. Peters 2009), we expect a main determinant of lack of spin off generation to be absence of experience of this activity before the time of our analysis. In other words, we test whether the zero outcome in our dependent variable linked to ASO stock is related to the lack of ASO generation activity by the university, or not.

A zero inflated model is preferred to a negative binomial because of the presence of excess zeros, and is preferred to a zero inflated Poisson regression because of over-dispersion of our dependent variable. The zip and the vuong tests to check for the best solution, confirm our choice. All the regression results present robust standard errors. Finally, given that the variables often register a high correlation coefficient we test for multicollinearity, which allows us to rule out the presence of multicollinearity (vif mean equal to 2.94, with the highest value of 6.13) (O'Brien 2007).

Table 1: descriptive statistics and correlation matrix

	Obs	Mean	Std. Dev	Min	Max
ASO	371	1.712	1.914	0	9
PUBINC	263	9.380	0.898	6.888	11.309
COMINC	263	8.193	1.221	3.807	10.663
TTO	369	0.772	0.420	0	1
ASOSTOCK	371	0.865	0.973	0	3.091
NOASO	371	0.358	0.480	0	1
PATUNI	265	1.732	3.067	0	22
SCIEPROD	263	8.145	1.511	0.693	10.547
PATREG	264	4.915	1.519	-1.050	7.305
SIZE	265	6.683	0.789	5.017	8.466

	ASO	PUBINC	COMINC	TTO	ASOSTOCK	NOASO	PATUNI	SCIEPROD	PATREG
ASO									
PUBINC	0.3692								
COMINC	0.3019	0.7196							
TTO	0.33	0.1422	0.0342						
ASOSTOCK	0.4324	0.4297	0.4854	0.2729					
NOASO	-0.3694	-0.349	-0.3941	-0.279	-0.6654				
PATUNI	0.2087	0.4304	0.4165	0.1174	0.4598	-0.2661			
SCIEPROD	0.3413	0.7579	0.5711	0.2922	0.4489	-0.4928	0.3461		
PATREG	0.0812	0.2926	0.2747	-0.1125	0.307	-0.0585	0.3374	0.2101	
SIZE	0.3139	0.8747	0.7029	0.0751	0.3863	-0.3702	0.4083	0.7521	0.1981

4. Results

The first two specifications report the model presented in Section 3. Specification (1) refers to the basic model where we test for the effect of research income, presence of a TTO, university experience of technology transfer activity; specification (2) adds the influence of the context and the university's scientific productivity. These two specifications show that the number of ASOs a university generates is positively and significantly influenced by the amount of public income received, and that income from industry does not play a significant role.[3] More specifically, an increase of 10% in the university's public funding leads to an increase of roughly 4% in the number of ASO firms it creates.

We assume that the non-correlation with industry funding might be due to the majority of Italian ASOs being service firms, often created by young scientists (Netval 2013, Rizzo 2014). Italian tenured scientists tend to be risk averse (Chiesa and Piccaluga 2000) and, since the 2010 Law 240, are not allowed to undertake any commercial activity that might conflict with the commercial activity of their employing university. In contrast, the important role of public funding on the university's propensity to create ASOs, is due on the one hand to the complementarity found between public funding and commercial and technology transfer activities at the level of the Italian university department (Muscio et al. 2013), and on the other

[3] Since the variables PUBINC, COMINC and SIZE are highly correlated (Table 1), we ran the regressions in Table 2 with the three separate variables, to test whether one of them was capturing the same effects. The results, not reported here, show that SIZE and COMINC are not significant in any model specification but PUBINC is strongly significant.

hand to the significant public expenditure on promoting the valorization of academic research since 2000 (Law 297/1999 and Decree 593/2000).

We find that the presence of a TTO and past experience of establishing ASOs have a positive and significant effect. Although past experience is not correlated with the rate of ASO generation by universities, the inflated part of the model shows that the generation of ASOs before 2005 negatively influences the propensity of the university not to be involved in ASO activity in the time interval analysed. This result is evidence that learning and knowledge accumulation, as expected, play an important role: experience of ASO activity increases the probability of establishment of additional ASO firms. However, the university's experience in technology transfer does not influence the propensity to establish ASO firms. This unexpected result is in line with the studies conducted on the US and UK (Powers and McDougall 2005, Lockett and Wright 2005) and may be strengthened by the specificities of Italian ASOs, which rarely exploit a protected invention.

We find no significant effect of university scientific productivity which contrasts with findings for the US (Powers and McDougall 2005, Di Gregorio and Shane 2003) and Italy (Baldini 2010) on the positive relationship between scientific productivity and ASO generation. Calculating scientific productivity at the institutional level may cause some bias since the majority of citations and publications are usually due to a few star scientists (Zucker et al. 1998a). Given that Italian ASOs are mostly established out of necessity rather than to exploit an opportunity, and often founded by young scientists (Rizzo 2014), this may explain this lack of significant effect. However, our results do not reveal a negative relationship: we simply find they are not related.

We find also that the innovativeness of the context is negatively related to the university's propensity to generate ASO firms. This result is partly in line with the results in Baldini (2010) which show that very rich regions are not the main contexts for ASO activity. These results, combined with the lack of correlation between ASO firm generation and university commercial income, might suggest that, in Italy, the innovativeness of the context and funding from industry may be substitutes for the creation of ASO firms. To confirm this, we test for whether the commercial income variable is significant in interaction with the other variables. We found no significant effect (results not reported here). In particular, we could perhaps expect a negative effect of the interaction between commercial income and context innovativeness. However, this interaction was not significant and a substitutive effect is not supported.

In addition to the interaction terms in the empirical exercise, we test also for various non-linear effects. The only significant quadratic effect is for public income in specifications (3) and (4). These specifications replicate specifications (1) and (2), but include the squared value of the public income. Note that the relationship between public income and the propensity of the university to generate ASO firms takes an inverted U-shape. More specifically, we observe that the effect of public income is positive up to a value of €35.5 million. If the university receives more than €35.5 million of public funding, the effect on the propensity to establish ASOs turns negative. This negative effect is present only for very large universities as the threshold at which public income become negative remains at the 88th percentile of our distribution. This result supports the findings in Baldini (2010) that very wealthy contexts are not the best for promoting ASOs. In addition, universities that receive higher amounts of public income are not those with the heaviest involvement in ASOs. Only four universities (Bologna, Firenze, Torino, Roma Sapienza) received amounts of public funding higher than the threshold for all of the five years in our time frame, while only five universities received this level of income for at least one year.

The control variables SIZE and MED do not have a significant effect, which is in line with studies confirming that in Italy the presence of a medical school is not the main driver of ASO creation (Baldini 2010).

To sum up, we find that university capacity to create ASO firms is positively related to the amount of public research funding from the state or via competitive grants, and this holds up to a certain high value threshold. We find also that there is no effect of industry funding. Hypothesis H1a is not rejected, while hypothesis H1b is rejected.

The main result of this analysis is that the phenomenon of ASO firms in Italy is singular and considerably different from the more widely studied situation of the US and UK. The relation between the capacity of a university to create ASOs and the source of the university's income is not consistent. In addition, we find that other variables are not consistent and do not support hypotheses H3b, H4 and H5.

Table 2: Zero inflated negative binomial regression analysis

	1	2	3	4
ASO				
PUBINC	0.355***	0.425***	4.364***	4.782***
	(0.129)	(0.133)	(1.507)	(1.519)
COMINC	0.0034	-0.0165	0.0166	-0.00437
	(0.0842)	(0.0805)	(0.0855)	(0.082)
PUBINC_SQ			-0.210***	-0.228***
			(0.0776)	(0.0782)
NOASO	-0.397	-0.363	-0.361	-0.322
	(0.258)	(0.246)	(0.254)	(0.242)
ASOSTOCK	0.103	0.0979	0.0793	0.0755
	(0.0825)	(0.0806)	(0.0806)	(0.0789)
TTO	0.891***	0.680***	0.899***	0.707***
	(0.242)	(0.25)	(0.249)	(0.25)
PATUNI	-0.00212	0.00876	-0.00236	0.00634
	(0.0141)	(0.0153)	(0.014)	(0.0151)
PATREG		-0.114**		-0.104*
		(0.0575)		(0.0564)
SCIEPROD		0.0935		0.0804
		(0.113)		(0.125)
Control variables				
SIZE	-0.102	-0.246	-0.0432	-0.163
	(0.173)	(0.183)	(0.173)	(0.185)
MED	0.239	0.161	0.176	0.0894
	(0.167)	(0.178)	(0.17)	(0.179)
SOUTH DUMMY	Yes	Yes	Yes	Yes
YEAR DUMMIES	Yes	Yes	Yes	Yes
Inflate				
NOASO	-2.243	-2.021	-1.738	-1.577
	(2.041)	(1.389)	(1.47)	(1.121)
ASOSTOCK	-22.06***	-19.91***	-33.26***	-41.83***
	(1.235)	(1.456)	(1.03)	(1.064)
Wald chi2	81.89***	83.65***	81.02***	81.96***
Vuong	1.689**	1.785**	1.607*	1.687**
N	260	258	260	258

Robust standard errors in parenthesis
* p<0.1, ** p<0.05, *** p<0.01

4.1 Robustness check

We conducted some robustness checks to confirm our analysis. We ran the same specifications using a negative binomial model; the results were very similar. We found a positive and significant effect of the amount of public income on the probability of generating ASO firms up to a certain high value threshold. We found no effect for industry income. The effect of TTO presence is strongly significant and the number of ASOs generated before 2005 has a significant and positive effect.

The only difference with the zero inflated negative binomial model was for context innovativeness, which in the negative binomial is negative, but not significant. Again, the number of academic patents and the university's scientific productivity are not related to the propensity to establish ASO firms.

Table 3: Robustness check: negative binomial regression analysis

	1	2	3	4
ASO				
PUBINC	0.354***	0.395***	4.595***	5.083***
	(0.133)	(0.137)	(1.513)	(1.535)
COMINC	0.0266	0.00633	0.0335	0.0103
	(0.0854)	(0.0843)	(0.0877)	(0.0864)
PUBINC_SQ			-0.224***	-0.246***
			(0.0779)	(0.079)
NOASO	-0.224	-0.195	-0.252	-0.225
	(0.212)	(0.212)	(0.216)	(0.218)
ASOSTOCK	0.209**	0.209**	0.172**	0.172**
	(0.0877)	(0.0871)	(0.0874)	(0.0865)
TTO	0.846***	0.664***	0.878***	0.709***
	(0.24)	(0.253)	(0.248)	(0.253)
PATUNI	-0.00791	-0.00296	-0.00386	0.00144
	(0.0156)	(0.0161)	(0.0156)	(0.0165)
PATREG		-0.0711		-0.0739
		(0.059)		(0.0578)
SCIEPROD		0.106		0.102
		(0.113)		(0.127)
Control variables				
SIZE	-0.076	-0.191	-0.0344	-0.145
	(0.178)	(0.189)	(0.176)	(0.191)
MED	0.162	0.06	0.137	0.0388
	(0.163)	(0.177)	(0.164)	(0.173)
SOUTH DUMMY	Yes	Yes	Yes	Yes
YEAR DUMMIES	Yes	Yes	Yes	Yes
Wald chi2	100***	98.78***	97.79***	98.27***
N	260	258	260	258

Robust standard errors in parenthesis
* p<0.1, ** p<0.05, *** p<0.01

5. Conclusions

The main result of this work is that industry funding does not exert an effect on the propensity of the university to generate ASO firms. We found that public funding is positively and significantly correlated up to a certain high value, and then the effect becomes negative. We found also that experience of ASO activity is important for the establishment of ASOs, and that the presence of a TTO positively influences the likelihood that the university will generate more ASO firms. We found that university scientific productivity and patenting activity are not related to the propensity of the university to create ASO firms. Finally, we found that the innovativeness of the context seems to be negatively, though weakly, correlated to the capacity of the university to establish spin-off firms. Further research is needed, but it would seem that ASO activity in Italy is an important means of technology transfer in less innovative contexts, and is separate from the more common interactions between universities and industry.

Our findings indicate that Italian ASOs are different from those in the US and UK. ASO activity in Italy is not complementary to the university's commercial activities: this contrasts with findings for the US. There are several reasons for these findings. First, it is plausible that our results are related to the nature of the Italian ASOs, which are mostly service firms based on a small amount of capital (Netval 2013, Salvador 2006), not involving a patented invention (Netval 2013) and founded often by young researchers who become entrepreneurs out of necessity (Rizzo 2014). In this context, it should be noted that Italy is less entrepreneurially endowed in the high-tech sector than the UK and the US and is not well endowed in infrastructure to support the generation and growth of ASO firms (Salvador 2006). For example, only a few ASOs are able to secure venture capitalist funding and, according to Salvador (2006), only a small number seek such funding, preferring less risky internal financing modes (Chiesa and Piccaluga 2000).

We found that public funding is positively related to the university's capability to generate ASO firms. In Italy, levels of both public and private expenditure on research are much lower than in other European countries. Our findings suggest that increasing public expenditure for university research could have a positive impact on the number of ASOs. However, note that we cannot disentangle the various sources of public funding and this is a limitation of this study. It would be interesting to distinguish the amount of block grants versus research monies from competitive grants. If a correlation could be established between the amount of research grant

funding compared with block grant funding and the number of spin-offs generated, this would provide some interesting insights and implications. Some studies claim that experience in managing research grants has a positive effect on technology transfer activity (Link et al. 2007), and that such funds could provide the researchers with the tools to carry out frontier research.

Another element linked to the positive effect of public income is the fact that various regions support the valorization of academic research through the implementation of specific policies and measures. For example, in Emilia-Romagna, which has a large number of ASO firms, significant funds are earmarked for the creation of a regional "High Technology Network" among universities, aimed at the transfer of academic research to industry and the market (Maini 2012). Similarly, in various Italian regions, public measures have been implemented and funds provided for the commercial exploitation of university research results. These factors have contributed to the current trend for an increased number of temporary university researcher positions (MIUR 2006). The decreased number of new permanent positions and the lack of academic career opportunities for young researchers might promote the creation of new ASO firms (Rizzo 2014).

In line with these considerations, and considering that this work represents a preliminary study of the determinants of ASO firms at Italian university level, it could be argued that more fine grained data would provide more robust findings. In addition to the type of public funding received by universities, it would be interesting to test our hypotheses at university department level. Studies at department rather than university level might provide more precise results and indications (Rasmussen et al. 2014).

There are some implications for policy from this work. Recognition of the peculiarity of the ASO phenomenon in Italy and the nature of these firms could be informative for policy makers. Italy is mostly specialized in low and medium-tech industries, and its growth prospects are based mostly on the integration of new and old technologies rather than the creation of new sectors (Freddi 2009, Santamaría et al. 2009). ASO firms may resemble knowledge intensive business services firms and, therefore, might represent an important means for the integration of new technologies in traditional productive systems. National and regional policy makers are aware of this situation. On the one hand, they are trying to incentivize the creation of these types of ASOs, through initiatives aimed at encouraging young researchers to create their own firms (Ramaciotti et al. 2011) and on the other hand, they are encouraging the creation of new ventures based on protected technologies, and showing high growth prospects. Recent policies

have been aimed at the exploitation of inventions – especially those protected by patents – through provision of equity funding (MISE 2013).

Very few universities have regulations that impose limits on the nature of ASO firms, and only a small percentage are based on patented inventions and developed using private investments. Moreover, TTO personnel tend to be academics or administrators, and many do not have the capabilities required to turn ASOs into high growth firms. If policy makers want to encourage establishment of ASO firms to promote the economic system – and recent policy measures would seem to be in this direction – it might be necessary to encourage manufacturing based ASOs, exploiting intellectual property and with industry partners. The involvement of experienced industry managers at firm and TTO level should be an objective .

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