Higher education institutions and innovative entrepreneurship: a regional analysis

Piero Esposito,[a,b] Francesco Ferrante[a,b] and Sergio Scicchitano[b,c]

[a] *University of Cassino and Southern Lazio, Cassino, Italy*
[b] *Global Labor Organization (GLO), Essen Germany*
[c] *John Cabot University, Rome, Italy*

Abstract

This article investigates the connections between Higher Education Institutions and their ecosystems by assessing the impact of the supply of new graduates on innovative entrepreneurship in Italian provinces between 2015 and 2022. We estimate panel data models using a novel dataset, allowing us to control for the different ways universities might affect start-up creation. Our results confirm that graduates contribute significantly to innovative entrepreneurship. We detect a substantial heterogeneity by field of education, with graduates in technology-related fields, particularly Computer Science and Industrial Engineering, playing a robust and significant role in start-up proliferation, especially in less developed provinces. As a main policy indication, we suggest that HEIs can play a pivotal role in combatting low development traps in peripheral regions by improving the quality of entrepreneurial ecosystems.

Keywords: entrepreneurship, higher education, innovation, startups, knowledge spillovers

JEL classification: J21, J24, L26, I23

Acknowledgments: we are grateful to NETVAL for providing us with data on university spin off and licensing contracts; we are also grateful to the participants on the the third edition of the International Conference of the journal "Scuola Democratica" (June 3-6, 2024, University of Cagliari) and to the participant of the workshop "Higher Education and Equality of Opportunities", University of Modena, 30th-31st June 2023 for useful comments.

1. Introduction

Higher education institutions (HEIs) are expected to foster innovation, development, and well-being in their ecosystems and networks. Since the 1980s, HEIs have proven to be active contributors to the public good and economy by effectively using collaboration to address complex social and economic issues (Callon, 1994; Martin, 2003; Wilsdon et al., 2005). Another function HEIs can play in regional development is the activation or participation in regional governance mechanisms (Anderton, 2016). Policymakers expect HEIs to produce talent, businesses, and research that drive regional development (Benneworth and Fitjar, 2019, Agasisti et al., 2019). Instead of focusing on top-level research knowledge, knowledge flows and knowledge-enabled activities between university, state, and private sector actors became the focus of policy and advocacy attention (Papatsiba and Cohen, 2020).

The multifaceted teaching and research activities carried out by universities translate - through the support offered by the Third Mission - into various outputs and interactions (Agasisti et al., 2019) with the different local players that make it particularly difficult to track them for empirical analysis purposes. Nevertheless, what universities transmit to local ecosystems are two essential ingredients of the development recipe: new knowledge, produced mainly through research activity, and skills generated through teaching and incorporated into people's human capital.

This paper explores the link between the supply of new knowledge and skills, of which young university graduates are endowed, and innovative entrepreneurship at the provincial level in Italy (Anelli et al., 2020). By doing so, we depart from the conventional approach to assessing the impact of university graduates on regional labor markets as employees (e.g., Evers, 2019; Marques, 2017). We build on the vast literature that analyses the effect of the local supply of university graduates on entrepreneurship and regional development. To our knowledge, this is the first study with a regional approach in which college graduates not only directly promote entrepreneurship but also indirectly provide the necessary human capital for the innovation production function of the start-ups that employ them. To this aim, we use a novel dataset built by merging data from different sources, including information on the number of innovative start-ups, the inflow of new graduates from local universities, university spinoff and licensing contracts, research productivity, and other controls for province-specific characteristics, for the years 2014-2022. We also account for the role of institutional quality, as institutions are fundamental mediators of the complex conversion process of innovative inputs in entrepreneurial outcomes[1]

[1] Our claim that institutional quality explains disparities across territories in providing local public goods that sustain innovative entrepreneurship (Del Monte and Pennacchio, 2020; Rodriguez-Pose and Ganau, 2022).

(Baumol, 1990; Chang, 2023). Empirically, we estimate panel data models by using a two-stage GMM estimator with heteroscedasticity and autocorrelation consistent standard errors (HAC) to control for the endogeneity of the supply of new graduates and the possible presence of serial correlation in the data. We account for neighbor effects in the supply of graduates by introducing its spatial lag in the specification. Our contribution innovates along three lines: i) we estimate the impact of skill supply on start-up activity using a regional perspective. Previous studies mostly used a micro approach whereby they looked directly at graduates' entrepreneurship, thus failing to capture the indirect effects through the availability of skilled labor. Regional-level studies focus primarily on economic development (Agasisti et al., 2019). ii) Our novel dataset allows controlling for the other channels through which HIEs can contribute to entrepreneurship. iii) We provide up-to-date evidence on Italian provinces. The country is an interesting case study being characterized by large variations in the rate of innovative entrepreneurship and socioeconomic development across regions and by the prevalence of micro and small firms whose managerial strategies and styles have been shown to affect their capability to absorb externally generated knowledge adversely (Del Monte and De Lutzenberger, 1988; Bugamelli et al. 2018; Del Monte and Pennacchio, 2020; Federici et al. 2022). This characterization of the Italian entrepreneurial landscape helps explain an apparent puzzle. On the one hand, the Italian national research system performs relatively well regarding scientific output and quality. Still, this stock of knowledge does not lead to comparable innovative performances[2] (European Commission, 2022 and 2023). On the other hand, although Italy records a very low share of university graduates in the workforce, it is a net exporter of them and suffers from significant skill mismatches in the labor market for graduates (OECD, 2017; Esposito and Scicchitano, 2022) in particular from lagging behind regions (Adessi et al., 2024). Here, we argue that this twin mismatch and the resulting apparent excess supply of knowledge and human capital are the faces of the same coin: the inability of a large share of Italian SMEs to valorize the university outputs. In addition to supply factors, i.e., the quality of education and the composition of the supply of graduates, this inability is due to the prevalent characteristics of SMEs. They embrace the presence of a large share of low-educated entrepreneurs and managers[3] and the prevalence of micro and small firms based on family management[4], which are financially constrained and rely on poor human resources management

[2] Italy ranks 4th for the top 10% cited publications in the EIS and 16th for the total Innovation Scoreboard Indicator (European Innovation Scoreboard, EC, 2023).
[3] In 2021, the share of entrepreneurs (managers) holding a level of education equal to ISCED 02 (compulsory education or below it) was 35% (29%) in Italy and 17% (16%) in Europe 27 (Source: Eurostat website). The educational attainment of entrepreneurs in Italy is, on average, below that of employees (Schivardi, 2020).
[4] The CEO and all the firm managers belong to the family.

strategies. These features help explain why demand-pull innovation mechanisms, relying on university-industry technology transfer activities, do not appear to function as they do in other entrepreneurial contexts.

This paper proposes two take-home messages in the realm of policy design. First, the provision by HEIs of innovative capabilities embodied in people can support lagging behind territories to escape from low development traps (Schivardi and Torrini, 2011; Aghion et al., 2015) and help them achieve a sustainable economic growth path. Second, by sustaining a bottom-up process of quality upgrading of the entrepreneurial ecosystems, HEIs can help tackle those factors limiting the valorization of scientific research from the knowledge demand side.

Specific actions to enhance the quality of entrepreneurial human capital can help escape the low-development trap by creating a virtuous cycle. Improved entrepreneurial skills enable local firms to better absorb knowledge and human capital, leading to the development of knowledge-intensive business projects and addressing the twin mismatch.

The paper is structured as follows: Section 2 assesses the main channels through which HEIs affects entrepreneurship; Section 3 describes the dataset and the empirical strategy; Section 4 summarizes the main results, and Section 5 draws main conclusions and policy implications.

2. HEIs, innovative entrepreneurship and local development: a survey

Regional start-up activity and its contribution to economic development have been investigated by looking at demand-push and supply-pull factors (Motoyama and Malizia, 2017; Fisher and Nijkamp, 2019). HIEs are a supply pull factor alongside government funding and high-tech industry concentrations. The literature on the role of HIEs in fostering local development is rich and diverse, encompassing innovation, entrepreneurship, and education. Summarising the main results in a single article can only provide a partial view of the knowledge frontier. A comprehensive survey of the early literature is provided by Rothaermel et al. (2007), who also developed a framework that describes the dynamic process of university entrepreneurship. Building on this framework, Benneworth and Fitjar (2019) summarise four avenues through which universities can support local innovation and the risks associated with each path. First, universities can enhance labor market quality and spur new industries (Marques, 2017). However, peripheral regions often struggle to absorb graduates, leading to mismatches and underemployment (Evers, 2019; Germain-Alamartine, 2019). Second, universities can create structures to guide academics toward regional engagement (Miller, 2014). In this case, the risk is that regional engagement aligns more with high-level strategic interests rather than genuine knowledge connections with regional partners (Salomaa, 2019; Cinar, 2019). Third, academics can bolster regional innovation networks, depending on local R&D geography, individual motivations, and researchers' willingness to stay long-term (Alpaydın, 2019; Atta-Owusu, 2019; Ahoba-Sam, 2019). Fourth, universities can improve regional innovation strategies by creating collective innovation assets, though success hinges on specific change agents within universities (Nieth, 2019; Fonseca, 2019; Radinger-Peer, 2019).

Much attention has been paid to HEIs' role in enhancing innovation through technology transfer activities - recently described as co-creation processes (De Silva et al., 2023), incubators, and academic entrepreneurship. Their effectiveness depends on critical boundary conditions unlikely to be fulfilled (Sandström et al., 2018). On the contrary, the effect of universities as suppliers of graduates, thus their teaching function, has been understated (Motoyama and Meyer, 2017).

A revived interest in the topic led to recent literature highlighting academic and student/graduate entrepreneurship as vital for local production systems (Perkmann et al., 2015; Arranz et al., 2017; Ferrante et al., 2019; Meoli et al., 2020). The interest in student and graduate entrepreneurship is driven by evidence that their start-ups play a significant role in bringing new knowledge to the market, often more so than traditional university technology transfer initiatives (Roberts and Eesley, 2011; Astebro et al., 2012; Roberts et al., 2015). This is evident in Sweden, where university graduates often start businesses in their study regions (Baltzopoulos and Broström, 2013).

Research-based start-ups can reduce technology transfer transaction costs. For example, a PhD student might prefer to start a spin-off company with colleagues instead of working under a boss. In this respect, Muscio et al. (2021) find that Ph.D. graduates are more likely to enter entrepreneurship, mainly when Ph.D. training is associated with business experience. These mechanisms are particularly valuable in local entrepreneurial ecosystems with low endogenous absorption capacity, where demand-pull knowledge transfer mechanisms are ineffective (Evers, 2019; Germain-Alamartine, 2019). In such contexts, HEIs can help escape low-innovation, low-growth traps. However, this approach requires entrepreneurial motivations and skills, necessitating universities to provide entrepreneurial education and training.

Among the many studies on the subject, Colombo and Piva (2020) explore the link between graduates' entrepreneurial entry and human capital developed through university education. They find an important role for curriculum specialization and the attendance of economics and management courses with a positive moderating effect of universities' scientific quality. Daziel and Basir (2024) find a substantial impact of technological imprinting on students' ventures and conclude that graduates' start-ups are more technologically innovative than existing firms. Rauch and Hulsink (2015) find a positive effect of entrepreneurial education on entrepreneurial Intentions, while Alakaalek et al. (2023) find no significant impact.

This article examines universities' contribution to innovative start-ups' local development, recognizing that demand-pull knowledge transfer mechanisms may be less effective in Italy than in other advanced countries, particularly in lagging regions. Empirical evidence shows that Italian SMEs struggle to absorb new knowledge and enhance human capital, leading to an oversupply of university-generated knowledge. Studies indicate this mismatch stems from poor managerial human capital and strategies (Schivardi and Torrini, 2011; Bugamelli et al., 2011). However, graduate retention at the local level depends on the similarity between universities' offers and local labor markets (Adessi et al., 2024).

This interpretative framework can be extended to other regions with similar features. For instance, Evers (2019) argues that peripheral regions face graduate employability risks and human capital mismatches, hindering innovation and economic growth. In this respect, university graduates' cognitive and non-cognitive skills enhance local innovation capabilities, whether in start-ups or established firms.

Knowledge spillovers due to human capital externalities are crucial for innovation and productivity growth, significantly influencing endogenous growth dynamics (Acemoglu, 1996; Aghion et al., 2015). Graduates facilitate knowledge spillovers through formal and informal channels, and their higher geographical mobility makes them effective generators of human capital spillovers across territories. Open innovation strategies have increased the importance of this knowledge diffusion channel linked to workers' intrapreneurial skills (European Commission, 2013; Kaufmann Foundation, 2013; Arranz et al., 2017).

New knowledge and skills from university graduates also improve firms' capability to absorb R&D spillovers and knowledge externalities (Aghion et al., 2015). Gennaioli et al. (2013) highlight the critical role of human capital in regional development, emphasizing entrepreneurial inputs and human capital externalities.

Anelli et al. (2023) link young people's emigration from Southern Italy to reduced new firm creation rates, particularly in knowledge-intensive sectors, emphasizing the importance of regional young talent for innovative entrepreneurship.

Institutions are crucial in converting graduates' skills and knowledge into entrepreneurship and innovation (Baumol, 1990; Ferrante et al., 2019; Chang, 2023). They determine entrepreneurial opportunities, the appropriability of innovative outputs, and environmental uncertainty, influencing financial and economic risks and returns on innovative investments (Abaidoo and Agyapong, 2023). Institutions also help explain disparities in innovative entrepreneurship at the sub-national level, i.e., across regions (Del Monte and Pennacchio, 2019; Rodriguez-Pose and Ganau, 2022).

In this paper, we build on this vast literature by analyzing the effect of the local supply of university graduates on start-up creation in Italy over the period 2014-2022. Differently from the previous studies, we analyze this effect by controlling for other channels of technology transfers: research productivity, academic spin-offs, and licensing contracts. In addition, while most of the literature relies on micro-level studies investigating graduates' entrepreneurship, we follow a regional approach where graduates foster entrepreneurship directly and indirectly by providing the necessary human capital for the innovation production function of start-ups employing them. To our knowledge, this is the first study of this kind. A similar study by Agasisti et al. (2019) analyses the effect of university efficiency on local economic development in Italy. However, their work aggregates the four channels through which universities can support local development – including the supply of graduates - by building a composite efficiency indicator. In addition, they do not focus specifically on entrepreneurship. Instead, they analyze the effect of university efficiency on local GDP per capita.

3. Data and empirical strategy

The empirical analysis aims to assess the effect of the supply of new graduates on the propensity to set up innovative business ventures. To this aim, we built a novel panel dataset of Italian provinces covering 2014-2022. We contend that innovative entrepreneurship should be stimulated by high-quality human capital, especially in the STEM fields. Other human capital related measures included in the analysis are the flow of new resident graduates, the stock of tertiary educated individuals, and overeducation as a measure of labor market mismatch.

We control for province characteristics in terms of size, specialization entrepreneurship intensity, regional public and private R&D, as well as for other channels through which universities can impact the creation of start-ups, namely research productivity, number of university spin-offs, active licenses, and regional university R&D expenditure. Finally, we control for institutional quality as a mediating factor affecting both the quantity and quality of graduates and the propensity to engage in innovative entrepreneurship.

3.1 Data

The empirical analysis will be performed using a novel database built by merging different sources at the province (NUTS3) level.[5] Data on innovative startups are provided by the Ministry of Enterprises and Made in Italy, which records all innovative startups (Manaresi et al., 2021) between 2014 and 2022. Startups are classified as innovative if they respect at least one of the following criteria: 1) at least 15% of production value is invested in R&D activities; 2) at least 2/3 of employees have a master degree, or 1/3 of employees hold a Ph.D or a master degree with three years of experience in research activities; 3) the firm holds a patent, a trademark or a licensed software. As for the supply of new graduates, data come from the Ministry of University and Research (MUR). It provides data on the flow of graduates from each University in Italy. The original MUR data are classified according to 17 fields of studies which we reaggregate into the following six categories: Computer Science and Industrial Engineering; Architecture, Civil Engineering, and Design; Medicine, Psychology, and Sport Science; Science, Agriculture, and Veterinary; Social Sciences (economics, political science, and law); Humanities, Languages, and Education. MUR also provides data on the flow of resident graduates for each NUTS-3 province. This allows for the separation of the effect of local graduates from that of the inflow/outflow of graduates who got their degree in another province or a foreign country. The stock of graduates in each province is obtained by aggregating individual-level data from the Italian Labour Force Survey, and it is included as a measure of the quality of human capital. Overeducation is calculated by aggregating individual self-assessed data from the INAPP-PLUS survey. The survey covers 2014, 2016, 2018, 2021 and 2022. We imputed the average between the previous and the following available data for the missing years. The number of university spinoffs and licenses are obtained from the annual NETVAL Survey on the growth and exploitation of public research results. Research productivity is calculated as the number of publications per researcher. Data on the number of publications are from OpenAlex, the open catalog to the global research system. The number of researchers (professors, assistant professors, or post-docs) is from MUR. University R&D expenditure is provided by ISTAT, the Italian National Statistical Institute, which also provides data on private and public R&D expenditure. As for the context indicators, data on the total number of enterprises, population, and Gross per capita Value Added in each province are provided by ISTAT. Moving to the measures of the economic structure of provinces, the shares of manufacturing, private services, and ICT in value added are built using ISTAT data on Gross Value Added by sector of activity. Finally, the quality of institutions is measured by the

[5] See Table A1 in the appendix for a detailed description of variables' construction.

Institutional Quality Index built by Nifo and Vecchione (2014). The index is constructed following the methodology used by the World Bank (Kauffman et al., 2010) to calculate governance indicators.[6] The final dataset includes 107 provinces observed between 2014 and 2022 (2021 for some variables) for a total sample size of 963 observations. All variables except institutional quality, overeducation, and research productivity are standardized to the provincial population. Given the significant presence of zeros for university-related variables - caused by the absence of universities in several provinces - and for the number of startups, we transformed data into natural logs by applying the following transformation: ln(0.5+ variable). This allows for reducing the skewness in the distribution of these variables and improving the model's overall fit.

Descriptive evidence

The distribution of variables used in the empirical analysis is reported in Table 1. To gain some preliminary information on the relationship between innovative entrepreneurship and the flow of new graduates, in Figure 1, we show a bivariate map of Italian provinces. Graduates increase following a green scale, while start-ups follow the purple scale. Both variables are divided into three categories, and the nine squares result from their interaction. A positive relationship between the two variables exists since almost 60% of provinces belong to the main diagonal. Looking at the map, we observe no clear geographical pattern in the data, while as a share of population graduates are more present in the Center-South, the simultaneous occurrence of high graduates' intensity and high start-up intensity is found in the largest provinces (Rome, Palermo, Naples, Catania) and some provinces of Campania, Abruzzo, Tuscany, and Emilia-Romagna. Low flow of graduates – which in most cases implies the absence of a HEI in the province, and low start-up creation is found in the western part of the country, especially Piemonte and Sardinia. The positive relationship is broadly confirmed by all six fields of education, with shares of provinces belonging to the diagonal ranging from 54%-55% in Computer Science and Industrial Engineering, and in Architecture, Civil Engineering, and Design, and with 54%-55% to 60% shares in Social Sciences, Medicine and Psychology. The provincial distribution closely matches that of Figure 1. Thus, sub-graphs are not shown.

[6] The index is the average of six components: rule of law, voice and accountability, control of corruption, government effectiveness, political stability, and regulatory quality. Individual indexes are built by aggregating different indicators. For example, the regulatory quality index aggregates five items: economic openness, local government employees, business density, business mortality, and business environment.

Table 1 Summary statistics

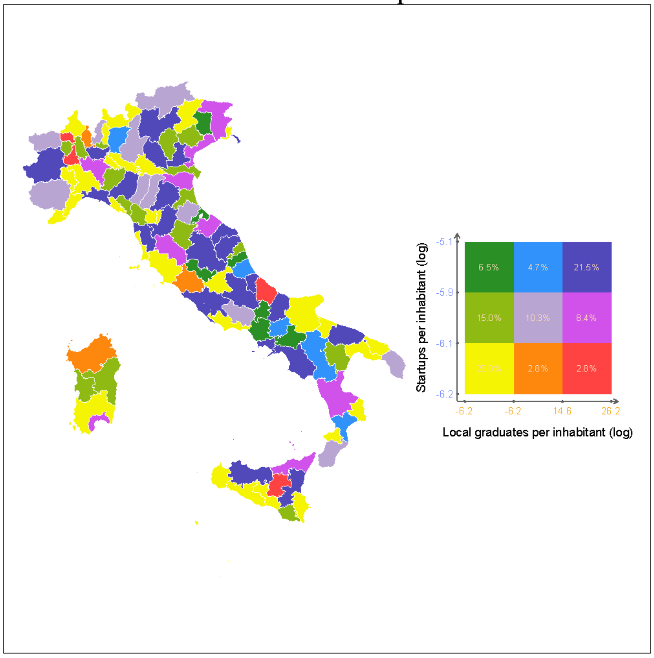
	Mean	SD	Min	Max
Start-ups	-0.665	0.037	-0.693	-0.371
LG	0.585	1.343	-0.693	3.001
LGScience	-0.262	0.568	-0.693	1.417
LGCompSciIndEng	-0.315	0.532	-0.693	1.381
LGMedPsySp	-0.072	0.768	-0.693	1.809
LGArCEDes	-0.372	0.441	-0.693	0.951
LGHumLaEd	-0.111	0.715	-0.693	1.843
LGSocSc	0.081	0.838	-0.693	1.911
RG	1.707	0.296	-0.590	2.336
WLG	0.580	0.741	-0.693	2.394
WLGScience	-0.268	0.280	-0.693	0.711
WLGCompSciIndEng	-0.331	0.264	-0.693	0.570
WLGMedPsySp	-0.069	0.414	-0.693	1.286
WLGArCEDes	-0.366	0.243	-0.693	0.498
WLGHumLaEd	-0.112	0.389	-0.693	1.192
WLGSocSc	0.075	0.451	-0.693	1.298
IQI	0.594	0.245	0.000	1.000
OE	0.103	0.034	0.020	0.269
TerStock	0.105	0.029	0.042	0.222
SpinOff	-0.666	0.051	-0.693	-0.350
ResProd	0.080	0.935	-0.693	4.138
Licenses	0.004	0.012	0.000	0.110
Pop	12.933	0.710	11.297	15.266
GVApc	10.031	0.283	9.469	10.893
Enter	0.072	0.012	0.048	0.115
ManSh	0.159	0.079	0.040	0.366
ICTsh	0.016	0.009	0.005	0.065
PvtSvcSh	0.106	0.020	0.061	0.203
R&Dpr	0.236	0.168	0.008	0.608
R&Dpub	0.045	0.049	0.002	0.284
R&Dun	0.099	0.029	0.028	0.197

Source: own elaboration on MUR, MIMI, OpenAlex, ISTAT, INAPP-PLUS and Nifo and Vecchione (2014). See table A1 in the appendix for variables definition and construction.

In Figure 2, we report the bivariate map showing the association between innovative start-ups and the flow and stock of resident graduates as a share of the local population. In this case, we also find a positive association between variables, although weaker than between innovative start-ups and the flow of local graduates. The share of provinces on the secondary diagonal is 45.8% for the flow of new resident graduates and 55.2% for the overall stock of graduates. The simultaneous presence of a high number of innovative start-ups and an intense flow of resident graduates is found in most provinces of Campania, Marche, and Abruzzo, whereas the simultaneous occurrence of a high number of innovative start-ups and a high stock of tertiary-educated workers more frequently in the central and northern provinces.

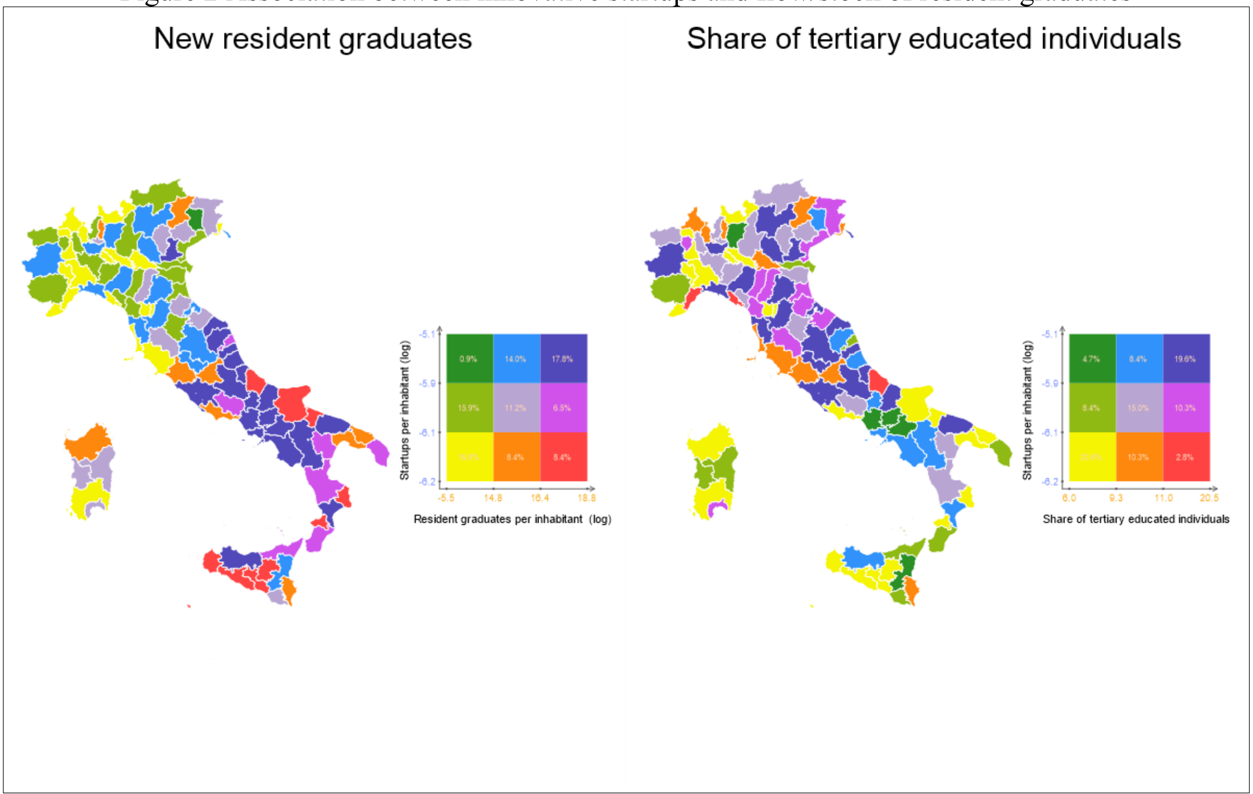
In summary, this bivariate evidence shows that the flow of local graduates is strongly related to the presence of innovative start-ups, and this relationship is stronger than that between innovative start-ups and other indicators of the presence of graduates. This provides preliminary evidence of our main assumption, which will be formally tested in the econometric analysis.

Figure 1. Association between innovative startups and total flow of local graduates



Source: own elaboration

Figure 2 Association between innovative startups and flow/stock of resident graduates



Source: own elaboration

3.2 Empirical strategy

To provide robust evidence of the positive relationship between the supply of graduates and the creation of innovative start-ups we rely on a Panel model with lagged regressors specified as follows:

$$StUp_{i,t} = \beta_1 LG_{i,t-1} + \beta_2 WLG_{i,t-1} + \beta_3 RG_{i,t-1} + \sum_{k=4}^{n} \beta_k X_{i,t-1}^{k} + \varphi_i + \theta_t + \gamma_a * \theta_t + \varepsilon_{i,t} \quad (1)$$

where LG is the flow of local graduates, RG is the flow of resident graduates, and WLG is the spatial lag of the flow of local graduates. The spatial lag is calculated as the average flow of graduates in neighboring provinces using a matrix of spatial weights W. To build the matrix, we rely on the contiguity approach, whereby cells assume the value one if two provinces share a common border and zero otherwise. WLG is introduced in the analysis to capture effects on the graduates' supply that can go beyond the province where the university is located. In other words, graduates from a university are likely to find an occupation or open a start-up not only close to the university but also in neighboring provinces.

The vector X includes the following variables: stock of tertiary educated workers (TerStock), Overeducation (OE), number of active spinoffs (SpinOff), research productivity (ResProd), active licenses (Lic), institutional quality index (IQI), total population (Pop), Value Added per capita (VApc), number of active enterprises (Enter), shares of manufacturing, ICT and private services (ManSh, ICTsh, and PvtSvcSh respectively), and public, private and universities R&D expenditure (RDpu, RDpr, RDun respectively). The terms φi and θt and province and time-specific fixed effects. We interact time dummies with area dummies (area=North-East, North-West, Center, South, and Islands) to control for general heterogeneity.

To estimate equation (1), we use a two-stage GMM (GMM2S) approach with heteroscedasticity and autocorrelation consistent standard errors. The GMM2S approach is used to take into account the endogeneity of the flows of new graduates (LG, WLG, and RG) due to omitted variables affecting both the flow and graduates and the creation of innovative start-ups. Controlling these sources of endogeneity allows for the interpretation of coefficients in a causal way, that is, the impact of the supply of graduates on innovative entrepreneurship.

The identification strategy relies on using lagged values of endogenous regressors as instruments. More specifically, we begin by using lags from 2 to 9 of LG and WLG and 2 to 5 of RG[7] and test for the exogeneity of the first lags and the redundancy of the last lags. When a lag is found endogenous or redundant, it is dropped from the analysis. In this way, we endure the goodness of instruments and avoid biases in the overidentification tests due to the quasi-collinearity of redundant instruments. Using lagged regressors in equation (1) reduces the sample size to 856 observations.

Together with estimating the model on the whole sample, we perform heterogeneity analyses by splitting the sample according to two different criteria. First, we consider the median stock of graduates in each province and split the sample into above and below the median. This allows for investigation of the role of human capital stock in determining the results. Second, we split the sample geographically by dividing provinces into North and South. The former include the macro-regions North-East and North West as well as Rome and the provinces of Tuscany and Marche. Southern provinces include the macro-regions of the South Island, the provinces of Umbria, and those of Lazio, excluding Rome. This second analysis is particularly important since it allows for understanding whether university graduates effectively stimulate innovative entrepreneurship in less developed provinces.

4. Results

3.1 Full sample

In Table 2, we report the full estimation results of equation (1) using the total flow of local graduates. The estimation technique works fine as test results show the validity overidentifying restrictions, the exogeneity of instruments, and, in some cases, a significant endogeneity of the instrumented regressor. However, instruments, especially the lags of the flow of resident graduates, are slightly weak. Estimates show that graduates' total flow significantly affects the creation of innovative start-ups only when high-tech industries and micro-firms are considered. In these two cases, the effect is positive, as expected, although in the case of micro-firms, the impact is significant at a 10% level only. The estimated impacts indicate that a 10% increase in the inflow of new graduates increases the number of innovative start-ups per 100,000 inhabitants by 0.8 when considering high-tech sectors and by 1.7 every 100,000 inhabitants when considering micro firms.

[7] Data for LG only go back to 2010, while data for LG and WGL go back to 2002, thus allowing us to use a higher number of lags.

While these numbers may appear small, considering the actual variability of data, a standard deviation increase in the log-inflow of new graduates per inhabitant increases the log number of innovative start-ups per inhabitant by 1.73 standard deviations when considering high-tech sectors and by 1.13 standard deviations when considering micro firms.

Moving to the spatial lag of the flow of new graduates, a positive and significant impact is found only in high-tech sectors. Instead, the flow of resident graduates is significant but negative only when considering start-ups satisfying the graduates criteria. This suggests that graduates move to other provinces expecting to find jobs as employees in existing firms rather than newly established ones. The overall stock of tertiary educated individuals is significant in most cases, with higher impacts on micro-firms and start-ups satisfying the R&D criteria. At the same time, overeducation is positive and significant for the whole sample, start-ups satisfying the R&D criteria, and non-micro firms (i.e., with more than nine employees).

As for the other university-related variables, the number of university spinoffs is significant only when considering non-micro firms. This result is not surprising considering the average size of university start-ups. Research productivity is significant in all cases except for high-tech sectors, and its impact is always positive. Instead, the number of active licenses is positive and significant in four out of seven cases.

Moving to the other controls, the institutional quality index is positive and significant in total and for micro-firms, thus confirming the positive effect of institutions on entrepreneurship. Population is significant in most cases, while per capita value added is never significant. The latter can be explained by the high correlation of this variable with the other regressors, leading to a quasi-collinearity. Looking at the economic structure indicators, the manufacturing share is negative and significant in all cases. At the same time, that of ICT services is positive in four out of seven cases. Instead, the share of professional services is significant, but it has a negative sign only when considering start-ups satisfying the graduates/Ph.D. criteria. Such a negative sign is not surprising as it indicates that the option of paid employment in existing firms is more rewarding when professional services are widespread in a province. Finally, regional R&D expenditure is significant in three cases only when performed by the private sector.

Table 2 Effect of the supply of graduates on the creation of innovative startups: all graduates

	StUp	STupRD	StUpInn	StUpGr	StUpHT	StUpMic	StUpNMic
LG	0.006	0.003	0.000	0.007	0.008**	0.017*	-0.005
	(0.012)	(0.009)	(0.004)	(0.005)	(0.003)	(0.010)	(0.008)
WLG	0.038	0.032	0.003	0.014	0.012*	0.032	0.010
	(0.028)	(0.021)	(0.007)	(0.009)	(0.007)	(0.021)	(0.015)
RG	-0.025	-0.005	-0.007	-0.022*	-0.009	-0.019	-0.015
	(0.023)	(0.017)	(0.010)	(0.012)	(0.009)	(0.022)	(0.016)
TerStock	0.380***	0.305***	0.043	0.056	0.071**	0.306***	0.094*
	(0.085)	(0.066)	(0.028)	(0.035)	(0.030)	(0.074)	(0.049)
OE	0.057**	0.041**	0.014	0.014	0.007	0.012	0.052***
	(0.024)	(0.019)	(0.010)	(0.011)	(0.009)	(0.020)	(0.016)
SpinOff	0.053	0.052	0.012	0.031	0.018	-0.051	0.139***
	(0.073)	(0.055)	(0.023)	(0.030)	(0.020)	(0.056)	(0.044)
ResProd	0.024***	0.015**	0.005*	0.008**	0.004	0.014**	0.010**
	(0.009)	(0.006)	(0.003)	(0.004)	(0.003)	(0.007)	(0.005)
Licences	0.596**	0.411*	0.065	0.208**	0.084	0.506**	0.156
	(0.273)	(0.215)	(0.057)	(0.083)	(0.054)	(0.211)	(0.113)
IQI	0.050**	0.022	0.009	0.004	-0.002	0.033*	0.015
	(0.021)	(0.016)	(0.007)	(0.010)	(0.008)	(0.018)	(0.015)
Pop	0.593***	0.397***	0.086***	0.067	0.031	0.375***	0.221***
	(0.111)	(0.083)	(0.032)	(0.041)	(0.033)	(0.092)	(0.067)
GVApc	0.020	0.012	0.000	-0.002	0.013	-0.004	0.026
	(0.038)	(0.027)	(0.012)	(0.015)	(0.013)	(0.029)	(0.023)
Enter	0.935**	0.644*	0.290***	0.150	0.089	0.288	0.636***
	(0.446)	(0.366)	(0.102)	(0.126)	(0.089)	(0.361)	(0.201)
ManSh	-0.788***	-0.383***	-0.171**	-0.228***	-0.102*	-0.528***	-0.249**
	(0.189)	(0.135)	(0.067)	(0.081)	(0.062)	(0.153)	(0.107)
ICTSh	3.455***	2.863***	0.302	0.343	0.349	2.408***	1.157**
	(0.884)	(0.666)	(0.206)	(0.295)	(0.239)	(0.665)	(0.469)
PvtSvcSh	-0.244	-0.137	0.109	-0.232***	-0.070	-0.210	-0.058
	(0.197)	(0.143)	(0.070)	(0.076)	(0.058)	(0.155)	(0.123)
R&Dpr	0.061*	0.019	0.027**	0.007	-0.014	0.014	0.041*
	(0.033)	(0.025)	(0.014)	(0.016)	(0.013)	(0.028)	(0.024)
R&Dpub	-0.057	-0.025	-0.007	0.007	-0.057	-0.092	0.044
	(0.110)	(0.091)	(0.046)	(0.044)	(0.035)	(0.072)	(0.088)
R&Dun	0.112	0.048	0.022	0.023	0.050	0.041	0.052
	(0.097)	(0.077)	(0.027)	(0.038)	(0.035)	(0.078)	(0.052)
N	854	854	854	854	854	854	854
J	13.080	17.730	15.270	11.220	11.620	10.490	12.630
Underid	64.850***	Weak id.	7.066				
C-LG	0.005	0.005	0.004	0.384	0.003	0.060	0.009
End-LC	0.010	0.015	0.015	0.002	6.085	0.643	2.785*
C-WLG	0.625	1.914	0.006	1.177	0.340	0.306	1.214
End-WLG	0.001	0.202	0.091	0.417	0.086	0.268	0.127
C-RG	0.292	0.0566	0.179	0.006	2.611	0.589	0.533
End-RG	2.774*	5.342**	1.282	0.866	0.010	1.191	2.17

Standard errors in brackets. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

In Table 3, we report the results using graduates in each of the six fields of education described in Section 3. To save space, we only report the coefficients of the inflow of new graduates (LG) and its spatial lag (WLG). The stronger positive impact is exerted by Computer Science and Industrial Engineering graduates, whose coefficients are significant overall and in most subsamples. Looking at the first column, a 10% increase in the number of graduates per inhabitant increases the number of innovative start-ups per inhabitant by 0.3%. Considering the actual variability of data, a standard deviation increase in this regressor causes the log number of start-ups per inhabitant to increase by 0.83 standard deviations. All test statistics are valid in this case too; the instrument is extremely strong, as shown by the weak identification test.

Looking at the other fields of education, we find a negative impact on graduates in Science, Agriculture, and Veterinary and on graduates in Architecture, Civil Engineering, and Design. Given the validity of all test statistics, this result can be interpreted as a more rewarding outside option for these graduates to enter paid employment in existing firms. Graduates in Medicine, Psychology, and Sport Science do not directly affect the creation of innovative start-ups. However, the spatial lag is significant in the overall group of innovative start-ups, the two groups of start-ups satisfying the R&D criteria and those belonging to high-tech industries. This suggests that the relevant labor market for these firms is not provincial but expands to neighboring provinces. Finally, we do not find any significant impact on graduates in Social Sciences, either in the province or from neighboring provinces.

Table 3 Effect of the supply of graduates on the creation of innovative startups: results by field of studies

		StUp	StUpRD	StUpINN	StUpGR	StUpHT_	StUpMic_	StUpNMic
Computer Science, Industrial engineering	LG	0.030**	0.010	0.008**	0.024***	0.027***	0.029***	0.002
		(0.012)	(0.010)	(0.004)	(0.005)	(0.010)	(0.010)	(0.007)
	WLG	0.007	-0.002	0.007	0.005	0.001	0.012	-0.009
		(0.022)	(0.017)	(0.007)	(0.009)	(0.017)	(0.016)	(0.014)
	N	856	856	856	856	856	856	856
	Hansen J	23.050	30.290	19.530	17.770	21.220	16.630	23.710
	Underid	184.5***	Weak id.	45.040				
	Cstat WLG	0.397	0.001	0.711	0.006	0.028	0.043	0.436
	Endog WLG	0.566	0.339	1.464	0.042	0.025	0.697	0.005
	Cstat LG	1.292	1.842	1.672	2.547	0.551	2.334	0.196
	Endog LG	3.903**	4.500**	0.029	0.205	4.649**	3.035*	2.968*
Science, Agriculture and Veterinary	LG	-0.019*	-0.015**	-0.005	-0.001	-0.017**	-0.009	-0.006
		(0.010)	(0.007)	(0.003)	(0.005)	(0.008)	(0.009)	(0.007)
	WLG	0.008	0.010	-0.001	0.005	0.003	0.007	0.005
		(0.026)	(0.019)	(0.008)	(0.010)	(0.019)	(0.018)	(0.016)
	Hansen J	12.210	6.196	15.400	14.790	11.110	10.110	15.550
	Underid	194.9***	Weak id.	42.980				
	Cstat WLG	0.793	0.525	1.112	0.870	1.565	1.157	0.052
	Endog WLG	4.108**	6.59***	0.417	1.372	2.281	4.799**	0.729
	Cstat LG	0.292	0.057	0.179	0.006	0.276	0.589	0.533
	Endog LG	2.774*	5.342**	1.282	0.866	3.273*	1.191	2.170
Architecture, Civil Engineering, Design and Arts	LG	-0.037**	-0.031**	-0.007	-0.002	-0.020*	-0.018	-0.014
		(0.015)	(0.012)	(0.005)	(0.007)	(0.012)	(0.012)	(0.009)
	WLG	0.026	0.030	0.005	0.007	0.007	0.030	-0.006
		(0.035)	(0.027)	(0.010)	(0.012)	(0.027)	(0.026)	(0.019)
	Hansen J	9.953	11.870	13.760	19.190	4.805	5.810	17.710
	Underid	181.3***	Weak id.	39.280				
	Cstat WLG	0.197	1.478	0.008	0.550	0.127	0.119	0.019
	Endog WLG	3.831*	5.018**	2.894*	0.297	0.775	3.534*	1.525
	Cstat LG	0.725	0.137	0.065	5.343	0.003	0.113	0.197
	Endog LG	18.28***	15.19***	10.990***	3.752*	7.271***	9.187***	5.102**
Medicine, Psycology, Sport Science	LG	0.019	0.014	0.001	0.002	0.016	0.014	0.006
		(0.013)	(0.011)	(0.005)	(0.005)	(0.011)	(0.011)	(0.008)
	WLG	0.058*	0.039*	0.005	0.018	0.046*	0.035	0.021
		(0.030)	(0.023)	(0.008)	(0.011)	(0.024)	(0.022)	(0.018)
	Underid	87.9***	Weak id.	13.390				
	Cstat WLG	2.490	1.139	2.601	0.112	2.493	3.452	0.517
	Endog WLG	0.066	0.014	0.204	0.579	0.009	0.020	0.038
	Cstat LG	0.917	0.544	0.394	0.114	2.701	0.730	0.609
	Endog LG	0.113	0.244	0.146	1.260	0.762	0.039	0.139
Humanities, Languages and Education	LG	-0.000	-0.003	-0.000	0.007**	0.005	0.002	-0.001
		(0.008)	(0.006)	(0.003)	(0.003)	(0.007)	(0.007)	(0.006)
	WLG	0.063**	0.039**	0.002	0.029***	0.041**	0.042**	0.022*
		(0.025)	(0.019)	(0.006)	(0.009)	(0.018)	(0.018)	(0.013)
	Underid	188.2***	Weak id.	40.740				
	Cstat WLG	0.380	0.192	0.300	0.000	0.138	1.307	0.026
	Endog WLG	3.042*	1.211	0.058	5.533**	2.206	2.693	0.878
	Cstat LG	0.893	2.131	2.169	0.061	1.094	2.898	0.131
	Endog LG	0.642	0.565	0.007	0.061	2.581	0.667	0.195
Social Sciences	LG	-0.010	-0.009	0.006	0.000	-0.000	0.005	-0.013
		(0.014)	(0.010)	(0.005)	(0.006)	(0.011)	(0.011)	(0.010)
	WLG	0.032	0.031	-0.000	0.012	0.012	0.019	0.009
		(0.027)	(0.021)	(0.008)	(0.009)	(0.022)	(0.021)	(0.016)
	Underid	74.2***	Weak id.	7.291				
	Cstat WLG	2.317	4.65**	0.019	0.238	3.704	3.497	0.522
	Endog WLG	0.102	0.122	0.055	0.161	0.680	0.001	0.624
	Cstat LG	0.040	0.046	1.260	0.023	0.156	0.855	0.056
	Endog LG	1.616	1.222	0.880	0.100	0.804	0.068	4.230

Standard errors in parenthesis. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

3.2 Heterogeneity analysis

We now analyze estimation results when the sample is split according to the overall stock of tertiary educated individuals - with a threshold given by the median - and to the main macro-region (North and South). Table 4 reports the results for provinces with a high share of tertiary-educated individuals. We only find a few significant impacts of the inflow of local graduates. However, the coefficients, when significant, are always negative. This is the case for graduates in Architecture, Civil Engineering and Design, in line with the results for the whole country, and for graduates in Social Sciences, although only when considering start-ups satisfying the graduates/Ph.D. criteria. Nevertheless, we find some significant and positive impacts of the spatial lag of local graduates. In particular for Medicine, Psychology and Sport Science, for Humanities, and for Computer Science and Industrial Engineering.

Moving to the sample of provinces with a low share of tertiary-educated workers, the results change substantially. We find positive and significant impacts of the overall flow of new local graduates and this positive impact is confirmed by almost all fields of education, the only exception being Science, Agriculture and Veterinary, where the effect is, again, negative. The spatial lag of local graduates is significant only when considering graduates in Architecture, Civil Engineering and Design, and Humanities, Languages, and Education. In both cases, the impact is significant only for start-ups satisfying the graduates/Ph.D. criteria.

Moving to sub-regional estimates, we find substantial differences between the North and the South provinces. In the former (table 6), we find no significant impact of the inflow of local graduates on innovative start-up activity. Looking at the different fields, Computer Science and Industrial Engineering graduates positively impact start-ups, but only those who satisfy the innovation criteria. The effect of Science graduates is negative for the whole group, confirming the aggregate evidence. In contrast, graduates in Architecture, Civil Engineering, and Design exert a positive indirect effect through the spatial lag of the variable. No significant effect, instead, is found for graduates in Medicine and Psychology, while positive and significant direct and indirect effects are found for graduates in Humanities, Languages, and Education. Graduates in Social Sciences positively affect start-ups that satisfy the innovation criteria, while indirect effects are negative in most cases.

As for southern provinces, the total inflow of graduates positively impacts start-ups satisfying the human capital (HC) criteria and those operating in high-tech sectors. However, Negative indirect impacts are found on the whole sample of start-ups and those satisfying the R&D criteria. Positive direct impacts are found for graduates in Computer Science and Industrial Engineering, for which some positive indirect impacts are found, and for Architecture, Civil Engineering, and Design. No significant impact is found for Science, and for Medicine and Psychology. At the same time, graduates in Humanities, Languages and Education, and, to a lesser extent, Social Sciences have negative impacts on start-up creation.

Summing up the results of the heterogeneity analysis, we find a substantial rebalancing effect of the inflow of local graduates. This is shown by the higher significance and impacts of graduates in provinces with a low share of tertiary educated workers and in southern provinces. This is in line with a catching-up process where lagging behind provinces experience higher impacts of graduates on start-up activity due to the latter's lower development and relative shortage of HC. Indirect effects are, on average, more significant in high-tertiary-educated workers provinces and in northern provinces. This is consistent with the catching-up assumption since local labor markets are integrated in better-endowed provinces, and the university effect goes beyond that of the location province. Instead, spatial effects are absent in provinces with a low share of tertiary-educated workers. Considering the differences between the North and South, the evidence on indirect effects is mixed with positive impacts in the North stemming from the humanities, languages, and education, and negative ones from graduates in social sciences. In the south, the negative and significant indirect effects of the total inflow of graduates point to confirmation of the catching-up assumption as negative effects might be due to the low diffusion of graduates and universities, which causes start-ups to locate close to the source of HC.

Table 4 Effect of the supply of graduates on the creation of innovative startups: provinces with a high share of tertiary educated workers

		StUp	StUpRD	StUpINN	StUpGR	StUpHT	StUpMIC	StUpNMIC
Total	LG	-0.014	0.002	-0.004	-0.014	-0.015	0.009	-0.020
		(0.035)	(0.023)	(0.012)	(0.013)	(0.025)	(0.025)	(0.019)
	WLG	0.057	0.040	0.008	0.015	0.036	0.026	0.015
		(0.036)	(0.026)	(0.008)	(0.011)	(0.025)	(0.023)	(0.019)
	N	424	424	424	424	424	424	424
	Hansen J	12.430	15.360	12.240	14.940	13.170	13.020	12.560
	Underid	51.62***	Weak id.	7.889				
	Cstat WLG	1.703	2.672	0.087	1.256	0.935	1.220	2.036
	Endog WLG	0.318	0.434	0.897	0.561	1.465	0.308	0.050
	Cstat LG	0.751	0.717	0.001	0.149	2.671	2.548	0.606
	Endog LG	0.153	0.451	0.824	2.445	0.115	0.038	0.711
Computer science and industrial engineering	LG	-0.011	-0.010	0.000	0.008	-0.017	0.002	-0.015
		(0.022)	(0.017)	(0.007)	(0.010)	(0.019)	(0.018)	(0.013)
	WLG	0.039	0.006	0.025**	0.026*	0.032	0.036	0.003
		(0.035)	(0.027)	(0.011)	(0.014)	(0.027)	(0.024)	(0.022)
	Hansen J	10.63	10.20	18.89	9.074	8.916	6.343	12.91
	Underid	92.87***	Weakid	32.57				
	Cstat WLG	0.184	0.0750	0.429	0.0269	0.00440	0.363	0.349
	Endog WLG	0.936	0.659	0.496	1.414	0.155	1.538	0.00844
	Cstat LG	0.775	0.192	5.631**	0.327	0.552	0.281	1.124
	Endog LG	23.49***	22.64***	5.429**	7.615***	23.34***	19.92***	10.48***
Science, Agriculture and Veterinarinary	LG	-0.002	-0.005	-0.007	-0.003	-0.008	0.006	-0.011
		(0.017)	(0.011)	(0.005)	(0.007)	(0.013)	(0.014)	(0.010)
	WLG	-0.033	-0.032	-0.000	-0.010	-0.031	-0.036	-0.008
		(0.036)	(0.025)	(0.011)	(0.011)	(0.025)	(0.025)	(0.018)
	Hansen J	18.010	10.580	27.240	21.820	22.390	18.650	17.290
	Underid	92.62***	Weak id.	18.430				
	Cstat WLG	0.825	1.252	0.001	0.640	0.373	0.250	2.606
	Endog WLG	0.045	0.021	0.569	0.000	0.104	0.032	0.002
	Cstat LG	0.072	0.392	0.054	0.284	0.563	0.997	1.148
	Endog LG	3.840**	5.519**	0.831	3.808*	1.081	0.917	6.141**
Architecture, Civil engineering, Design and Arts	LG	-0.036*	-0.031**	-0.008	-0.008	-0.014	-0.028*	-0.014
		(0.019)	(0.014)	(0.005)	(0.008)	(0.015)	(0.015)	(0.009)
	WLG	0.010	-0.001	0.008	0.005	0.004	0.019	-0.030
		(0.049)	(0.035)	(0.012)	(0.015)	(0.035)	(0.032)	(0.025)
	Hansen J	8.273	9.925	12.890	22.060	9.064	9.851	15.150
	Underid	88.96***	Weak id.	18.450				
	Cstat WLG	0.001	0.299	0.687	0.813	0.972	0.157	0.000
	Endog WLG	0.244	1.750	2.631	2.066	0.222	0.487	0.144
	Cstat LG	1.733	0.068	0.192	4.919	0.181	0.094	2.110
	Endog LG	10.15***	7.326***	7.487***	1.527	4.164**	12.92***	0.946
Medicine, Psychology and Sport Science	LG	0.020	0.004	0.002	-0.010	0.004	0.024	-0.010
		(0.033)	(0.024)	(0.012)	(0.012)	(0.027)	(0.027)	(0.017)
	WLG	0.106**	0.071**	0.016	0.018	0.071**	0.057*	0.023
		(0.049)	(0.034)	(0.012)	(0.014)	(0.032)	(0.030)	(0.024)
	Hansen J	14.770	13.230	13.330	18.550	16.340	16.770	10.120
	Underid	41.47***	Weak id.	4.600				
	Cstat WLG	1.581	1.945	0.194	0.140	0.504	1.071	1.279
	Endog WLG	0.561	1.279	1.439	0.246	0.168	0.001	0.972
	Cstat LG	2.631	0.878	0.720	2.619	4.964	2.563	0.257
	Endog LG	0.001	0.275	3.516	0.948	0.212	0.149	0.148
Humanities, Languages And Education	LG	-0.012	-0.009	-0.009	0.004	-0.010	0.007	-0.015
		(0.025)	(0.017)	(0.007)	(0.009)	(0.018)	(0.017)	(0.012)
	WLG	0.066**	0.030	-0.000	0.027***	0.037*	0.043**	0.004
		(0.031)	(0.022)	(0.007)	(0.009)	(0.021)	(0.021)	(0.015)
	Hansen J	15.100	13.830	12.000	19.210	14.160	12.580	16.160
	Underid	76.75***	Weak id.	12.970				
	Cstat WLG	0.360	0.051	0.021	2.567	0.371	0.107	0.607
	Endog WLG	1.339	1.677	0.039	0.275	3.444*	1.608	0.245
	Cstat LG	1.986	0.768	0.070	0.316	0.214	0.587	0.057
	Endog LG	0.041	0.002	0.825	0.115	0.539	0.841	0.295
Social Sciences	LG	-0.021	-0.019	0.009	-0.025**	-0.013	-0.016	-0.014
		(0.031)	(0.020)	(0.010)	(0.012)	(0.024)	(0.022)	(0.015)
	WLG	0.032	0.032	-0.009	0.017	0.011	0.006	0.008
		(0.035)	(0.024)	(0.009)	(0.011)	(0.024)	(0.022)	(0.019)
	Hansen J	13.220	15.090	14.590	13.330	16.110	15.930	15.390
	Underid	64.34***	Weak id.	5.992				
	Cstat WLG	0.623	0.510	0.533	0.331	1.462	0.466	0.045
	Endog WLG	0.068	0.709	1.401	0.096	0.519	0.279	0.310
	Cstat LG	0.032	1.026	0.429	0.121	0.010	1.216	0.005
	Endog LG	2.889	3.739	0.619	2.868	2.547	1.231	2.215

Standard errors in parenthesis. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 5 Effect of the supply of graduates on the creation of innovative startups: provinces with a low share of tertiary educated individuals

		StUp	StUpRD	StUpINN	StUpGR	StUpHT	StUpMIC	StUpNMIC
Total	LG	0.022**	0.009	0.006*	0.015***	0.017*	0.022**	0.003
		(0.011)	(0.007)	(0.004)	(0.004)	(0.009)	(0.010)	(0.007)
	WLG	-0.036	-0.016	-0.019	0.008	-0.034	0.003	-0.033
		(0.034)	(0.025)	(0.012)	(0.015)	(0.029)	(0.026)	(0.023)
	N	430	430	430	430	430	430	430
	Hansen J	21.240	23.520	27.710	19.930	18.310	19.640	16.510
	Underid	80.9***	Weak id.	9.459				
	Cstat WLG	0.281	1.758	0.124	0.469	1.781	0.152	1.453
	Endog WLG	0.088	1.691	0.408	0.298	0.056	0.102	0.242
	Cstat LG	0.967	1.173	0.0241	1.006	0.249	0.382	0.553
	Endog LG	0.895	1.495	0.0985	3.095*	0.813	1.92	0.296
Computer science and industrial engineering	LG	0.026*	0.007	0.010**	0.020***	0.029**	0.029**	0.004
		(0.014)	(0.011)	(0.004)	(0.006)	(0.012)	(0.013)	(0.011)
	WLG	-0.016	-0.002	0.003	-0.009	-0.001	0.003	-0.020
		(0.028)	(0.020)	(0.010)	(0.012)	(0.023)	(0.022)	(0.018)
	Hansen J	19.850	21.860	15.130	25.030	26.660	22.370	12.520
	Underid	124.2***	Weak id.	28.990				
	Cstat WLG	0.161	1.163	0.378	1.253	0.005	0.005	0.920
	Endog WLG	0.019	0.104	1.893	1.030	0.295	0.984	0.211
	Cstat LG	0.629	0.469	0.537	3.540	0.759	0.176	0.085
	Endog LG	0.787	0.041	0.619	0.536	0.032	0.024	0.835
Hard sciences, Agrarian and Veterinarian studies	LG	-0.022	-0.019*	-0.006	-0.008	-0.032***	-0.023**	-0.000
		(0.014)	(0.010)	(0.004)	(0.007)	(0.011)	(0.011)	(0.011)
	WLG	-0.001	0.003	-0.009	0.005	0.006	0.015	0.009
		(0.037)	(0.028)	(0.008)	(0.016)	(0.029)	(0.023)	(0.025)
	Hansen J	12.710	12.170	24.920	18.130	10.650	10.210	16.620
	Underid	121.9***	Weak id.	31.650				
	Cstat WLG	0.835	0.080	0.683	6.885	0.261	0.032	2.006
	Endog WLG	2.212	2.440	1.400	2.457	2.326	4.515**	3.321*
	Cstat LG	0.678	0.832	2.605	0.236	0.531	0.128	1.722
	Endog LG	0.408	0.011	0.422	0.078	1.313	0.026	0.723
Architecture, Civil engineering, Design and Arts	LG	0.038***	0.026**	0.010**	0.012*	0.034***	0.020	0.023***
		(0.014)	(0.011)	(0.004)	(0.006)	(0.012)	(0.012)	(0.009)
	WLG	0.003	-0.009	-0.016	0.032**	0.030	0.005	0.001
		(0.037)	(0.027)	(0.011)	(0.015)	(0.029)	(0.026)	(0.025)
	Hansen J	23.670	20.680	18.480	16.500	18.020	20.010	21.070
	Underid	58.090	Weak id.	9.278				
	Cstat WLG	1.018	0.323	2.133	0.269	1.902	1.942	0.017
	Endog WLG	0.009	0.677	0.685	2.776	0.182	0.007	0.225
	Cstat LG	0.738	1.293	2.354	1.735	0.018	0.195	0.015
	Endog LG	1.365	5.562**	0.016	0.077	4.007	0.536	1.129
Medicine, Psychology and Sport Science	LG	0.030	0.001	0.001	0.018*	0.021	0.032*	-0.001
		(0.024)	(0.019)	(0.008)	(0.011)	(0.018)	(0.017)	(0.016)
	WLG	-0.013	-0.028	0.012	0.001	-0.042	-0.002	-0.018
		(0.038)	(0.027)	(0.015)	(0.018)	(0.033)	(0.033)	(0.026)
	Hansen J	13.690	14.980	15.500	17.210	11.330	6.019	23.300
	Underid	60.7***	Weak id.	9.761				
	Cstat WLG	1.289	1.569	1.556	2.872	0.093	0.001	3.457
	Endog WLG	0.157	0.107	2.016	1.155	3.031	0.682	2.024
	Cstat LG	0.757	1.175	2.299	0.189	1.420	0.055	3.738
	Endog LG	2.082	0.858	3.007*	0.128	0.315	0.021	0.480
Humanities, Languages And Education	LG	0.011*	0.000	0.005**	0.008***	0.012**	0.009	0.007
		(0.006)	(0.004)	(0.002)	(0.003)	(0.005)	(0.007)	(0.006)
	WLG	0.042	0.022	0.007	0.034**	0.025	0.041	0.017
		(0.034)	(0.023)	(0.012)	(0.016)	(0.025)	(0.027)	(0.022)
	Hansen J	12.88	10.38	22.36	18.59	12.01	15.16	18.20
	Underid	89.370	Weak id.	16.410				
	Cstat WLG	0.165	1.375	0.237	0.481	0.103	0.090	0.103
	Endog WLG	1.086	0.015	0.809	5.194**	1.212	2.537	0.221
	Cstat LG	0.256	1.103	0.000	0.696	1.202	0.631	0.025
	Endog LG	2.822*	0.507	0.278	1.198	7.335	4.126	2.321
Social Sciences	LG	0.024**	0.007	0.004	0.018***	0.020**	0.031**	-0.007
		(0.012)	(0.008)	(0.005)	(0.006)	(0.010)	(0.012)	(0.011)
	WLG	0.004	0.008	0.004	0.011	-0.032	0.035	-0.012
		(0.039)	(0.030)	(0.015)	(0.017)	(0.034)	(0.035)	(0.031)
	Hansen J	20.500	25.73*	26.9*	19.600	17.300	16.450	16.340
	Underid	73.1***	Weak id.	7.513				
	Cstat WLG	2.502	1.427	0.675	6.571***	0.179	3.467	0.872
	Endog WLG	0.114	0.232	0.411	0.010	0.672	0.063	0.350
	Cstat LG	0.439	2.743	0.010	1.188	0.007	0.020	0.836
	Endog LG	1.451	1.651	0.096	3.182*	0.963	4.053	0.818

Standard errors in parenthesis. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 6 Effect of the supply of graduates on the creation of innovative startups: centre-north provinces

		StUp	StUpRD	StUpINN	StUpGR	StUpHT	StUpMIC	StUpNMIC
Total	LG	0.005	-0.001	0.006	0.003	-0.001	0.003	0.001
		(0.009)	(0.007)	(0.004)	(0.004)	(0.007)	(0.008)	(0.007)
	WLG	0.016	0.007	0.012	-0.002	-0.008	-0.004	0.009
		(0.042)	(0.031)	(0.013)	(0.014)	(0.033)	(0.030)	(0.024)
	N	496	496	496	496	496	496	496
	Hansen J	19.94	16.74	15.38	17.14	20.68	16.04	15.74
	Underid	75.77	Weakid	12.44				
	Cstat WLG	0.420	0.183	0.040	0.0111	1.349	0.329	0.100
	Endog WLG	0.027	0.003	0.894	1.013	0.219	0.0434	0.337
	Cstat LG	1.201	2.681	0.167	0.811	1.338	0.993	1.723
	Endog LG	2.165	3.025*	0.0185	1.089	3.104*	3.845**	1.079
Computer science and industrial engineering	LG	0.013	-0.009	0.011**	0.020***	0.007	0.016	0.003
		(0.012)	(0.009)	(0.005)	(0.005)	(0.011)	(0.011)	(0.009)
	WLG	0.014	0.000	0.005	0.016	-0.000	0.010	0.008
		(0.035)	(0.027)	(0.011)	(0.012)	(0.026)	(0.025)	(0.022)
	Hansen J	19.86	19.12	17.32	19.45	22.06	17.03	23.41
	Underid	111.5	Weakid	40.84				
	Cstat WLG	0.003	0.002	2.320	1.874	0.123	1.130	0.086
	Endog WLG	3.499*	7.200***	1.295	1.364	11.32***	3.066*	2.555
	Cstat LG	0.860	0.723	0.257	0.621	1.156	0.408	0.467
	Endog LG	0.207	0.011	0.0344	0.002	0.003	0.178	0.005
Hard sciences, Agrarian and Veterinarian studies	LG	-0.021**	-0.022***	-0.001	-0.004	-0.014*	-0.016*	-0.005
		(0.010)	(0.006)	(0.003)	(0.004)	(0.008)	(0.009)	(0.007)
	WLG	-0.032	-0.008	-0.008	-0.013	-0.022	-0.009	-0.023
		(0.030)	(0.022)	(0.011)	(0.010)	(0.024)	(0.024)	(0.017)
	Hansen J	17.49	16.77	16.30	14.73	17.45	13.50	11.78
	Underid	118.7	Weakid	32.63				
	Cstat WLG	0.672	0.920	2.557	0.610	1.008	0.446	0.241
	Endog WLG	3.336*	5.113**	1.491	4.944	5.131	2.244	2.437
	Cstat LG	0.444	1.108	0.023	0.706	0.462	0.124	1.621
	Endog LG	0.0324	0.272	0.145	0.582	0.371	0.130	0.0881
Architecture, Civil engineering, Design and Arts	LG	0.010	0.003	0.004	0.006	0.001	0.010	-0.001
		(0.014)	(0.011)	(0.006)	(0.006)	(0.012)	(0.013)	(0.010)
	WLG	0.075**	0.051*	0.017	0.014	0.056**	0.050*	0.027
		(0.037)	(0.027)	(0.012)	(0.013)	(0.028)	(0.027)	(0.021)
	Hansen J	14.90	8.306	19.54	21.67	12.10	15.44	7.676
	Underid	38.43	Weakid	4.595				
	Cstat WLG	0.487	1.254	0.0631	5.466**	1.236	0.134	0.031
	Endog WLG	0.287	0.001	0.086	2.369	1.757	0.0183	0.345
	Cstat LG	1.084	0.206	2.085	0.140	0.701	2.130	0.0111
	Endog LG	1.375	5.103	0.673	0.360	1.496	0.842	2.263
Medicine, Psychology and Sport Science	LG	-0.015	-0.014	-0.002	0.004	-0.014	-0.014	-0.001
		(0.014)	(0.011)	(0.005)	(0.007)	(0.012)	(0.012)	(0.008)
	WLG	-0.002	0.012	0.010	0.009	0.011	0.009	-0.013
		(0.041)	(0.032)	(0.011)	(0.013)	(0.031)	(0.028)	(0.023)
	Hansen J	16.16	15.13	16	23.02	12.26	14.29	17.94
	Underid	111.5	Weakid	34.53				
	Cstat WLG	0.414	0.00816	0.213	5.374**	0.0235	0.111	1.255
	Endog WLG	6.040**	1.509	8.307***	3.855**	4.374**	3.837*	0.979
	Cstat LG	0.323	2.127	0.121	1.556	0.128	0.284	0.029
	Endog LG	0.146	0.070	1.712	0.595	0.008	0.316	0.023
Humanities, Languages And Education	LG	0.015**	0.005	0.005	0.011***	0.017**	0.011	0.005
		(0.008)	(0.006)	(0.003)	(0.003)	(0.007)	(0.008)	(0.006)
	WLG	0.120***	0.102***	0.003	0.026**	0.065**	0.060**	0.050**
		(0.036)	(0.027)	(0.012)	(0.013)	(0.030)	(0.027)	(0.021)
	Hansen J	15.42	13.44	22.15	16.01	11.47	13.86	17.82
	Underid	102.1	Weakid	18.65				
	Cstat WLG	0.163	0.327	0.107	1.183	0.238	0.476	0.519
	Endog WLG	0.087	0.0222	0.173	0.354	0.038	0.069	0.012
	Cstat LG	0.251	0.146	2.322	0.003	0.204	0.142	1.508
	Endog LG	3.458*	2.447	1.476	1.376	7.592***	3.215*	0.0017
Social Sciences l2wlg	LG	0.018	0.007	0.018***	-0.003	0.012	0.016	-0.000
		(0.014)	(0.011)	(0.006)	(0.006)	(0.012)	(0.013)	(0.009)
	WLG	-0.176***	-0.111**	-0.027	-0.024	-0.170***	-0.138***	-0.035
		(0.065)	(0.051)	(0.019)	(0.019)	(0.052)	(0.044)	(0.036)
	Hansen J	19.95	19.50	12.08	15.01	18.34	20.17	16.01
	Underid	39.72	Weakid	2.946				
	Cstat WLG	0.0256	0.145	0.803	0.004	0.020	0.563	0.0631
	Endog WLG	0.163	0.039	9.329***	2.075	0.033	0.273	1.140
	Cstat LG	1.203	1.261	0.049	0.266	0.001	1.417	0.016
	Endog LG	8.539***	8.125***	2.101	3.111*	12.32***	10.94***	1.618

Standard errors in parenthesis. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 7 Effect of the supply of graduates on the creation of innovative startups: centre-south provinces

		StUp	StUpRD	StUpINN	StUpGR	StUpHT	StUpMIC	StUpNMIC
Total	LG	0.002	-0.020	0.003	0.031**	0.021**	0.036	-0.025
		(0.037)	(0.031)	(0.011)	(0.013)	(0.010)	(0.026)	(0.022)
	WLG	-0.100**	-0.109***	0.008	0.011	-0.010	-0.023	-0.033
		(0.042)	(0.033)	(0.012)	(0.020)	(0.013)	(0.033)	(0.027)
	N	358	358	358	358	358	358	358
	Hansen J	21.58	21.99	16.15	20.49	14.17	26.02*	14.29
	Underid	33.27	Weakid	1.524				
	Cstat WLG	0.108	0.181	0.540	0.241	0.214	2.567	0.0578
	Endog WLG	0.951	2.578	0.0128	1.748	1.017	0.0127	1.239
	Cstat LG	0.987	0.958	0.290	0.559	0.316	1.952	0.366
	Endog LG	2.570	3.182*	0.493	0.218	0.0836	0.169	0.344
Computer science and industrial engineering	LG	0.014	0.004	0.010	0.021**	-0.002	0.032*	-0.017
		(0.025)	(0.021)	(0.006)	(0.010)	(0.007)	(0.018)	(0.014)
	WLG	0.042	0.001	0.028***	0.016	0.007	0.017	0.006
		(0.033)	(0.025)	(0.010)	(0.015)	(0.010)	(0.025)	(0.022)
	Hansen J	17.86	27.38**	16.03	25.78*	15.63	23.05	10.67
	Underid	69.21	Weakid	13.02				
	Cstat WLG	0.0396	0.123	0.115	0.100	0.160	0.317	0.188
	Endog WLG	0.0633	0.633	1.234	0.789	0.176	0.550	0.000546
	Cstat LG	0.0480	0.0582	0.222	1.319	1.316	0.123	0.0365
	Endog LG	10.67***	4.317**	9.480***	2.328	1.703	5.300**	3.627*
Hard sciences, Agrarian and Veterinarian studies	LG	0.005	-0.008	0.017	-0.010	-0.000	0.002	-0.004
		(0.030)	(0.025)	(0.011)	(0.016)	(0.010)	(0.026)	(0.020)
	WLG	0.043	0.028	0.001	0.013	-0.009	0.009	0.047*
		(0.040)	(0.031)	(0.009)	(0.017)	(0.010)	(0.025)	(0.027)
	Hansen J	13.10	10.77	18.95	21.10	18.60	18.95	9.284
	Underid	64.21	Weakid	11.10				
	Cstat WLG	0.424	0.475	1.517	1.286	1.631	0.567	0.000327
	Endog WLG	0.443	0.564	0.796	0.459	0.883	0.360	1.936
	Cstat LG	0.485	0.0366	0.235	0.0423	0.387	0.0257	0.759
	Endog LG	0.835	3.519*	4.422**	0.297	0.00177	1.006	0.134
Architecture, Civil engineering, Design and Arts	LG	0.049***	0.037**	0.005	0.007	0.019***	0.033**	0.023**
		(0.018)	(0.015)	(0.006)	(0.008)	(0.007)	(0.014)	(0.011)
	WLG	-0.023	-0.026	-0.011	0.019	-0.008	-0.013	-0.035
		(0.038)	(0.030)	(0.009)	(0.017)	(0.010)	(0.027)	(0.028)
	Hansen J	16.37	21.85	11.46	17.14	7.919	15.40	15.50
	Underid	43.45	Weakid	5.723				
	Cstat WLG	0.123	0.170	0.521	0.387	0.211	0.133	0.469
	Endog WLG	0.000986	0.0109	2.102	1.390	0.0260	0.00513	0.356
	Cstat LG	0.00171	0.0325	0.0256	0.0444	0.0145	0.00731	1.418
	Endog LG	1.021	0.466	0.0940	0.0451	6.380	0.145	1.712
Medicine, Psychology and Sport Science	LG	-0.016	-0.029	-0.007	0.009	0.002	0.003	-0.011
		(0.028)	(0.021)	(0.008)	(0.012)	(0.008)	(0.020)	(0.017)
	WLG	0.022	0.011	0.003	0.003	0.002	0.040	-0.013
		(0.045)	(0.038)	(0.014)	(0.019)	(0.016)	(0.036)	(0.028)
	Hansen J	10.79	21.59	9.581	18.55	7.204	10.20	10.93
	Underid	81.91	Weakid	17.40				
	Cstat WLG	0.535	0.376	0.247	1.318	0.250	0.159	0.0420
	Endog WLG	5.094**	5.089**	5.103**	0.107	0.645	2.895	1.422
	Cstat LG	0.0201	4.02e-07	0.00975	0.530	0.425	0.0139	0.0254
	Endog LG	9.486***	11.93***	3.647*	0.0260	2.802*	10.29***	2.656
Humanities, Languages And Education	LG	-0.070***	-0.043***	-0.014**	-0.003	-0.008	-0.048***	-0.020*
		(0.020)	(0.014)	(0.006)	(0.008)	(0.006)	(0.017)	(0.011)
	WLG	0.001	-0.017	-0.001	0.012	-0.001	0.008	-0.013
		(0.018)	(0.014)	(0.006)	(0.009)	(0.006)	(0.017)	(0.012)
	Hansen J	23.72	20.61	21.86	20.74	12.20	20.44	18.95
	Underid	54.76	Weakid	8.967				
	Cstat WLG	1.213	1.318	0.0315	0.194	0.789	2.231	0.0649
	Endog WLG	4.159**	2.931*	0.863	0.118	0.348	3.070*	0.145
	Cstat LG	0.596	0.0168	6.660	3.645	1.730	1.375	0.244
	Endog LG	0.165	6.96e-06	0.00631	2.373	1.961	1.150	0.00200
Social Sciences l2wlg	LG	-0.038	-0.062**	-0.006	0.017	0.008	-0.004	-0.038**
		(0.031)	(0.025)	(0.009)	(0.012)	(0.009)	(0.022)	(0.019)
	WLG	0.005	-0.009	0.011	0.019*	-0.004	0.012	-0.005
		(0.031)	(0.023)	(0.009)	(0.011)	(0.008)	(0.025)	(0.016)
	Hansen J	23.06	21.18	15.40	23.82	17.30	23.57	14.35
	Underid	46.03	Weakid	5.830				
	Cstat WLG	1.094	1.536	0.158	1.439	0.192	0.293	1.206
	Endog WLG	6.182**	7.016***	2.974*	0.340	0.0629	2.599	5.574**
	Cstat LG	0.673	0.976	3.317*	0.00826	1.579	0.0465	0.822
	Endog LG	1.170	0.989	1.704	1.827	0.00463	1.187	2.332

Standard errors in parenthesis. *significant at 10% level; **significant at 5% level; ***significant at 1% level.

5. Conclusions and policy implications

This paper aims to help understand the connections between HEIs and their ecosystems, particularly from a geographic perspective, as our concept of the 'place-responsive HEI' builds on ideas of the 'entrepreneurial university', the 'engaged university', and the 'systems-based university' (Kempton et al., 2021).

We provide evidence of this role for HIEs by assessing the impact of the supply of new graduates on innovative entrepreneurship in Italian provinces and by adding other channels through which HIEs affect entrepreneurship. We estimate spatial panel data models using a novel dataset, including information on innovative start-ups, the number of graduates by main field, university activity in terms of spinoffs, licences and research productivity, institutional quality, and the main structural characteristics of provinces, including R&D by main sector.

Our results can be summarised as follows: first, the effect of the total inflow of new graduates is limited to some groups of innovative start-ups. At the same time, research productivity and spinoffs exert robust positive effects on the number of new start-ups. Second, there is substantial heterogeneity in the field of education, with graduates in technology-related fields, particularly Computer Science and Industrial Engineering, having a robust and significant impact on start-up proliferation. Negative effects are, instead, found for graduates in Science, and Architecture, Civil Engineering and Design. Negative effects stem from the high value of the outside option of working as employees in well-established firms or the public sector. Third, the results are heterogeneous, with higher positive impacts of graduates in provinces with a low share of tertiary educated workers and in the South. This is in line with a catching-up behavior where start-ups located in lagging behind regions tend to benefit more from the supply of graduates and to be located close to the source. Finally, we find some indirect effects stemming from new local graduates in neighboring provinces. However, these effects seem to favor mostly well-endowed and advanced provinces. In lagging behind provinces, indirect effects, when significant, are often negative, suggesting that start-ups in these provinces tend to be located close to the source, given the relative shortage of HC.

These findings have important policy implications concerning the function of HIEs in fostering innovation and growth. First, thanks to their multidisciplinary skills and knowledge endowment, HEIs should be considered leading actors in the entrepreneurial discovery and valorization of territorial assets. Furthermore, being at the crossroads between demand and supply of knowledge and human capital, they should be acknowledged as central parts of a package of measures aimed at exploiting policy complementarities in technology transfer activities (Acemoglu 1997; Redding 1996, Trapasso and Staats, 2019).

The provision of innovative capabilities by HEIs, in the form of entrepreneurial human capital, can support lagging behind regions in their economic restructuring process and help them achieve a sustainable path of economic growth. A solution that exploits supply-demand complementarities and would help escape from the low-development trap that seems to affect the Italian economy (Scicchitano, 2010).

Second, providing entrepreneurial education to enhance graduates' entrepreneurship can be an essential tool for dealing with the twin mismatch affecting labor and knowledge markets. Developing entrepreneurial mindsets among students and graduates (OECD, 2019), including PhD students, should be seen as a means to improve the quality of graduates' labor market insertion as employees or self-employed and as a tool to transfer knowledge to society. PhDs can be crucial vehicles to promote knowledge-intensive business ventures and, by doing so, activate demand-pull innovation mechanisms (Torrini and Schivardi, 2011; Muscio et al., 2021). Industrial doctorate programs are a central part of this package.

Third, the entrepreneurial and innovative role of HEIs should be reinforced: they should also be able to maintain a proactive role within the innovative ecosystem. Increasing knowledge intensities in productive processes have strengthened the linkage between HEIs and firms in several business sectors. Several examples of this dynamic exist in the biotechnology, computer science, and engineering industries. In addition, HEIs could play a proactive role by stimulating business creation – or interacting with existing firms - in more traditional sectors, in which a "grain" of knowledge would dramatically impact productivity and competitiveness. Not only would HEIs generate innovation, but they would also favor the "percolation" of innovation throughout productive ecosystems by promoting entrepreneurship and intrapreneurship, which makes innovation actionable.

To promote entrepreneurship and innovation, HEIs should become entrepreneurial themselves. New challenges in the labor market, particularly population ageing, require new strategies to allow individuals to acquire new skills in their adult age. HEIs can become key actors within life-long learning policies and empower workers by providing them with resilient competencies and the capacity to be open and flexible, i.e., by cultivating entrepreneurial mindsets.

Overall, our results suggest that an effective organizational approach by universities to enhance their capabilities to promote innovation is to manage job placement and technology transfer activities as part of a coherent organizational strategy relying on entrepreneurial education and training as a pillar.

Skills and knowledge are essential ingredients of innovation and development, but governance mechanisms of the local ecosystems of innovation are equally important enabling factors. HEIs should be involved in governance, and their role in the ecosystem should be strengthened (Canto-Farachala et al., 2022). The positive impact of institutional quality that we find is in line with this argument (Baumol, 1990)

Finally, the local endowment of entrepreneurial human capital is not the only binding constraint to developing R&D-based and knowledge-intensive business ventures. The shape of the Death Valley curve of deep-tech entrepreneurial projects and the resulting equity gap call for the implementation of specific instruments to tackle those financial barriers that may deter the development of socially highly valuable projects from HEIs.

References

Abaidoo, R. & Agyapong, E.K. (2023), Institutional quality, macroeconomic uncertainty and efficiency of financial institutions in Sub-Saharan Africa. *Journal of Financial Regulation and Compliance*, 31(2), 200-2019. https://doi.org/10.1108/JFRC-01-2022-0003

Acemoglu, D. (1997). Training and Innovation in an Imperfect Labour Market. *Review of Economic Studies,* 64(3), 445-464.

Acemoglu, D. (1996). A micro foundation for social increasing returns in human capital accumulation. *Quarterly Journal of Economics,* 111(3), 779–804.

Addessi, W., Biagi, B., Ciucci, L., Detotto, C., & Pulina, M. (2024). Exploring the misalignment between HEIs' educational offerings and the local economy in low(er) income regions. *Regional Studies*, 1–17. https://doi.org/10.1080/00343404.2024.2358827

Agasisti, T., Barra, C., & Zotti, R. (2019). Research, knowledge transfer, and innovation: The effect of Italian universities' efficiency on local economic development 2006– 2012. *Journal of Regional Science*, 59(5), 819-849.

Aghion, P., Jaravel, X., Cohen, W. M., & Levinthal D.A. (2015). Knowledge Spillovers, Innovation And Growth. *The Economic Journal*, *125*(583), 533–573. http://www.jstor.org/stable/24737124

Ahoba-Sam, R. (2019). Why do academics engage locally? Insights from the University of Stavanger. *Regional Studies, Regional Science*, 6(1), 250-264. doi:10.1080/21681376.2019.1583600

Alakaleek, W., Harb, Y., Harb, A.A., and A. Al Shishnay. (2023). The impact of entrepreneurship education: A study of entrepreneurial outcomes. *The International Journal of Management Education,* 21 (2), 1-10. https://doi.org/10.1016/j.ijme.2023.100800

Alpaydın, U. A. R. (2019). Exploring the spatial reach of co-publication partnerships of multinational enterprises: To what extent does geographical proximity matter? *Regional Studies, Regional Science*, 6(1), 281-298. doi:10.1080/21681376.2019.1583601

Anderton, D. (2016). Science in the city region: Establishing Liverpool's life science ecology. *Regional Studies, Regional Science*, 3(1), 437–444.

Anelli, M., Basso, G., Ippedico, G., and Peri, G. (2023). Emigration and Entrepreneurial Drain. *American Economic Journal: Applied Economics*, 15 (2): 218-52.

Arranz N., F. Ubierna, M. Arroyabe, C. Perez, & de Arroyabe, F. (2017). The Effect of Curricular and Extracurricular Activities on University Students' Entrepreneurial Intention and Competences. *Studies in Higher Education*, 42(11): 1979–2008.

Astebro, T., N. Bazzazian, and Braguinsky, S. (2012). Startups by Recent University Graduates and Their Faculty: Implications for University Entrepreneurship Policy. *Research Policy* 41, 663–667.

Atta-Owusu, K. (2019). Oasis in the desert? Bridging academics' collaboration activities as conduit for global knowledge flows to peripheral regions. *Regional Studies, Regional Science*, 6(1), 265-280. doi:10.1080/21681376.2019.1590230

Baltzopoulos A and Broström A. (2013). Attractors of Entrepreneurial Activity: Universities,Regions and Alumni Entrepreneurs. *Regional Studies*, 47(6), 934-949, DOI: 10.1080/00343404.2011.602335To

Baumol, W. J. (1990). Entrepreneurship: Productive, Unproductive, and Destructive. *Journal of Political Economy*, *98*(5), 893–921. http://www.jstor.org/stable/2937617

Benneworth, P., & Fitjar, R.D. (2019). Contextualizing the role of universities to regional development: introduction to the special issue, *Regional Studies, Regional Science*, 6(1), 331-338, DOI: 10.1080/21681376.2019.160159

Bugamelli M., F. Amatori, and A. Colli. (2011). Italian Firms in History: Size, Technology and Entrepreneurship. *Economic History Working Papers*, 13, Bank of Italy.

Bugamelli M., F. Lotti, M. Amici, E. Ciapanna, F. Colonna, F. D'Amuri, S. Giacomelli, A. Linarello, F. Manaresi, G. Palumbo, F. Scoccianti, Sette, E. (2018). La crescita della produttività in Italia: la storia di un cambiamento al rallentatore, *Bank of Italy Occasional Papers*, n. 422.

Callon, M. (1994). Is Science a Public Good? *Science Technology and Human Values*, 19(4).

Canto-Farachala P. Wilson P. & Arregui-Pabollet R. (2022). Innovative practices from Higher Education for Smart Specialisation. *JRC Technical Report for the European Commission*. doi: 102760/310895

Chang, C.C. (2023). The impact of quality of institutions on firm performance: A global analysis, *International Review of Economics & Finance*, 83, 694-716. https://doi.org/10.1016/j.iref.2022.10.002.

Cinar, R. (2019). Delving into social entrepreneurship in universities: Is it legitimate yet? *Regional Studies, Regional Science*, 6(1), 217-232. doi:10.1080/21681376.2019.1583602

Colombo, M.G. & Piva, E. (2020). Start-ups launched by recent STEM university graduates: The impact of university education on entrepreneurial entry. *Research Policy*, 49(6), 103993.

Daziel, M. & N. Basir. (2024). The technological imprinting of educational experiences on student startups. *Research Policy* 52 (2). https://doi.org/10.1016/j.respol.2023.104940

De Silva M., Al-Tabbaa O., & Pinto, J. (2023). Academics engaging in knowledge transfer and co-creation: Push causation and pull effectuation? *Research Policy*, 52(2), 104668 https://doi.org/10.1016/j.respol.2022.104668.

Del Monte A. & Pennacchio, L. (2020). Historical roots of regional entrepreneurship: the role of knowledge and creativity. *Small Business Economics*, 55(1), 1-22.

Del Monte A. & de Lutzemberger R. (1988). The effect of regional policy on new firm formation in Southern Italy. *Regional Studies*, 23(3): 219-230.

Esposito, P. and Scicchitano, S. (2022). Educational mismatch and labour market transitions in Italy: Is there an unemployment trap? *Structural Change and Economic Dynamics*, 61, 138-155.

Evers, G. (2019). The impact of the establishment of a university in a peripheral region on the local labour market for graduates. *Regional Studies, Regional Science*, 6(1), 319-330. doi:10.1080/21681376.2019.1584051

European Commission (2013). *Entrepreneurship 2020 Action Plan. Rethinking the entrepreneurial spirit in Europe.* Brussels: COM (2012).

European Commission (2022). Science Research and Innovation Performance of the EU 2022. European Commission Directorate-General for Research and Innovation

European Commission (2023). European Innovation Scoreboard 2023. European Commission Directorate-General for Research and Innovation.

Federici, D., Ferrante, F. & Parisi, V. (2022) The educational roots of persistent territorial disparities: the case of Italy. *GeoJournal,* 88, 2063-2082. https://doi.org/10.1007/s10708-022-10740-2

Ferrante, F. Federici, D. Parisi, V. (2019). The entrepreneurial engagement of Italian university students: some insights from a population-based survey. Studies in Higher Education, 44(11), 1-24, doi: 10.1080/03075079.2018.1458223

Fisher, M.M. & Nijkamp, P. (2019). The nexus of entrepreneurship and regional development *Handbook of Regional Growth and Development Theories*, 198-217.

Fonseca, L. (2019). Designing regional development? Exploring the University of Aveiro's role in the innovation policy process. *Regional Studies, Regional Science*, 6(1), 186-202. doi:10.1080/21681376.2019.1584050

Gennaioli N., La Porta R., Lopez-de-Silanes F., & Shleifer, A. (2013). Human Capital and Regional Development , *The Quarterly Journal of Economics*, 128(1). 105–164. https://doi.org/10.1093/qje/qjs050

Germain-Alamartine, E. (2019). Doctoral education and employment in the regions: The case of Catalonia. *Regional Studies, Regional Science*, 6(1), 299-318. doi:10.1080/21681376.2019.1584049

Kaufmann, D., Kraay, A., & M., Mastruzzi. (2010). The Worldwide Governance Indicators: Methodology and Analytical Issues. *World Bank Policy Research Working Paper* 5430. http://hdl.handle.net/10986/3913

Kauffman Foundation. (2013). Entrepreneurship Education Comes of Age on Campus. *Kansas City: Ewing Marion Kauffman Foundation.*

Kempton, L., Conceição Rego, M., Alves, L.R, Vallance, P., Aguiar Serra, M., & Tewdwr-Jones, M. (2021), Putting Universities in their Place, http://dx.doi.org/10.4324/9781003198154.

Manaresi F, Menon C., & Santoleri P. (2021), Supporting innovative entrepreneurship: an evaluation of the Italian "Start-up Act", *Industrial and Corporate Change*, 30(6), 1591–1614, https://doi.org/10.1093/icc/dtab033

Martin, B. (2003). The changing social contract for science and the evolution of the university. Geuna, A., Salter, A.J. & Steinmueller, E. (eds) *Science and Innovation: Rethinking the Rationales for Funding and Governance*, http://dx.doi.org/10.4337/9781781950241.00011.

Marques, P. (2017). Human capital and university–business interactions: An example from the wine industry. *Regional Studies, Regional Science*, 4(1), 154–160.

Meoli, A., Fini R., Sobrero M. & Wiklund, J. (2020). How entrepreneurial intentions influence entrepreneurial career choices: thew moderating influence of social context. *Journal of Business Venturing*, 35(3) https://doi.org/10.1016/j.jbusvent.2019.105982.

Miller, S. (2014). The Strathclyde technology and innovation centre (TIC) in Scotland's innovation system. *Regional Studies, Regional Science*, 1(1), 145–151.

Motoyama, Y & Malizia, E. (2017). Demand pull or supply push? Metro-level analysis of start-ups in the United States. *Regional Studies, Regional Science*, 4(1), 232-246, DOI: 10.1080/21681376.2017.1379885

Motoyama, Y., & H. Meyer, H. (2017). Revisiting the roles of the university in regional economic development: A triangulation of data. *Growth and change*, 48 (4), 787-804.

Muscio, A., Shibayama, S. & Ramaciotti, L. (2021). Universities and start-up creation by Ph.D. graduates: the role of scientific and social capital of academic laboratories. *The Journal of Technology Transfer* 47, 147–175. https://doi.org/10.1007/s10961-020-09841-2

Nieth, L. (2019). Understanding the strategic ‘black hole’ in regional innovation coalitions: Reflections from the Twente region, eastern Netherlands. *Regional Studies, Regional Science*, 6(1), 203-216. doi:10.1080/21681376.2019.1578259

Nifo A. & Vecchione G. (2014). Do Institutions play a role in skilled migration? The case of Italy, *Regional Studies*, 48(10): 1628-1649

OECD (2017), Skills strategy diagnostic reports: Italy, 2017. *OECD Publishing, Paris.*

OECD/EU (2019), Supporting Entrepreneurship and Innovation in Higher Education in Italy, OECD Skills Studies, *OECD Publishing, Paris,* https://doi.org/10.1787/43e88f48-en.

Papatsiba, V. & Cohen, E. (2020). “Institutional hierarchies and research impact: new academic currencies, capital and position-taking in UK higher education. *British Journal of Sociology of Education*, 41(2)., 178-196. http://dx.doi.org/10.1080/01425692.2019.1676700.

Perkmann, M., R. Fini, J. M. Ross, A. Salter, C. Silvestri, & Tartari, V. (2015). Accounting for Universities’ Impact: Using Augmented Data to Measure Academic Engagement and Commercialization by Academic Scientists. *Research Evaluation* 24 (4): 380–391.

Radinger-Peer, V. (2019). What influences universities’ regional engagement? A multi-stakeholder perspective applying a Q-methodological approach. *Regional Studies, Regional Science*, 6(1), 170-185. doi:10.1080/21681376.2019.1578258

Rauch, A., & Hulsink, W. (2015). Putting entrepreneurship education where the intention to act lies: An investigation into the impact of entrepreneurship education on entrepreneurial behavior. *The Academy of Management Learning and Education*, 14(2), 187–204. https://doi.org/10.5465/amle.2012.0293

Redding, S. (1996). The Low-Skill, Low-Quality Trap: Strategic Complementarities between Human Capital and R&D. *The Economic Journal,* 106(435), 458-70.

Roberts, E. B & Eesley, C.E. (2011). Entrepreneurial Impact: The Role of MIT. *Foundations and Trends in Entrepreneurship* 7(1): 1–149.

Roberts, E. B., F. Murray, & Kim, D. (2015). Entrepreneurship and Innovation at MIT. Continuing Global Growth and Impact. *MIT Sloan School of Management*, Massachussents Institute of Technology.

Rodríguez-Pose & Ganau, R. (2022). Institutions and the productivity challenge for European regions, *Journal of Economic Geography*, 22(1), 1–25 https://doi.org/10.1093/jeg/lbab003

Rothaermel, F.T., Agung, S., & Jiang, L. (2007). University Entrepreneurship: A Taxonomy of the Literature. *Industrial and Corporate Change* 16(4), 691-791

Sandström, C., K. Wennberg, M. W. Wallin, & Zherlygina, Y. (2018). Public Policy for Academic Entrepreneurship Initiatives: A Review and Critical Discussion. *The Journal of Technology Transfer*, 43 (5): 1232–1256.

Salomaa, M. (2019). Third mission and regional context: Assessing universities' entrepreneurial architecture in rural regions. Regional Studies, Regional Science, 6(1), 233-249. doi:10.1080/21681376.2019.1586574

Schivardi, F. & Torrini, R. (2011). Structural Change And Human Capital In Italy's Productive Economy. *Questioni di Economia e Finanza* (Occasional Papers) 108, Bank of Italy.

Schivardi, F. (2020). The education of Italian Entrepreneurs. *Polic Brief 04, IGIER*, Università Bocconi.

Scicchitano, S. (2010). Complementarity between heterogeneous human capital and R&D: can job-training avoid low development traps?, *Empirica,* 37, 361-380.

Trapasso, R. & Staats, B. (2019). Policy complementarities and OECD National Skills Policies. *Working Paper OECD*.

Wilsdon, J., B. Wynne & Stilgoe, J. (2005). The Public Value of Science. Or how to ensure that science really matters. *Demos, London*. DOI: 10.13140/RG.2.1.2281.7449

Table A1 Variables description

Short name	Full name	Formula	Source
Start-ups	Number of startups	log(0.5+N. of startups/Population*1000)	Ministry of Enterprises and Made in Italy (Manaresi et al., 2021)
LG	Local graduates	log(0.5+N. of local ghraduates/population*1000)	Ministry of University and Research
WLG	Spatial lag of local graduates	Simple average of LG in neighbouring provinces	Ministry of University and Research
IQI	Institutional Quality Index		Nifo and Vecchione (2010)
OE	Overedcuation	Weighted average of individual level self-assessed Overeducation	INAPP-PLUS
TerStock	Share of tertiary educated individuals	Tertiary eduated individuals/population 25-64 years	ISTAT-LFS
SpinOff	Number of university Spin-Offs	log(0.5+Spin offs/population)	NETVAL
ResProd	Research Productivity	log(0.5+number of publication of universities in each province/total university research personnel in each province)	OpenAlex and Ministry of University and Research
Licenses	Number of licensing contracts	log(0.5+number of licensing contracts/population)	NETVAL
Pop	Population	log(Population)	ISTAT
GVApc	Gross Value Added per capita	log(Gross Value Added(€)/Population)	ISTAT
Enter	Number of enterprises	log(Enterprises)	ISTAT
ManSh	Share of manufacturing in Value Added	Manufacturing GVA(€)/Total GVA(€)	ISTAT
ICTsh	Share of ICT in Value Added	ICT GVA(€)/Total GVA(€)	ISTAT
PvtSvcSh	Share pf Privare Services in Value Added	Private Services GVA(€)/Total GVA(€)	ISTAT
R&Dpr	Private regional R&D expenditure	log(Private R&D expenditure in current €)	ISTAT
R&Dpub	Public regional R&D expenditure	log(Public R&D expenditure in current €)	ISTAT
R&Dun	University R&D expenditure	log(University R&D expenditure in current €)	ISTAT