Investigating the human capital development-growth nexus: Does the efficiency of universities matter?

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Abstract

In this paper, we test whether economic growth depends on human capital development mainly operating through an upgrading of human capital stock in the area where the universities are located. We specify a growth model where a qualitative measure of human capital development, university efficiency, is considered in conjunction with a customary quantitative measure of human capital development, number of graduates. The model is estimated on panel data over the period 2003 to 2011. The evidence suggests that both indicators of human capital development have a positive and significant impact on gross domestic product per capita. Results also show that knowledge spillovers occur between areas through the geographical proximity to the efficient universities, suggesting that the geography of production is affected. Results hold when robustness checks are performed.

Keywords: Higher education; Knowledge spillovers; Local economic development; Parametric technique.

JEL-Codes: I21; C14; C67

1. Introduction

Since the early seventies, researchers have tried to identify and to estimate the regional economic impact of higher education institutions (HEIs) and there has been much discussion about whether the increase in a region's economic activity could be attributable to the presence of a university (see among others Caffrey and Isaacs, 1971; Elliot et al. 1988; Goldstein, 1989; Florax, 1992; Bleaney et al. 1992). Indeed, human capital creation and knowledge accumulation produce positive effects to the local economic development (see Romer, 1994), calling for more investment in education and, furthermore, suggesting that more universities in a certain area might imply a higher growth rate of the economy (see also Martin and Sunley, 1998). Several are the contributions that universities can make in order to increase local economic development; among them, both knowledge creation and regional innovation through research and technology transfer represent relevant channels; knowledge transfer through education and human resources development, which is linked to the teaching function of the universities, plays an important role, too; moreover, social, cultural and community development, which is, instead, linked to the public role of the universities, has to be taken into account. Promoting enterprise, business development and growth, all activities linked to the possibility of busting a more entrepreneurial culture and a more favourable business environment, also have to be considered (see OECD, 2007). As Potì and Reale (2005) have underlined, higher education institutions (HEIs) "play a crucial role in the knowledge-based economy, as institutions able to supply education, knowledge and services, which contribute substantially to the wealth creation" as well as, according to Lambert and Butler (2006), they "are important engines of regional and national economic development".

Our main hypothesis is that the presence of HEIs will have positive effects on local gross domestic product per capita (GDPC) mainly operating through an upgrading of human capital stock in the area where the university is located; indeed, we also highlight the importance of regional spillovers examining whether part of the HEIs positive effects spill over to neighbouring regions. Although we briefly discuss the possible economic mechanism through which these effects might occur, we address this question from an empirical perspective. Therefore, an important contribution of the paper is, relying upon highly disaggregated data at territorial level (at SLL, Sistema Locale del Lavoro[1], level being enable to better capture the differences across geographical areas – see Section 3 for more details on the data specification) to investigate whether a measure of human capital development (HCD) affects local economic performances in Italy, under the hypothesis that the presence of an efficient university in a specific area might have a positive influence on its growth. We suggest the use of universities' efficiency estimates as a qualitative measure of human capital development[2]. Clearly efficiency cannot be the

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[1] The SLL is a group of municipalities (akin to the UK's Travel-to-Work-Areas) adjacent to each other, geographically and statistically comparable, characterized by common commuting flows of the working population. ISTAT has identified 686 SLLs (ISTAT, 2005), while there are nowadays in Italy 110 provinces (the NUTS3 category) and 20 regions (the NUTS2 category). In our opinion, SLLs are analytical tools appropriate for the investigation of socio-economic structure at a fairly disaggregated territorial level. The identification of the SLLs made by ISTAT (the Italian Statistical Office) in some recent research (ISTAT, 2005) has highlighted remarkable differences in economic performance across the Italian territory.

[2] Although the efficiency is not typically the only objective or a structural imperative of HEIs, a growing number of researchers analysed the efficiency of educational institutions. The analysis of universities' performances is at the hearth of institutional and academic debates since when Cohn et al. (1989) identified these organizations as multi-output, thus posing the challenge of measuring their scale and scope effects. Universities have become important engines of regional and national economic development by providing management training and contribute to the expansion of life-long learning (Lambert and Butler, 2006). Therefore, the organization of tertiary education systems world-wide is under continuous scrutiny by the policymakers in order to improve the efficiency and relevance of the education provided. Moreover, the move towards increased efficiency of universities has led to a clamour for performance indicators of various sort (Johnes and Johnes, 1995); indeed, as an analysis carried out by the The Organisation for Economic Co-operation and Development (OECD) has remarked, "formulas to allocate public funds to higher education institutions are now related to performance indicators such as graduation or completion rates". In other words, universities have started being financed according to their level of virtuosity in order to achieve higher research performances and to promote academic excellence. Borrowing an expression made in an OECD report (OECD 2008), which fits very well to describe also the situation the Italian universities started to deal with, "higher education institutions have become

only goal of higher education and also equity considerations play an important role. In fact, some efficiency loss may be traded off against equity gain, depending on political preferences. The extent to which the expansion of post-compulsory education has enhanced equality of opportunities to access and the distribution of costs and benefits of public spending on post-compulsory education are important issues to take into account. Indeed, "over the past 30 years participation rates in post-compulsory education have increased rapidly. This is reflected in the higher attainment rates of people. A question arises over whether this overall expansion in educational opportunity has been equitably shared" (Blöndal et al. 2002). In fact, some efficiency loss may be traded off against equity gain, depending on political preferences. Indeed, given the social outcomes of higher education and its contribution to social mobility and equity "efforts to improve student completion and institutional productivity must be carefully undertaken so that they do not further inhibit access and success for sub-populations already underrepresented in higher education" (Tremblay et al. 2012).

A similar approach has already been considered in the financial context (see Hasan et al. 2009, and Destefanis et al. 2014) where the banks' efficiency estimates are used as quality measures of financial institutions in order to examine whether regional growth depends on financial development. As far as we know, this is the first attempt to apply this idea in the higher education environment. More specifically, the analysis is performed in two stages: firstly, we use a Stochastic Frontier Analysis (SFA) to calculate an index of efficiency for each university and secondly, a growth model is tested, through a system generalized method moment (sys-GMM) estimator, to evaluate the nexus between a qualitative measure of human capital development (measured by the efficiency scores of universities[3]) in conjunction with a customary quantitative measure of human capital development (number of graduates) and local economic growth. Moreover, the nature of spatial spillovers is also taken into account to examine whether geographical space has an impact on this relationship; indeed, spatially mediated knowledge externalities might play an important role in explaining differences in economic performances between areas (Anselin et al. 1997) and specifically, universities are generally considered to be important actors in the production of this type of externality and consequently important sources of localized knowledge spillovers (Etzkowitz and Leydesdorff, 2000). Therefore, we expect HEIs knowledge spillovers to occur between areas through geographical proximity meaning that the productivity of an area increases with the level of geographical proximity to the efficient universities. The evidence suggests that both indicators of human capital development have a positive and significant impact on local gross domestic product per capita; results also show that knowledge spillovers occur between areas through the geographical proximity to the efficient universities, suggesting that the geography of production is affected. In other words, HEIs have a key economic impact in the host areas. This result could be interpreted as evidence of knowledge transfer arising from the presence of a particular highly quality institution in that area. Results hold when different measures of human capital development are used and robustness checks are performed.

The rest of the paper is organized as follows. Section 2 briefly discuss the various schools of thought relating human capital development and economic growth, Section 3 introduces the empirical strategy and the data, Section 4 illustrates the results, Section 5 provides a sensitivity analysis and finally Section 6 concludes.

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increasingly accountable for their use of public funds and are required to demonstrate value for money". Italian universities are increasingly concerned with reducing the length of studies, and improving the number of graduates, in order to compete for public money.

[3] Although there is still no general consensus about which method has to be adopted in measuring university efficiency and despite the fact that the absence of profit motivation, combined with the diversity of goals pursued by HEIs, makes the measurement of efficiency in higher education particularly problematic, we believe this relative measure is conceptually less prone to reverse causality criticism and might be well assess the nexus between human capital development and local economic growth.

2. The role of universities and some background

Although there is a large evidence on the positive effects that HEIs have on their regional environment (see Drucker and Goldstein, 2007, for a review of the current approaches to assess the impact of universities on regional economic development), the discussion is still open in the literature on the transfer mechanisms and interaction channels through which these positive effects are generated. It is not the aim of the paper to analyse further the theoretical details behind these mechanisms; however, in what follows, we provide a short discussion on the various schools of thought that seek to identify how human capital development might foster economic growth (see Drucker and Goldstein, 2007; Benneworth et al. 2009; Uyarra, 2010 for more details).

Universities could contribute to the economy of the area in which they are located both in a direct and indirect way (see Bleaney et al. 1992)[4]. The former channel mainly regards the increase in local income as a consequence of the institutions activities; these are what have been called directly observable demand side effects (Florax, 1992; Shubert and Kroll, 2014) such as HEIs investments, additional demand due to students, employees[5]. The latter one, instead, operates through the increase of the human capital stock and creation such as providing highly educated graduates being able to generate positive supply side effects to the regional economy. More specifically, there are some first order impacts called short-term expenditure-based demand-side effects (i.e. consumption, investment) and long-term knowledge-based supply-side effects (i.e. human capital creation, knowledge production) which in turn generate second order impacts on macroeconomic outputs such as local gross domestic product and employment (see Florax, 1992)[6].

Most of the studies on the contribution of universities to local development are focused on the technology transfer channel, highlighting the importance of HEIs services for the industry sector and specifically for boosting the innovation activities of the firms. According to Goldstein and Renault (2004), universities' research activities contribute to the creation of knowledge spillovers within the regional environment leading to an improvement of local economies; Chatterton and Goddard (2000), underline that HEIs should focus more on research activities and funding in order to respond to regional needs; Walshok (1997) focuses on the contribution that HEIs research activities could make in order to contribute to the local economic development such as, among others, new product development, industry formation, job creation and access to advanced professional and management services. Del Barrio-Castro and García-Quevedo (2005) find that university research has a positive impact on the regional distribution of innovation. Empirical evidence from firm surveys (Mansfield, 1995, 1997; Cohen et al. 2002; Veugelers and Cassiman, 2005) confirms the importance of university research for corporate innovation performance. Knowledge transfers from academia has been investigated through licensing (Shane, 2002), academic spin-off activities (Shane, 2002) and citation to academic patents (Henderson et al. 1998). On the presence of localized knowledge spillovers from university research and on the role of geographic proximity in firm-university innovation linkages see also D'Este et al. (2012) and Abramovsky and Simpson (2011).

There is also an other side of the coin, which is less explored so far (see Abel and Deitz, 2011, 2012), such as the teaching mission of the universities which might lead to important and strong territorial effects. The idea is to emphasize a wider set of aspects concerning higher education rather than research activities, on the extent that academic institutions are recognized as engines of local development since they provide highly skilled human capital and they support ongoing knowledge

[4] Goldstein et al. (1995), instead, classified all the activities through which universities generate economic impact in several categories such as knowledge creation, creation of human capital, transfer of technology, investment in capital goods, regional leadership and influence on the regional environment.

[5] Goldstein and Drucker (2006) have found these effects having a positive, but not very large, impact on local economies.

[6] Higher education institutions raise the local human capital stock also by increasing access to higher education for local residents and make it more likely that local high school graduates will pursue post-secondary education (Card, 1995; Alm and Winters, 2009).

creation, that result in positive spillovers to the local environment in terms of innovation and economic growth (e.g. Audretsch and Feldman 1996) and that HEIs might strongly contribute to increase the local human development (Etzkowitz, 2003); highly skilled and well-educated individuals are one of the main outputs of universities and at the same time are considered as an important drive of economic development (Florida et al. 2008). Indeed, since the works of Becker (1960) and Shultz (1961), the underlying driver of economic development and of regional economic performance is highly skilled and educated people; part of the literature has emphasised the reasons why occupations that apply a high content of creativity and/or knowledge tend to locate in particular areas and how in doing this they can serve local markets, generate economic growth, and benefit local communities overall (Florida, 2002; Markusen, 2008; Sacchetti et al., 2009). Improvements in the population's human capital lead to improvements in labour, which in turn lead to higher activity rates in the region and lower unemployment rates, thus fostering greater economic growth in the region. Indeed, among the main channels, above mentioned, through which the HEIs activities might contribute to sustain local economies (see also Abel and Deitz, 2011; Anselin et al. 1997), the university contribution to economic growth, through the development of human capital and skills, is the main one analysed in our research project; in other words, economic performances might increase through the production of highly skilled graduates and consequently of a highly educated workforce. Human capital creation is one of the knowledge-based supply-side effects considered by Florax (1992). Indeed, as well summarized by Shubert and Kroll (2014), the production of highly educated graduates is likely to cause positive supply-side effects in the regional economy. They may decide to start up new firms that boost the dynamics of the local economic environment (Florax 1992; Goldstein et al. 1995) as well as increase the innovativeness, creativity and productivity of local firms. According to Haapanen and Tervo (2012) "the most competitive regions are typically those with high levels of human capital" and "universities play a key role in bringing the human capital into regions". Bauer, Schweitzer, and Shane (2012) demonstrate that concentrations of college graduates in some American states increased their per capita incomes and slowed down income convergence across states. Riddel and Schwer (2003) and Martin (1998) find that the most significant positive contribution made by the universities to innovation, and to generating and transmitting knowledge are attributable to university graduates. More skilled and educated workers have a higher chance of being involved in the implementation of new technologies as found by Bartel and Lichtenberg (1987) and Woznaik (1987) who support the idea that the skill composition of the labour force affects the technology used by the firms. Indeed, the provision of graduates is the main contribution of the universities to innovation (Etzkowitz and Leydesdorff, 2000). This mechanism works especially if graduates remain in the area in which the university is located and thus enter in the local labour market. In general, there is evidence that graduates are very mobile (Whisler et al. 2008; Faggian et al. 2007), even though they can still influence the local economic development (Faggian and McCann, 2009); however, Haapanen and Tervo (2012) find that, although university graduates are particularly mobile, most of them do not move from their region of studies within 10 years after graduation. More specifically, as it turned out from an analysis on Italian graduates and their employment conditions at one, three and five years from graduation, about 90% of graduates reported working in the same region where they live and completed their university education (Bacci et al. 2008)[7]. Evidence of the effects that the human capital stock (measured through the share of adults with a college degree[8]) and the presence of higher education institutions (measured through the

[7] Although we cannot specifically control for the graduates migration issue in the empirical analysis, we can reasonably assume that, as pointed out by Huffman and Quigley (2002), "during the years spent as students and residents of local communities, students develop specific networks and contacts, and perhaps their tastes change as well. After graduation, these students may be more likely to reside in the locality or region in which they have been educated".

[8] Similarly, Manca (2012) uses the share of the active population in each educational attainment level over the total active population in the region as measure of human capital.

share of the population enrolled in college) have on the quality of life has also been provided by Winters (2011); moreover, Andersson et al. (2004) show, taking also into account potential spillovers, that the productivity is higher in regions that have received larger university-based investment measured by the number of researchers employed and the number of students enrolled[9].

3. Empirical Strategy

3.1. Local economic development

In order to analyse the relationship between human capital development and local economic growth, we specify the following dynamic panel model (for a similar approach but in a different environment see Hasan et al. 2009, and Destefanis et al. 2014):

$$\ln GDPC_{i,j,t} = \alpha lnGDPC_{i,j,t-1} + \beta_1 lnHCD_{i,j,t} + \beta_2 \ln HCD_{i,j,t} * W + \beta_3 \ln GDPC_{i,j,t} * W + \beta_4 lnTPC_{i,j,t} + \beta_5 lnLF_{i,j,t} + \beta_6 lnMK_{i,j,t} + \beta_7 RD\_EMPL\_HEI + \mu_{i,j} + \tau_t + \varepsilon_{i,j,t} \quad (1)$$

where ln is the natural logarithm, $GDPC$ is gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located) explained by its lagged value, by the human capital development measured as efficiency estimates of the universities (HCD), by $HCD * W$ (spatial lagged value of the HEIs efficiency estimates), by $GDPC * W$ (spatial lagged value of the gross domestic product per capita), by TPC (Technology proxy per capita as a proxy controlling for local state of technology and industry structure measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area), by LF (share of the labour force with a university degree as proxy of the quality of the labour market), by MK (market share measured as the ratio between the number of enrolments at university i and the total number of enrolments in the universities located in the same province, included for capturing the potential effects due to the presence of more concentration or competition between universities) and by *RD_EMPL_HEI*[10] (number of R&D employees in the higher education institutions[11] in order to control for the contribution of universities to local development based on the technology transfer channel for boosting the innovation activities of the firms[12]); μ is the unobserved area-specific effect, τ are year dummies controlling for time-specific effect, and finally ε are the disturbance erros. Subscripts i, j and t refer to the unit of analysis (universities), area where the university is located and time periods (years), respectively. Finally, in order to pay attention to the role of the financial crisis on the human capital development-growth nexus, a dummy (CRISIS) taking the value of 1 for years before 2008 and 0 otherwise has been also included in the estimation. We have a highly detailed spatial stratification than enables us to capture the differences between geographical areas and to obtain more accurate estimates. Specifically, our analysis is fully conducted on a local basis to accurately capture the contribution of HEIs. More

[9] See also Henderson (2007) for a critical review of the literature on human capital externalities.

[10] We specifically estimates equation (1) both without and with RD_EMPL_HEI, in order to explore whether the introduction of a control for the contribution of universities to local development based on the technology transfer channel would change the results.

[11] The number of R&D employees refers to the researchers, technical employees and any other operator in R&D activities in the universities. It is expressed as full time equivalent units per 1,000 inhabitants.

[12] It is known that knowledge is also generated through R&D activities carried out by universities and other research institutions (see Acs et al. 2002). Both knowledge creation and regional innovation through research and technology transfer represent relevant channels to economic development. As among university characteristics, one of the determinant of university–industry collaboration that have been identified in the literature is academic research quality (see Maietta, 2015), we include among the controls a proxy of academic quality which may act as a catalyst for industrial labs that are interested in conducting joint research activities by attracting firms with cutting-edge technologies. See Fritsch and Slavtchev (2011) and Buesa et al. (2010) for the use of such kind of innovation input.

specifically, GDPC and TPC are not measured at the national level as in previous studies, but at the local level such as at SLL level (SLL stands for a group of municipalities - akin to the UK's Travel-to-Work-Areas - adjacent to each other, geographically and statistically comparable, characterized by common commuting flows of the working population). In our opinion, two are the main advantages of using some data at such disaggregated level; first of all, we are able to better underline the economic performances across the Italian territory; indeed, according to the Italian Statistical Office (ISTAT) , the SLL represents the place where the individuals live and work and, above all, where take place their economic and social relationships. SLLs have been constructed considering daily commuting flows for working reasons; in other words they have been build taking into account the number of employees who daily reach the working place and then go back home[13]. Secondly, the other advantage of having information of the above described variables at SLL level is that we assign almost to each university a unique value of the environmental variables; the only exception consists in those areas like Rome, Naples or Milan where more than one university is located (for instance the same value of GDPC or TPC is assigned to each university in Rome). This allows us to better capture the differences across geographical areas and to consider in some detail how the performances of HEIs influence local growth[14]. Moreover, the idea of such disaggregated territorial level is not completely new in the literature. McHenry (2014), with the aim of investigating the geographic distribution of human capital in US, use the commuting zone described as a collection of counties making up a coherent local economy—as the location measure. He stated that, although states tend to be larger and thus offer more data for measurement, they are poor proxies for local labor markets. Therefore, he consider the smallest geographic space where most residents work and most workers reside such as the commuting zone being a collection of counties (or single county) that share particularly strong commuting links[15]. This means that, for each university in the sample, we are able to match a value of GDPC and TPC corresponding to the municipality where the university is located. MK is also measured at university level. LF and RD_EMPL_HEI are measured, instead, at regional level (because not available at a more disaggregated level).

To eliminate μ_i, the unobserved area-specific effect, and given the dynamic panel specification of the model, we use the two-step system GMM estimator with Windmeijer (2005) corrected standard error in dynamic panel specification developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). Moreover, in order to deal with suspected endogeneity problem between human capital development and economic growth (i.e. for instance changes in the economic conditions could lead to an increase in the demand or supply of graduates) we include lagged levels and differences as instruments of HCD.

Specifically, in order to examine whether geographical space has an impact on the relationship between human capital development and local economic growth, we specify a spatial-lag model such that the efficiency levels of the HEIs can spill over to the area j; in other words, we take into account that growth in area j depends systematically on the human capital

[13] In the census of the population made by ISTAT, among the SLLs located, in more that 330 of them (thus more than 70% of the population), more the three quarter of the individual employed live and work in the same SLL.

[14] In order to underline why we think the last point is very important in our empirical framework, take for instance one of the representative regions in the North-Central part of Italy such as Emilia Romagna. In Emilia Romagna, the main universities are the University of Bologna (located in the city of Bologna), the University of Ferrara (located in the city of Ferrara), the University of Modena (located in the area of Modena) and the University of Parma (located in the city of Parma). When constructing the dataset, we assigned a value of GDP to each university according to the location where the university is placed. If we had considered values of GDP at regional level, we would have assigned the same value to all the universities located in the region of Emilia Romagna; instead, by proceeding using SLL, the University of Bologna gets the value of GDP corresponding to the municipality where Bologna is located, the University of Ferrara gets the value of GDP where the city of Ferrara is located, the University of Modena gets the GDP value when the city of Modena is located and finally the University of Parma gets the GDP value of the municipality where the city of Parma is located.

[15] Considering a different scenario, such as the financial system, the SLL geographical measure data had already been used in the literature; indeed, Destefanis et al. (2014), with the aim of explaining the nexus between local financial development and economic growth, rely upon Italian data highly disaggregated at the territorial level such as SLL. According to them, this high level of disaggregation allows to decisively reduce the potential role of omitted time invariant factors.

development in neighbouring areas $j \in J$, where J is the set of all areas (Anselin, 1988). We use an inverse distance weighed matrix to weight HCD of all neighboring areas[16]. In matrix notation, $HCD * W$ is the weighted average of human capital development proxies across J_j areas neighboring area j, and $GDPC * W$ is the weighted average gross domestic product per capita proxies across J_j areas neighboring area j. In other words, the spatial weight matrix is assumed to reflect the geographical structure of the knowledge spillover mechanisms operating at local level. The parameter we are most interested in is β_2 which measures whether economic growth at community level benefits ($\beta_2 > 0$), suffers ($\beta_2 < 0$) or is independent ($\beta_2 = 0$) from the human capital development (due to the presence of the universities with a high level of efficiency) of neighbours. As usual, we check the correctness of the model through the Sargan test of over-identifying restrictions for validity of the instruments, while the Arellano-Bond test is, instead, used for testing the autocorrelation between the errors terms over-time. See Table 1 below for a description of the variables used as controls.

In estimating the GMM model we rely on STATA 12[17].

[Table 1 around here]

3.2. University efficiency

In order to provide a qualitative measure of human capital development, we calculate a university's relative efficiency in converting inputs into a production set while maximizing outputs. The idea is that an area in which universities comply with their functions (i.e. producing highly skilled and well-educated individuals with the utilization and the combination of different resources) is on average more efficient than other areas and should benefit in terms of growth because they contribute to increasing local human capital.

In literature, two main methods have been extensively applied for measuring efficiency: non-parametric[18] and parametric[19]. There is no general consensus about which method is to be adopted to measure higher education institutions efficiency[20]. These two main approaches have not only different features, but also advantages and disadvantages (Lewin and Lovell 1990). On one hand, the non-parametric method does not require the building of a theoretical production frontier, but the imposition of certain, a priori, hypotheses about the technology (free-disposability, convexity, constant or variable returns to scale). However, if these assumptions are too weak, the level of inefficiency could be systematically underestimated in small samples, generating inconsistent estimates. Furthermore, this method is very sensitive to the presence of outliers. On the other hand, the parametric method uses a theoretical analysis to construct the efficient frontier, it's not sensitive to extreme values because imposes some assumptions on the error distribution, but must deal with the problem of decomposing the error term. In particular, SFA, proposed by Aigner et al. (1977), Meeusen and Van den Broeck (1977) and Battese and Corra (1977), assumes that the error term is composed by two components with different distributions (see

[16] We also take into account that growth in area j depends systematically on growth in neighbouring areas j ∈ J, where J is the set of all areas (Anselin, 1988). We use an inverse distance weighed matrix to weight GDPC of all neighboring areas.

[17] Coordinates of the areas where universities are located have been extracted from the mapping ISTAT website (http://www.istat.it/it/strumenti/cartografia). The spatial weights matrix has been constructed using the module so called "spwmatrix" by Jeanty (2010a). The spatial weights matrix is row-standardized, i.e. the elements of each row sum up to one. Instead, the spatial lagged variables involved in the analysis, i.e. HCD and GDPC, was built using the module so called "splagvar" by Jeanty (2010b).

[18] Such as the DEA (Data Envelopment Analysis) and FDH (Free Disposable Hull), proposed by Charnes et al. (1978) and due to the original contribution of Farrell (1957), based on deterministic frontier models (see also Cazals et al. 2002).

[19] Such as Stochastic Frontier Approach (SFA), Distribution-Free Approach (DFA) and Thick Frontier Approach (TFA), based on stochastic frontier models (see Aigner et al. 1977).

[20] A possible concern regards the fact that all of these types of approaches apply a frontier that is determined empirically, and that involves the assumption that the most efficient unit is within the set of observations. This is a flaw that is intrinsic to this class of methods; a possible implication is that the efficiency of universities may be overestimated consistently across the board.

Kumbhakar and Lovell (2000) for analytical details on stochastic frontier analysis). The first component, regarding the "inefficiency", is asymmetrically distributed (typically as a semi-normal), while the second component, concerning the "error", is distributed as a white noise. In this way, it is necessary to assume that both components are uncorrelated (independent) to avoid distortions in the estimates[21].

In this paper, we prefer to employ a Stochastic Frontier Analysis because it offers useful information on the underlying education production process, as well as information on the extent of inefficiency[22]. Nowadays, the most widely applied SFA technique is the model proposed by Battese and Coelli (1995) to measure technical efficiency across production units. Intuitively, technical efficiency is a measure of the extent to which an institution efficiently allocates the physical inputs at its disposal for a given level of output. On a methodological ground, the most recent literature, which deals with panel data, emphasized the importance of separating inefficiency and fixed individual effects. Indeed, the efficiency scores may suffer from the presence of incidental parameters (number of fixed-effect parameters) or time-invariant effects, often unobservable, that may distort the estimates (Greene, 2005; Wang and Ho, 2010). For instance, students' or researchers (average) innate ability may be an important determinant of their individual academic achievement and thus account for an important share of the heterogeneity in data when evaluating the efficiency of the institution in which they are studying or working. As Wang and Ho (2010) have underlined: "(…) stochastic frontier models do not distinguish between unobserved individual heterogeneity and inefficiency", forcing "all time-invariant individual heterogeneity into the estimated inefficiency". In order to deal with this problem and to estimate the technical efficiency, we apply a procedure developed by Wang and Ho (2010), according to whom after transforming the model by either first-difference or within-transformation, the fixed effects are removed before estimation. More specifically, we impose to data a within transformation. As Wang and Ho (2010) specified, "by within-transformation, the sample mean of each panel is subtracted from every observation in the panel. The transformation thus removes the time-invariant individual effect from the model". Following the notation in Wang and Ho (2010), the transformation employed in our model is (being w any variable to be transformed):

$$w_{i.} = (1/T)\sum_{t=1}^{T} w_{it}, w_{it.} = w_{it} - w_{i.} \quad (2)$$

The stacked vector of $w_{it.}$ for a given i is:

$$\widetilde{w}_{i.} = (w_{i1.}, w_{i2.}, \dots, w_{iT.})' \quad (3)$$

For simplicity, hereafter in our formulation does not include a subscript t. The baseline model associated to conventional stochastic frontier after the "within transformation" can be written as:

$$\tilde{y}_{i.} = f(\tilde{x}_{i.}, \tilde{\beta})\exp\{\tilde{v}_{i.} - \tilde{u}_{i.}\} \quad (4)$$

where $\tilde{y}_{i.}$ is the output of university i (our DMU: decision making unit); $\tilde{x}_{i.}$ is a vector of input quantities of university i; $\tilde{\beta}$ is a vector of unknown parameters; $f(\tilde{x}_{i.}, \tilde{\beta})$ is the production function or conventional regression model (adding the

[21] Instead, DEA, unlike SFA, assumes that the "error" is fixed over time, while the "inefficiency" component is normally distributed. Finally, TFA assumes that the radial distance between the efficient frontier and the lowest and highest quartile is the white noise, while the deviation between the two quartiles indicates inefficiency.

[22] Apart from the strict statistical distinctions between the two type of approaches, an important reason according to which a Stochastic Frontier Analysis (SFA) has been applied, instead of a Data Envelopment Analysis (DEA), is the need of keeping the empirical analysis as a parametric estimation. Indeed, as specified in the paper, the analysis is performed in two stages: firstly, we use a Stochastic Frontier Analysis (SFA) to calculate an index of efficiency for each university and secondly, a growth model is tested, through a system generalized method moment (sys-GMM) estimator, to measure the effects of the human capital development on local growth. As the GMM is a parametric method, we decide to keep parametric also the measure of the higher education institutions and therefore to apply a Stochastic Frontier Analysis.

stochastic error, $\tilde{v}_{i.}$); $\tilde{v}_{i.}$ is a vector of random variables related to the idiosyncratic or stochastic error term of university i assumed to be $i.i.d.$ $N(0,\sigma_v^2)$ and independent of the $\tilde{u}_{i.}$, while $\tilde{u}_{i.}$ is a vector of non-negative random variables measuring the inefficiency term of university i. In equation (4), $\tilde{u}_{i.}$ is assumed to be heteroschedastic and, in particular, distributed as $\sigma_u^2 = exp(z_i;\delta)$ following a half-normal distribution, i.e. $N^+(0,\sigma_u^2)$, where z_i is a vector of exogenous variables employed to explain university-specific inefficiency, and δ denotes a vector of unknown coefficients. In other words, the inefficiency of university i is assumed to systematically vary with respect to the geographical macro-areas and governance institutional differences (see Section 3.2.1. below for more detail on production set). Notice that notation ‘‘+’’ indicates that the underlying distribution is truncated from below at zero so that realized values of the random variable inefficiency are positive. In this analysis, we do not impose the "scaling property" (for more details see Wang and Schmidt (2002) and Alvarez et al. (2006)) because produces estimation problems in our model. In fact, as suggested in literature (see for instance Wang and Ho, 2010), whether the scaling property holds in the data is ultimately an empirical question. In other words, we assume changes not only in scale but also in the shape of the inefficiency distribution. The validity of the heteroschedastic assumption is tested using a Likelihood Ratio (LR) test which allows us to identify the fit of the model.

Specifically, a Cobb-Douglas production function[23] is preferred in this paper especially because it allows us to overcome the multicollinearity problem and biases in the coefficients associated to estimate a few number of parameters with respect to the translog function (see Laureti, 2008)[24]. All coefficients of parameters in equation (4) are estimated using "maximum likelihood estimation". As suggested by Lovell et al. (1994), we impose the linear homogeneity of degree 1 in inputs[25]. By within transformation, α_i (intercept that changes over time according to a linear trend with unit-specific time-variation coefficients and that represents time-invariant effects) disappears from our specification described in equation (4).

In estimating the efficiency of universities we rely on STATA 12[26].

3.2.1. Production set and specification of the models

More precisely, the output ($\tilde{y}$) is the number of graduates weighted by their degree marks[27] ($GRAD_{MARKS}$)[28]. The vector of input ($\tilde{x}$) is composed as follows. The first input is the number of academic staff ($ACAD_{STAFF}$). It is a measure of a human

[23] Therefore, all inputs and outputs are in log level.

[24] For robustness, we also repeat the estimates selecting a translog production function to see whether the choice of the functional form affects the results (standard linear and suitable symmetry restrictions are imposed). With stochastic frontier analysis, a frontier is estimated on the relation between inputs and outputs. This can, for example, be a linear function, a quadratic function or a translog function. This paper uses a Cobb-Douglas function and, for robustness, a translog function. However, there is no general consensus about which one is to be adopted in the higher education environment (for a discussion on the different function forms, see Cohn and Cooper, 2004; Agasisti and Johnes, 2009). The assumptions behind the use of Cobb–Douglas production functions are plausible in view of the theoretical model which describes the human capital formation in the university system. It allows us to overcome the multicollinearity problem associated to estimate a few number of parameters with respect to the translog function; therefore it is less susceptible to multicollinearity and degrees of freedom problems than the translog function (see Laureti, 2008, who uses a Cobb-Douglas function in order to model exogenous variables in human capital formation). On the other hand, concerning the structure of production possibilities, a more general functional form, that is, the transcendental logarithmic, or "translog", could be considered for the frontier production function. The translog functional form may be preferred to the Cobb–Douglas form because of the latter's restrictive elasticity of substitution and scale properties, it allows for non-linear causalities, compared with the more simple Cobb-Douglas function (see Agasisti and Haelermans, 2015, who use a translog function in order to compare the efficiency of public universities among European countries).

[25] For robustness, we also estimate the coefficients of parameters in equation (4) without imposing such restriction to see whether the imposition of linear homogeneity of degree 1 in inputs have impacts on the main estimates.

[26] The within transformation to data is employed using the "sf_fixeff" command as proposed by Wang and Ho (2010).

[27] For the readers who are not familiar with the characteristics of the Italian higher education system, in Italy students can graduate obtaining marks from 66 to 110 with distinction. This grade is calculated mainly according to the average grades students have obtained in the exams; then a certain number of points is added after the final dissertation has been graded. In order to weight the graduates according to their degree marks, we apply the following procedure: $GRAD_{MARKS}$ =1* graduates with marks between 106 and 110 with distinction +0.75*graduates with marks between 101 and 105 + 0.5*graduates with marks between 91 and 100+0.25*graduates with

capital input and it aims to capture the human resources used by the universities for teaching activities.[29] The second and third inputs are the percentage of enrolments with a score higher the 9/10 in secondary school (ENR_{HSG}) and the percentage of enrolments who attended a lyceum[30] (ENR_{LYC}), with respect to the total number of students enrolled, employed alternatively in the model. Indeed, among the inputs which are commonly known to have effects on students' performances there is the quality of the students on arrival at university. There is a strong evidence that the type of secondary high school and pre-university academic achievement are important determinants of the students' performances (Boero et al. 2001; Smith and Naylor, 2001; Arulampalam et al. 2004; Lassibille, 2011). The underlying theory is that ability of students lowers their educational costs and increases their motivation (DesJardins et al. 2002). Thus, these two inputs aim to capture the quality of students on arrival at university (i.e. proxies of the knowledge and skills of students when entering tertiary education). The fourth and last input is the total number of students (STUD) in order to measure the quantity of undergraduates in each university[31]. Finally, the vector of exogenous variables (z) included in the variance of inefficiency is composed by: a dummy variable equal to 1 if the university has a Medical School and 0 otherwise ($MEDICAL_{SCHOOL}$) to control for the fact that universities with medical schools may be more efficient than those without, because it is easier for them to conduct clinical trials and produce a large fraction of university licenses related to biomedical inventions[32]

marks between 66 and 90. The weights have been chosen so that the distance between two ranks is $1/4 = 0.25$. For robustness, we also further test how alternative weights given to the $GRAD_{MARKS}$ variable, to avoid a severe discounting of the students earning less than top marks, would change the results as follows: $GRAD_{MARKS}$=1*graduates with marks between 106 and 110 with distinction+0.75*graduates with marks between 101 and 105+0.5*graduates with marks between 91 and 100+0.50*graduates with marks between 66 and 90.

[28] Some concerns might be related to the fact that the mission of HEIs is not just teaching and producing graduates but it is also research and that, therefore, omitting other functions and activities of HEIs likely to affect the findings obtained. Usually two types of outputs are mainly used in the studies which try to measure the efficiency of higher education institutions. Firstly, outputs that are related to the teaching activities of higher education; secondly, outputs that are related to research activities. More specifically, some studies use only teaching outputs or only research outputs; other studies use a combination of the two. However, the idea of using only teaching outputs (i.e. number of graduates) is not new in the literature (see for instance Stevens, 2005; Agasisti and Salerno, 2007; Abbott and Doucouliagos, 2009; Agasisti and Dal Bianco, 2009; Agasisti, 2011; Johnes, 2006a; Johnes, 2006b). We decide to focus mainly of teaching outputs as the main idea of the research is to emphasize a different aspect concerning higher education rather than research, mainly operating through an upgrading of human capital stock in the area where the university is located, which is linked to the teaching function of the universities. Thus, we place the emphasis on the teaching mission, but we are also aware that leaving out the research mission might be considered an omitted variable problem that could bias the findings regarding efficiency via teaching. Therefore, we do include in the analysis (see Section 3.1.) an academic quality proxy such as the number of R&D employees in the higher education institutions (RD_EMPL_HEI); by including measures of other university activities (which are not very highly correlated with teaching measures) we aim to improve the statistical validity of the findings regarding teaching.

[29] The variable $ACAD_{STAFF}$ indicates the number of total academic staff adjusting for the respective academic position. Specifically, the academic staff has been disentangled in four categories, namely professors, associate professors, assistant professors and lectures. In order to take into account this categorization, we assign weights to each category according to their salary and to the amount of institutional, educational and research duties the academic staff has to deal with (see Madden et al. 1997) and assuming that a professor is expected to produce more research and teaching work than an associate professors and so on (see Carrington et al. 2005). We follow Halkos et al. (2012) where professors are assigned with 1, associate professors with 0.75, assistant professors with 0.5 and lecturers with 0.25. They basically choose weights so that the distance between two ranks is 1/4=0.25. Thus, we use the following aggregate measure of human capital input: Equivalent personnel (EP)=1*professors+0.75*associate professors+0.50* assistant professors +0.25* lectures. Unfortunately, we do not have information on the auxiliary staff such as the administrative staff.

[30] For the readers who are not familiar with the characteristics of the Italian secondary school system, in Italy, students before entering at University attend five years of high school. This secondary school is divided in two type: a) vocational schools are higher-level learning institution which are specialized in providing students with the vocational education and technical skills they need in order to perform the tasks of a particular job; b) non-vocational secondary schools, instead, are more academic oriented and are specialized in providing the students the skills needed in order to enroll in the university. The latter, in Italy, is also called Lyceum. So, basically, the variable percentage of enrolments who attended a lyceum (ENR_{LYC}) is the percentage of students who attend a Lyceum (i.e. secondary schools who prepare students to the university). In other words, supported by the literature on the education system using Italian data, the idea is that the higher is the percentage of enrolments who come from "Lyceum" the higher is the quality of the university.

[31] The second and third inputs (ENR_{HSG} and ENR_{LYC}) are used as percentages in order to avoid a double counting problem due to presence of the total number of students (STUD) among the inputs. In this way we are able to measure the quantity of undergraduates in each university (through STUD) and include in the production process also two important information regarding the quality of the students enrolled in each university (ENR_{HSG} and ENR_{LYC}).

[32] Even though the empirical evidence is controversial. Thursby and Kemp (2002), Anderson et al. (2007) and Chapple et al. (2005) show that the presence of a medical school reduces the efficiency level, probably due to the heavy service commitments of medical

(see Kempkes and Pohl (2010), for a similar approach); a dummy variable equal to 1 if the university is public and 0 if the university is private (OWNERSHIP) in order to capture governance institutional differences; a dummy variable associated to a macro area (we divide the Italian territory in four parts such as North-Western, North-Eastern, Central and Southern regions) has been added, using as benchmark the Southern area (AREA), in order to capture geographical areas effects. Finally, the time dummies (YEAR) capture two different effects: (i) technical change over time when it's included in the production function and (ii) inefficiency change over time when it's included in the variance of inefficiency term (see Table 2 below for a description of the variables used in the production set).

[Table 2 around here]

In the benchmark model (Table 3, Model 1, below), the academic staff ($ACAD_{STAFF}$), the percentage of enrolments who attended a lyceum (ENR_{LYC}) and the total number of students (STUD) are used as inputs[33], while the number of graduates weighted by their degree marks ($GRAD_{MARKS}$) is used as output. Keeping constant the output side, we than use the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), instead of ENR_{LYC} as an alternative measure of the quality of the students on arrival at university[34]. See Table 3 below for the specification of the models.

[Table 3 around here]

3.3. Data

The dataset refers to 72 Italian universities (61 of them are public and 11 are private[35]) from academic year 2003/2004 to 2011/2012[36] (see Figure 1 below for a map of Italy with the localization of the universities included in the dataset). Variables included in the production set of the universities, such as $ACAD_{STAFF,}$ ENR_{LYC}, ENR_{HSG}, STUD and $GRAD_{MARKS}$, have been collected from the National Committee for the Evaluation of the University System (CNVSU) website[37]. The environmental variables used in order to estimate the local economic impact of HEIs, such as GDPC, TPC

schools or to differences in the health product market. For a different perspective, see Siegel et al. (2008) who, instead, show that the presence of a medical school does have a statistically significant impact on universities' efficiencies.

[33] We choose to use ENR_{HSG}, ENR_{LYC} and STUD as inputs variables simultaneously. This does not represent a redundant selection problem as both ENR_{HSG} and ENR_{LYC} enter as a percentage of the total number of students (STUD). We use ENR_{HSG}, ENR_{LYC} as a measure of the quality of the enrolments and STUD as a measure of the quantity of the students.

[34] We look at the correlation between ENR_{HSG} and ENR_{LYC}. Both Pearson and Spearman correlation coefficients are positive and statistically significant, but their magnitude does not suggest to have concerns regarding multicollinearity problems. In other words, we believe these variables control for two different aspects of pre-enrollment characteristics such as the quality of the secondary school attended (secondary school track chosen) and the secondary high school grade (a measure of academic preparedness). Correlation coefficients are not presented in the paper due to space constraints and available on request.

[35] Regarding the ownership of the universities, it has to be specified that there are both public and private universities in Italy, even though the large majority of universities are public. Independently of their status, universities must follow the same rules regarding a range of decisions (e.g. the degree they can confer, their curriculum, hiring and pay practices for professors) in order to be accredited to deliver a degree. The main differences between public and private universities concern funding and admissions. While both public and private universities receive yearly transfers from the Government, private universities receive much less and rely more on much higher tuition fees and private funding. Other differences regard their size, the number of degrees they typically offer (private universities tend to be much smaller than public universities and may have only a few thousand students; public universities and colleges can be big, and some are huge. Students who want a wide choice of majors can find them at public universities) and class-size (private universities keep classes small, with easy access to professors). We explored the possibility to take out from the sample the private universities, but both SFA and GMM estimates did not change. Therefore, we decide to keep private universities in the range of the universities analysed in order to do not lose observations.

[36] The dataset originally contained data on 81 universities. Nine universities are excluded from our analysis because of incomplete data. This leaves us with a sample of 72 universities.

[37] Http://www.cnvsu.it. Specifically, data have been collected by the Italian Ministry of Education, Universities and Research Statistical Office.

LF and RD_EMPL_HEI , are, instead, taken from the Italian National Institute of Statistics (ISTAT) website[38] (see Figure 2 for a graphical representation regarding the GDPC values of the municipality where the universities are located).

[Figures 1 and 2 around here]

4. The Empirical Evidence

Examination of Table 1[39] shows the presence of some geographical effects (by macro-areas) with institutions in the Central-North area (North-Western, North-Eastern and Central) outperforming those in the Southern area; this is customary for the literature on Italian universities (see, e.g., Agasisti and Dal Bianco, 2009)[40]. The GMM estimates of the growth model are presented in Table 4. The Arellano-Bond test results vouch for the appropriateness of the 2nd-order autoregressive specification while the Sargan tests are always insignificant validating the validity of the instruments and thus the correctness of the model. The lagged value of GDP per capita (GDPC) has a significant coefficient with positive sign in both models. Moreover, the estimates suggest that the efficiency of universities (HCD) has a positive and significant effect on local growth. An increase by 1% in technical efficiency of universities increases the local growth by about 0.060% (see Table 4, columns 1, 2, 3 and 4). In other words, we find evidence that the presence of more efficient universities fosters local economic growth[41].

To take into account whether the environment plays a role, we control for local state of technology and industry structure (TPC), a measure of labor-force quality (LF), for a measure of the concentration of the universities (MK), and finally for a proxy of the university-industry collaboration (RD_EMPL_HEI). Estimates show a positive a statistically significant relationship between the technology and labour market quality proxies and local economic growth; indeed, both a high level of technology in the industry sector as well as a high presence of university graduates in the labour force brings up local GDP per capita. It is particularly interesting the negative and significant coefficient we found on the market share variable, meaning the higher is the concentration of the universities the lower is the local growth. In other words, we found evidence that productivity gains are larger in areas where there is more competition between universities. This finding suggests that differences in local economic development might be due to the market structure of higher education, in the direction that a more competitive environment could lead to a higher human capital creation which in turn might imply a higher growth of the economy; thus, multiple HEIs located in the same region, or HEI effects spilling across regions, could be seen as competition leading to greater efficiency and student choice (i.e. for example stimulating the students' freedom of choice

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[38] Http://www3.istat.it/salastampa/comunicati/non_calendario/20050721_00/.

[39] Due to space constraint, the efficiency estimates are presented by geographical areas and on average over the period 2003-2011. Estimates for each year and for each university are available on request.

[40] Results may suffer from some potential limitation regarding the functional form chosen in the analysis, its assumptions and the way some variables are constructed. Firstly, some concerns are related to the Cobb-Douglas production function justified for overcoming multicollinearity and bias. We also test for a different functional form such as a translog function (see footnote 24 for more details), therefore by including the cross-products and calculations of marginal effects of independent variables, because the difference from the simpler Cobb-Douglas form may be in the estimated coefficients of the interaction terms among the independent variables. A second concern regards the imposition of the linear homogeneity of degree 1 in inputs (see footnote 24 for more details). We again repeat the analysis by not-imposing such restriction; finally, a third potential limitation of these results is represented by the decision to assign weights to the output variable $GRAD_{MARKS}$ (see footnote 27 for more details). Therefore, we also test how alternative weights given to this variables would change the results. For all this robustness, we did not find any statistically significant difference in the results. Due to space constraints, estimates are not reported in the paper and are available upon request.

[41] Also according to the literature we are dealing with, we think that is the human capital creation and development, and knowledge accumulation, operating through the teaching mission of the universities and through the provision of highly skilled human capital, to affect local economic growth. It could be true, indeed, that a universities located in higher growth regions respond to the demand for their graduates by attempting to improve efficiency, even though this possible bidirectional effect is more difficult to disentangle from the empirical perspective and more theoretical discussion is needed.

through additional grants, loans and vouchers). Moreover, another explanation is that close proximity of multiple institutions permit collaboration, sharing of resources, greater division of production of qualified labor according to desired knowledge and skill sets, and thus have a positive impact on economic development. Both views provide a clue towards the expansion of pro-competitive policies in the Italian higher education sector. Results also show a positive and statistical significant nexus between the number of R&D employees in the universities and local economic growth, confirming the contribution of universities to local development focused on the technology transfer channel (i.e. potential interactions between HEI's research and firms regarding the part of knowledge creation which is generated through R&D activities carried out by the universities). Finally, we find that the crisis has a negative impact on the efficiency of universities.

[Table 4 around here]

4.1. A spatially weighted human capital development and local growth

We extend the analysis to address potential geographical spillovers, considering the effects of the presence of higher education institutions on local economic development (results are shown in Table 5 below). We consider two measures of spatial dependence such as *Human Capital Development * Spatial (HCD * W)*, a spatially lagged regressor which measures whether the average productivity of labour is higher for those areas closer to the most efficient universities (see Table 5, Columns 1, 2, 3 and 4) and *GDPC * Spatial (GDPC * W)*, a spatially lagged dependent variable which, instead, tests the effects for an area, in term of economic development, being closer to a prosperous area (see Table 5, Columns 5, 6, 7 and 8). First of all, when we introduce the specification of the spatially weighted regressors[42], the efficiency estimates do not change and remain still statistically significant. Not only the introduction of the spatial effects does not alter our previous results, but we also find a significant and statistically positive effect of the spatially weighted variables. More precisely, when the specification of the spatially weighted human capital development has been included (see Table 5, Columns 1, 2, 3 and 4), we find evidence that the average productivity of labour is higher in areas that are supported by the presence of universities which well-contribute to the supply of high level human capital; this suggests the presence of knowledge spillovers within areas having virtuous institutions. Moreover, when instead the specification of the spatially weighted dependent variable has been included (see Table 5, Columns 5, 6, 7 and 8), we also find evidence of a positive effect for an area, in term of economic development, being closer to a prosperous area.

[Table 5 around here]

5. Sensitivity analysis: Does a different measure of human capital development affect the estimates?

For robustness, in order to examine whether a different measure of human capital development affects the analysis, we use the number of graduates weighted by their degree marks (estimates are presented in Table 6 below). For a similar approach, see Andersson et al. (2004), who used the number of researchers and the number of students enrolled for measuring the university-based investment in an area, and Winters (2011), who used the share of adults with a college degree to measure

[42] As already specified in Section 3.1., we use an inverse distance weighed matrix. In order to check whether a different solution regarding the choice of the distance matrix could affect the results, we have also repeated the main analysis using s different weighting matrix such as a squared inverse distance matrix (following again Andersson et al. 2004). We did not find any statistically significant difference in the results. Due to space constraints, results are not presented in the paper and are available upon request.

the local human capital level and the share of the population enrolled in college to quantify the presence of higher education institutions; McHenry (2014) uses the attainment of a four-year college degree as a proxy for skills with educational attainment. The idea is that the number of graduates weighted by their degree marks could be used as a more quantitative proxy of the human capital development.

We again find (see Table 6, Columns 1 and 2) that the number of graduates has positive and significant effects on local growth, much lower in magnitude but still significant at 1% level[43]. The results also confirm the importance of the university geographical distribution; indeed, the spatially lagged regressor *(GR * W)*, which measures whether the average productivity of labour is higher for those areas closer to the universities which produce highly skilled graduates, is still positive and statistically significant at 1% level, leaving almost unchanged the effects of the number of graduates (see Table 6, Columns 3 and 4). Moreover, the spatially weighted dependent variable (*GDPC*W*), measuring the effects for an area, in term of economic development, being closer to a prosperous area, is also positive and statistical significant (see Table 6, Columns 5 and 6). Interestingly, when this variable has been included (see Table 6, Column 5 and 6 versus Columns 3 and 4), the effects of the number of graduates on local growth is still positive and statistically significant, but higher in magnitude.

[Table 6 around here]

5.1. How the distribution of efficiency affects the estimates?

As a second robustness check, we examine whether the results depend on the distribution of the qualitative measure of human capital development used in the analysis by dividing the universities' efficiency scores (obtained through the procedure described in Section 3.2 above) in quartiles (see Table 7 below).

[Table 7 around here]

Specifically, we repeat the analysis firstly removing from the sample those universities with an efficiency score in the first quartile - i.e. taking out the less efficient universities (see Table 8, Columns 1 and 2 for Model 1 and Columns 5 and 6 for Model 2); then, we remove those universities with an efficiency score in the fourth quartile – i.e. taking out the most efficient universities (see Table 8, Columns 3 and 4 for Model 1 and Columns 7 and 8 for Model 2). Results are generally confirmed and we still find that efficiency of universities has a positive and significant effect on local growth (still significant at 1% level). It is interestingly to notice that when we exclude from the analysis the most efficient universities (those in the 4th quartile) the efficiency contribution on growth is, almost in all models, lower with respect to the case in which we exclude the less efficient one (those in the 1st quartile). Table 9 below, instead, shows the estimates addressing potential geographical spillovers; more specifically, Table 9, Columns 1, 2, 5 and 6 (for Model 1) and Columns 9, 10, 13 and 14 (for Model 2), shows the results when the less efficient universities are excluded from the sample while Table 9, Columns 3, 4, 7 and 8 (Model 1) and Columns 11, 12, 15 and 16, shows the results when, instead, the most efficient universities are excluded from the sample.

[43] A possible explanation for the reduction in magnitude, when the number of graduates is used as a quantitative measure of human capital development, is that perhaps the variable captures some negative effect of greater numbers of graduates increasing the labor supply and competition for satisfying job demand.

[Table 8 and 9 around here]

Including the measures of spatial dependence does not change the results[44]. There is still evidence that the existence of knowledge spillovers is particularly evident both when the upper and lower quartiles of the distribution are considered. In other words, geographical space has an impact on the relationship between human capital development and local economic growth both when the highest and lowest HEIs' efficiency scores are not taken into account. This support the idea that the presence of universities in a certain area might imply a higher growth of the economy independently from the distribution of the HEIs' efficiency scores considered.

Results are confirmed when we apply the same approach using the number of graduates weighted by their degree marks as a more quantitative measure of human capital development (see Table 10 below).

[Table 10 around here]

6. Conclusion

This paper examines the relationship between human capital, skills development and economic growth, analysing the effects of knowledge spillovers from universities' performances on local productivity using territorially disaggregated data (SLL level) in Italy. As far as we know this is the first study to explore the human capital development-growth association paying particular attention on the role of higher education institutions and specifically proposing the use of the efficiency of universities as an alternative measure of the human capital development. Efficiency scores, computed using proposed by Wang and Ho (2010), are the qualitative measure of human capital development, while the number of graduates are its quantitative measure. We use SFA to calculate an index of efficiency for each university and then, a growth model is tested, through a sys-GMM estimator, to evaluate the relationship between human capital development and local economic growth. Moreover, we also explore the nature of spatial spillovers by taking into account whether geographical space has an impact on the relationship between human capital development (measured by the HEIs' efficiency scores and number of graduates) and local economic growth. Our estimates suggest that both qualitative and quantitative proxies of human capital development have a positive and significant impact on GDP per capita. On the top of that, university efficiency comes out from our estimates as a significant determinant of growth. It is worth recalling that our estimation procedures attempt in various manners to minimize the role of unobserved heterogeneity. Indeed, results show that the proxy of human capital development (efficiency of universities) has a positive and significant effect on local growth meaning that the presence of efficient universities fosters local GDP per capita. Turning to the potential existence of knowledge spillovers, we firstly find evidence of a positive effect for an area, in term of economic development, being closer to a prosperous area; moreover, we show that productivity gains are larger in areas in which efficient universities are located meaning that the closer an area is to an efficient university the higher is the effect of the level of efficiency of the university on the economic development of

[44] When the spatial dependence is taken into account, instead, it is interestingly to notice that when we exclude from the analysis the most efficient universities (those in the 4th quartile) the efficiency contribution on growth is still lower with respect to the case in which we exclude the less efficient one (those in the 1st quartile) but only for Model 2. The different evidence in Model 1 might firstly depends on the reduction in the sample composition; indeed, the GMM estimation could suffer when the number of observation is reduced due to the exclusion of the quartiles. Moreover, in terms of convergence, the most efficient universities (such as those who produce highly skilled graduates) have, in a sense, saturated their contribution on growth (i.e. that have already reached their steady state). On the other hand, the less efficiency universities have more space for improving their performances, through the development of human capital and skills, being far away from their optimal point.

that area; in other words, the presence of spillovers means that the geography of production is affected; even though, it's probably not very easy to capture a qualitative difference in the characterization of the spillover impacts of education versus the within-region impacts (i.e. the geographic distribution of production would be affected even without any interregional spillovers because of the non-uniform locations and levels of HEIs' activities and efficiencies within regions).

Results are robust to a more quantitative measure of the human capital development such as the number of graduates weighted by their degree marks. Moreover, further robustness checks show that geographical space has still an impact on the human capital-growth relationship when estimates are repeated by dividing the universities in quartiles according to the human capital development measures[45] (HCD and GR), although the positive and significant impact of the university efficiency on local growth has been reduced. These findings confirm the conclusions of existing empirical studies on the presence of localized knowledge spillovers from presence of higher education institutions (Andersson et al. 2004 and Winters, 2011), supporting the use of efficiency estimates as an alternative qualitative measure of human capital development. Our analysis could suffer from some limitations and some potential concerns. A possible concern regards the Arellano-Bond system GMM model and the influence that the spatial dependence might have on the covariance estimators. Indeed, in case of spatial dependence, the GMM model could not allow a consistent estimation of the standard errors of the coefficients. In particular, when a spatial lag of the dependent variable is included in the model, a consistent estimation is based on the maximization of a compressed likelihood and the Windmeijer correction might not be enough to solve the problem. An alternative strategy would be relaying on a fixed effects panel model with spatially dependent variables (i.e. Millo and Piras, 2012) which is able to treat the special dependence appropriately. However, in this way, we won't be able to take into account the more than suspected endogeneity problem between human capital development and economic growth (see also Hasan et al. 2009 who applied the same procedure in the financial environment).

Keeping these concerns in mind, we believe that the paper contributes to the existing research shedding further light on the effects that universities might have on raising the ratio of local income per capita including the spatial structure into our analysis. The conclusions that can be drawn from this study lead to some interesting policy implications; indeed, we think the results provide important information for regulators and decision makers towards the adoption of improving policies in the higher education sector. In other words, the importance of the spatial effects leads to a call for more investments in the tertiary education system given that they would affect not only the performances of the universities but also the economic conditions of the areas where the institutions are located. This is not a secondary issue considering the substantial reforms that have been taken place in the last years in Italy and that the basis for allocating core funding to HEIs has become more output-oriented. Future works is needed to incorporate the missions of universities more explicitly in our analysis by taking into account also the contribution of research activities (i.e. licensing, academic spin-off activities, patents), whether available, on the creation of knowledge spillovers within the local environment leading to an improvement of the related economies.

[45] By not taking into account firstly the lowest and then the highest HEIs' efficiency scores.

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Appendix 1 – Tables and Figures

Table 1 - Environmental variables: descriptive statistics - Mean values by geographical areas

	Obs	HCD_1	HCD_2	GDP	TP	LF	MK	RD_EMPL_HEI
Geographical areas								
North-Western	153	0.8701 (0.1107)	0.8718 (0.1116)	59389.69 (51913.72)	0.729 (0.074)	82.895 (1.825)	0.588 (0.416)	7713.01 (3603.85)
North-Eastern	108	0.9571 (0.0288)	0.9526 (0.0325)	12136.96 (6507.549)	0.746 (0.051)	81.777 (1.939)	0.916 (0.210)	4226.18 (2237.55)
Central	162	0.8711 (0.1063)	0.8725 (0.1067)	41142.24 (51780.00)	0.795 (0.086)	78.777 (1.622)	0.555 (0.423)	5796.83 (3015.84)
Southern	225	0.7208 (0.1488)	0.7197 (0.1491)	11971.64 (11561.27)	0.802 (0.041)	71.146 (3.387)	0.760 (0.382)	3923.70 (2263.00)
Total								
Italy	648	0.8330 (0.1454)	0.8326 (0.1457)	30487.77 (41892.79)	0.774 (0.072)	77.600 (5.514)	0.694 (0.400)	5352.53 (3199.62)

Note: Authors calculation on data collected by the Italian Ministry of Education, Universities and Research Statistical Office and by the Italian National Institute of Statistics Office. Standard deviations in parentheses. HCD_1 and HCD_2: Human capital development measured as efficiency of the universities; GDPC: Gross domestic product (sum of the gross values added of all units); TPC: Technology progress per capita (the ratio between service workers and the sum of industry plus service workers all divided by the population in each area); LF: Labour Force (Share of the labour force with a university degree); MK: Market share (# of enrolments university$_i$/total enrolments province); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities). All monetary aggregates are in thousands of Euros (at 2007 prices). GDP is expressed in million of euros. In order to get an easy and comprehensible measure, the total values of GDP and TP are reported in the descriptive statistics. In the analysis they are both divided by the population in each area where the university is located.

Table 2 - The production set: descriptive statistics - Mean values by geographical areas

		Mean values			
		North-Western	North-Eastern	Central	Southern
Inputs					
$ACAD_{STAFF}$[1]	# of academic staff	788.91 (718.21)	956.17 (827.51)	825.77 (1025.07)	749.64 (690.13)
ENR_{HSG}[2]	% of enrolments with a score higher than 9/10 in secondary school	4.61 (2.40)	4.19 (1.06)	4.34 (2.35)	4.20 (1.48)
ENR_{LYC}[2]	% of enrolments who attended a lyceum	8.73 (3.07)	7.19 (1.55)	7.67 (3.07)	7.37 (1.43)
STUD	Total number of students	22176.17 (18564.81)	25838.73 (23817.23)	24872.56 (29898.56)	25734.1 (21330.38)
Output					
$GRAD_{MARKS}$	# of graduates weighted by their degree marks	2438.84 (2043.64)	2836.98 (2622.02)	2690.63 (3066.18)	227.35 (1907.23)

Note: Authors calculation on data collected by the Italian Ministry of Education, Universities and Research Statistical Office. Standard deviations in parentheses.
The variables $MEDICAL_{SCHOOL}$ (a dummy variable equal to 1 if the university has a Medical School and 0 otherwise), OWNERSHIP (a dummy variable equal to 1 if the university is public and 0 if the university is private) and AREA (a dummy variable equal to 1 if the university is located in the Southern area and 0 otherwise) have been included in the variance of the inefficiency term. The variable YEAR (time dummies) has been included both in the production function and in the variance of the inefficiency term.
[1]In order to get an easy and comprehensible measure, the total number of academic staff is reported in the descriptive statistics. In the analysis, the total number of academic staff has been, instead, adjusted for their respective academic position (i.e. professors, associate professors, assistant professors and lectures).
[2]Both ENR_{HSG} and ENR_{LYC} are percentages of the total number of students enrolled.

Table 3 - Specification of outputs and inputs

Models	Inputs	Outputs
Model 1	$ACAD_{STAFF}$;ENR_{LYC}; STUD	$GRAD_{MARKS}$
Model 2	$ACAD_{STAFF}$; ENR_{HSG}; STUD	$GRAD_{MARKS}$

Notes (1):
$ACAD_{STAFF}$: *Number of academic staff*
ENR_{LYC}: *% of enrolments who attended a lyceum respect to the total number of students*
STUD: Total number of students
ENR_{HSG}: *% of enrolments with a score higher than 9/10 in secondary school respect to the total number of students*
$GRAD_{MARKS}$: *Number of graduates weighted by their degree marks*

Notes (2): In both models, the variables $MEDICAL_{SCHOOL}$ (a dummy variable equal to 1 if the university has a Medical School and 0 otherwise), OWNERSHIP (a dummy variable equal to 1 if the university is public and 0 if the university is private) and AREA (a dummy variable equal to 1 if the university is located in the Southern area and 0 otherwise) have been included in the variance of the inefficiency term. The variable YEAR (time dummies) has been included both in the production function and in the variance of the inefficiency term.

Table 4 - Human capital development effects on local growth

	Model 1	*Model 1*	*Model 2*	*Model 2*
	(1)	*(2)*	*(3)*	*(4)*
$GDPC_{t-1}$	*0.818**** *(0.007)*	*0.800**** *(0.010)*	*0.837**** *(0.009)*	*0.796**** *(0.011)*
HCD	*0.068**** *(0.003)*	*0.062**** *(0.003)*	*0.061**** *(0.003)*	*0.058**** *(0.002)*
TPC	*0.006**** *(0.002)*	*0.026**** *(0.003)*	*0.008**** *(0.001)*	*0.027**** *(0.002)*
LF	*0.332**** *(0.016)*	*0.245**** *(0.024)*	*0.300**** *(0.020)*	*0.240**** *(0.022)*
MK	*-0.0006* *(0.0008)*	*-0.011**** *(0.001)*	*-0.0004* *(0.0008)*	*-0.012**** *(0.002)*
RD_EMPL_HEI		*0.033*** *(0.004)*		*0.033**** *(0.003)*
CRISIS	*-0.025**** *(0.001)*	*-0.055**** *(0.001)*	*-0.027**** *(0.001)*	*-0.056**** *(0.001)*
N	*576*	*569*	*576*	*569*
SARGAN	*0.4301*	*0.5342*	*0.4980*	*0.5522*
AR(2)	*0.7342*	*0.6710*	*0.7198*	*0.6678*

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the human capital development variable measured as the efficiency level of the universities (HCD) is specified as endogenous variable. All variables are in log level. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree), MK: Market share (measured as # of enrolments university$_i$/total enrolments province$_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities).CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. From the total of 648, we are left with 576 observations due to the fact that a growth model has been estimated, including the lagged value of the dependent variable (1 lag). When RD_EMPL_HEI is used we lose 7 observations due to the fact that the this variable is not available for three regions in 2010 (Molise, Basilicata and Calabria) and for two regions in 2011 (Molise and Basilicata). *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Table 5 - Human capital development effects on local growth - Spatial spillovers

	Model 1	*Model 1*	*Model 2*	*Model 2*	*Model 1*	*Model 1*	*Model 2*	*Model 2*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
$GDPC_{t-1}$	*0.756**** *(0.011)*	*0.678**** *(0.016)*	*0.776**** *(0.011)*	*0.699**** *(0.014)*	*0.769**** *(0.010)*	*0.692**** *(0.016)*	*0.781**** *(0.010)*	*0.714**** *(0.014)*
HCD	*0.051**** *(0.003)*	*0.049**** *(0.003)*	*0.053**** *(0.002)*	*0.043**** *(0.003)*	*0.059**** *(0.003)*	*0.052**** *(0.004)*	*0.056**** *(0.003)*	*0.047**** *(0.004)*
*HCD *W*	*0.588**** *(0.069)*	*0.829**** *(0.085)*	*0.521**** *(0.048)*	*0.731**** *(0.082)*				
*GDPC*W*					*0.239**** *(0.029)*	*0.440**** *(0.045)*	*0.241**** *(0.016)*	*0.417**** *(0.049)*
TPC	*0.002** *(0.001)*	*0.021**** *(0.004)*	*0.003**** *(0.001)*	*0.025**** *(0.004)*	*0.003*** *(0.001)*	*0.028**** *(0.005)*	*0.005**** *(0.001)*	*0.028**** *(0.005)*
LF	*0.183**** *(0.029)*	*0.026* *(0.025)*	*0.168**** *(0.026)*	*0.046** *(0.026)*	*0.255**** *(0.023)*	*0.033* *(0.031)*	*0.240**** *(0.026)*	*0.056*** *(0.027)*
MK	*-0.0004* *(0.001)*	*-0.018**** *(0.002)*	*-0.001* *(0.001)*	*-0.016**** *(0.002)*	*-0.0008* *(0.001)*	*-0.016**** *(0.002)*	*-0.0008* *(0.0009)*	*-0.012**** *(0.002)*
RD_EMPL_HEI		*0.034**** *(0.006)*		*0.039**** *(0.005)*		*0.038**** *(0.006)*		*0.040**** *(0.006)*
CRISIS	*-0.017**** *(0.001)*	*-0.054**** *(0.001)*	*-0.022**** *(0.002)*	*-0.055**** *(0.001)*	*-0.019**** *(0.001)*	*-0.056**** *(0.002)*	*-0.021**** *(0.001)*	*-0.058**** *(0.002)*
N	*576*	*576*	*569*	*569*	*576*	*576*	*569*	*569*
SARGAN	*0.5310*	*0.7890*	*0.5067*	*0.6272*	*0.5083*	*0.7940*	*0.4329*	*0.6141*
AR(2)	*0.7655*	*0.7414*	*0.7155*	*0.7023*	*0.7619*	*0.7279*	*0.7385*	*0.6937*

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the human capital development variable measured as the efficiency level of the universities (HCD) is specified as endogenous variable. All variables are in log level. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree); MK: Market share (measured as # of enrolments university$_i$/total enrolments province$_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities); CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. From the total of 648, we are left with 576 observations due to the fact that a growth model has been estimated, including the lagged value of the dependent variable (1 lag). When RD_EMPL_HEI is used we lose 7 observations due to the fact that the this variable is not available for three regions in 2010 (Molise, Basilicata and Calabria) and for two regions in 2011 (Molise and Basilicata). *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Table 6 - Human capital development effects on local growth and spatial spillovers using the number of graduates weighted by their degree marks as a quantitative measure of human capital development

	(1)	(2)	(3)	(4)	(5)	(6)
$GDPC_{t-1}$	0.889***	0.890***	0.835***	0.886***	0.799***	0.806***
	(0.008)	(0.012)	(0.013)	(0.018)	(0.015)	(0.016)
$GR*10^4$	0.024***	0.017***	0.028***	0.024***	0.086***	0.067***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)
$GR*W*10^2$			0.002***	0.002***		
			(0.0003)	(0.0004)		
GDPC*W					0.442***	0.448***
					(0.035)	(0.037)
TPC	0.014***	0.020***	-0.011**	-0.007	0.034***	0.037***
	(0.002)	(0.003)	(0.005)	(0.006)	(0.002)	(0.004)
LF	0.261***	0.159***	0.209***	0.136***	0.116***	0.025
	(0.025)	(0.033)	(0.027)	(0.039)	(0.040)	(0.037)
MK	-0.018***	-0.015***	-0.017***	-0.005	-0.041***	-0.029***
	(0.003)	(0.002)	(0.005)	(0.005)	(0.004)	(0.006)
RD_EMPL_HEI		0.026***		0.006		0.019***
		(0.004)		(0.009)		(0.007)
CRISIS	-0.023***	-0.068***	-0.021***	-0.050***	-0.019***	-0.069***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
N	576	569	576	569	576	569
SARGAN	0.5836	0.7694	0.5559	0.7195	0.6098	0.8161
AR(2)	0.7403	0.6291	0.7170	0.6249	0.7337	0.6323

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the number of graduates weighted by their degree marks (GR) is specified as endogenous variable. All variables are in log level except for GR. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree); MK: Market share (measured as # of enrolments university$_i$/total enrolments province$_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities); CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. From the total of 648, we are left with 576 observations due to the fact that a growth model has been estimated, including the lagged value of the dependent variable (1 lag). When RD_EMPL_HEI is used we lose 7 observations due to the fact that the this variable is not available for three regions in 2010 (Molise, Basilicata and Calabria) and for two regions in 2011 (Molise and Basilicata). *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Table 7 – Qualitative and quantitative measures of human capital development: quartiles

	1st quartile	2st quartile	3st quartile	4st quartile
	(1)	(2)	(3)	(4)
HCD (1)	HCD (1)≤0.804	0.804< HCD (1)≤0.910	0.910< HCD (1)≤0.944	HCD (1)>0.944
HCD (2)	HCD (2)≤0.785	0.785< HCD (2)≤0.892	0.892< HCD (2)≤0.929	HCD (2)>0.929
GR	GR≤1016.2	1016.2< GR≤2048.2	2048.2< GR≤3817.7	GR>3817.7

Notes: HCD (1): human capital development referring to the university efficiency scores obtained according to Model 1 (see Table 3 for the specification of the models). HCD (2): human capital development referring to the university efficiency scores obtained according to Model 2 (see Table 3 for the specification of the models). GR indicates the number of graduates weighted by their degree marks used as a quantitative measure of human capital development.

Table 8 - Human capital development effects on local growth using quartile university efficiency scores

	Model 1		*Model 1*		*Model 2*		*Model 2*	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
$GDPC_{t-1}$	0.871***	0.850***	0.812***	0.784***	0.865***	0.863***	0.804***	0.815***
	(0.006)	(0.011)	(0.014)	(0.016)	(0.008)	(0.013)	(0.009)	(0.013)
HCD	0.059***	0.070***	0.069***	0.064***	0.084***	0.096***	0.068***	0.061***
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.005)	(0.002)	(0.003)
TPC	0.009***	0.017***	0.005***	0.026***	0.012***	0.017***	0.007***	0.025***
	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
LF	0.243***	0.050*	0.351***	0.315***	0.280***	0.095***	0.378***	0.254***
	(0.022)	(0.029)	(0.036)	(0.026)	(0.023)	(0.032)	(0.015)	(0.028)
MK	-0.007***	0.0001	0.00001	-0.012***	-0.006***	0.0008	-0.001	-0.012***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
RD_EMPL_HEI		0.049***		0.030***		0.040***		0.021***
		(0.006)		(0.003)		(0.005)		(0.005)
CRISIS	-0.029***	-0.053***	-0.060***	-0.008***	-0.008***	-0.084***	-0.003	-0.063***
	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.0009)
N	454	451	420	413	454	451	420	413
SARGAN	0.6884	0.8113	0.8846	0.9614	0.7093	0.8284	0.9113	0.9743
AR(2)	0.9470	0.8572	0.4391	0.3983	0.8385	0.7265	0.4043	0.3580

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the human capital development variable measured as the efficiency level of the universities (HCD) is specified as endogenous variable. All variables are in log level. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree); MK: Market share (measured as # of enrolments university$_i$/total enrolments province$_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities); CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. Columns (1), (2), (5) and (6) are associated with university efficiency scores without the 1st quartile, Columns (3), (4), (5) and (6) are associated with university efficiency scores without the 4st quartile. *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Table 9 - Human capital development effects on local growth and spatial spillovers using quartile university efficiency scores

	Model 1		*Model 1*		*Model 1*		*Model 1*		*Model 2*		*Model 2*		*Model 2*		*Model 2*	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*
$GDPC_{t-1}$	0.803***	0.731***	0.794***	0.755***	0.802***	0.730***	0.810***	0.773***	0.765***	0.692***	0.777***	0.736***	0.774***	0.708***	0.826***	0.773***
	(0.010)	(0.017)	(0.017)	(0.028)	(0.012)	(0.021)	(0.017)	(0.021)	(0.018)	(0.019)	(0.010)	(0.011)	(0.013)	(0.022)	(0.011)	(0.017)
HCD	0.047***	0.045***	0.067***	0.059***	0.054***	0.058***	0.070***	0.061***	0.070***	0.064***	0.064***	0.055***	0.084***	0.085***	0.061***	0.061***
	(0.004)	(0.006)	(0.003)	(0.004)	(0.005)	(0.006)	(0.003)	(0.003)	(0.005)	(0.008)	(0.002)	(0.002)	(0.004)	(0.008)	(0.002)	(0.002)
*HCD *W*	0.598***	0.882***	0.262***	0.419***					0.912***	1.183***	0.335***	0.555***				
	(0.061)	(0.087)	(0.038)	(0.130)					(0.090)	(0.086)	(0.028)	(0.079)				
*GDPC*W*					0.309***	0.533***	0.079***	0.198***					0.497***	0.659***	0.216***	0.187***
					(0.034)	(0.057)	(0.025)	(0.050)					(0.033)	(0.043)	(0.023)	(0.036)
TPC	0.009***	0.011***	0.006**	0.027***	0.009***	0.015***	0.008***	0.033***	0.007**	0.002	0.006***	0.026***	0.012***	0.016**	0.016***	0.028***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.005)	(0.002)	(0.002)	(0.003)	(0.004)	(0.001)	(0.002)	(0.004)	(0.007)	(0.002)	(0.002)
LF	0.093***	0.085**	0.272***	0.138**	0.136***	0.059**	0.295***	0.164***	0.065**	-0.017	0.268***	0.136***	0.108***	-0.030	0.092***	0.179
	(0.032)	(0.036)	(0.037)	(0.029)	(0.033)	(0.028)	(0.040)	(0.029)	(0.028)	(0.002)	(0.029)	(0.031)	(0.034)	(0.031)	(0.007)	(0.028)
MK	-0.010***	-0.006***	0.001	-0.012***	-0.012***	-0.010***	0.0006	-0.014***	-0.011***	-0.010***	0.0004	-0.015***	-0.011***	-0.009**	-0.001	-0.010***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)
RD_EMPL_HEI		0.043***		0.038***		0.051***		0.030***		0.027***		0.032***		0.041***		0.029***
		(0.005)		(0.005)		(0.005)		(0.005)		(0.007)		(0.005)		(0.007)		(0.005)
CRISIS	-0.022***	-0.035***	-0.063***	-0.020***	-0.022***	-0.040***	-0.064***	-0.019***	-0.0002***	-0.068***	-0.008***	-0.064***	-0.002	-0.072***	-0.016***	-0.065***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)
N	454	451	420	413	454	451	420	413	454	451	420	413	454	451	420	413
SARGAN	0.7336	0.8712	0.9248	0.9652	0.7176	0.8651	0.9377	0.9652	0.7014	0.7891	0.8851	0.8981	0.6830	0.8912	0.8050	0.9370
AR(2)	0.9409	0.9181	0.4522	0.3951	0.9570	0.8825	0.4477	0.3937	0.8431	0.8834	0.4087	0.3678	0.8077	0.7798	0.4110	0.3680

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the human capital development variable measured as the efficiency level of the universities (HCD) is specified as endogenous variable. All variables are in log level. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree); MK: Market share (measured as # of enrolments $university_i$/total enrolments $province_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities); CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. Columns (1), (2), (5), (6), (9), (10), (13) and (14) are associated with university efficiency scores without the 1st quartile, Columns (3), (4), (7), (8), (11), (12), (15) and (16) are associated with university efficiency scores without the 4st quartile. *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Table 10 - Human capital development effects on local growth and spatial spillovers using quartile university efficiency scores - Number of graduates weighted by their degree marks used as a quantitative measure of human capital development

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$lnGDPC_{t-1}$	0.873***	0.924***	0.886***	0.911***	0.872***	0.917***	0.811***	0.803***	0.810***	0.812***	0.797***	0.730***
	(0.015)	(0.015)	(0.015)	(0.024)	(0.015)	(0.018)	(0.024)	(0.042)	(0.014)	(0.020)	(0.036)	(0.051)
$GR*10^4$	0.042***	0.035***	0.025	0.031	0.041***	0.035***	0.096***	0.108***	0.081***	0.076***	0.028***	0.031*
	(0.007)	(0.009)	(0.002)	(0.002)	(0.008)	(0.009)	(0.023)	(0.022)	(0.010)	(0.012)	(0.018)	(0.018)
$GR*W*10^2$					0.006***	0.003	0.022***	0.030***				
					(0.002)	(0.003)	(0.002)	(0.009)				
GDPC*W									0.329***	0.360***	0.343***	0.566***
									(0.045)	(0.072)	(0.085)	(0.111)
TPC	0.024**	0.023***	0.007	0.001	0.011*	0.018**	-0.006	-0.022	0.026***	0.031***	0.025***	0.032***
	(0.004)	(0.004)	(0.004)	(0.008)	(0.006)	(0.007)	(0.008)	(0.023)	(0.004)	(0.008)	(0.008)	(0.010)
LF	0.313***	0.067	0.173***	0.128**	0.267***	0.077	0.173**	0.094*	0.206***	-0.060	0.159**	-0.018
	(0.051)	(0.049)	(0.040)	(0.057)	(0.050)	(0.051)	(0.067)	(0.055)	(0.004)	(0.088)	(0.062)	(0.042)
MK	-0.059***	-0.048***	-0.015	-0.00002	-0.047***	-0.046***	-0.025	-0.022	-0.063***	-0.064***	-0.022***	-0.025***
	(0.008)	(0.008)	(0.005)	(0.005)	(0.009)	(0.009)	(0.009)	(0.015)	(0.009)	(0.010)	(0.006)	(0.008)
RD_EMPL_HEI		0.019***		0.012*		0.013		-0.001		0.031***		0.027**
		(0.006)		(0.007)		(0.009)		(0.014)		(0.008)		(0.011)
CRISIS	-0.035***	-0.012***	-0.041***	-0.049***	-0.036***	-0.011***	-0.036***	-0.009	-0.032***	-0.018***	-0.035***	-0.002
	(0.002)	(0.003)	(0.005)	(0.007)	(0.002)	(0.003)	(0.005)	(0.007)	(0.001)	(0.005)	(0.006)	(0.006)
N	441	438	428	421	441	438	428	421	441	438	428	421
SARGAN	0.9726	0.9994	0.9908	0.9932	0.9357	0.9994	0.9963	0.9959	0.9527	0.9982	0.9927	0.9959
AR(2)	0.9183	0.8268	0.9256	0.9994	0.9032	0.8397	0.9096	0.9655	0.9258	0.8366	0.888	0.9655

*Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the number of graduates weighted by their degree marks (GR) is specified as endogenous variable. All variables are in log level except for GR. GDPC: Gross domestic product per capita (measured as the sum of the gross values added of all units divided by population in each area where the university is located). TPC: Technology progress per capita (measured as the ratio between service workers and the sum of industry plus service workers all divided by the population in each area). LF: Labour force (measured as the share of the labour force with a university degree); MK: Market share (measured as # of enrolments $university_i$/total enrolments $province_i$); RD_EMPL_HEI: R&D employees in HEIs (# of operator in R&D activities in the universities); CRISIS: a dummy taking the value of 1 for years before 2008 and 0 otherwise. Lagged levels and differences are used as instruments. Year dummies included but not reported. N is the sample size. Statistics for the Sargan and Arellano-Bond, AR(2), tests are p-values. Columns (1), (2), (5), (6), (9) and (10) are associated with university efficiency scores without the 1st quartile, Columns (3), (4), (7), (8), (11) and (12) are associated with university efficiency scores without the 4st quartile. *, **, *** stand for significant at 10%, 5% and 1% respectively.*

Figure n. 1 – Map of Italy with the localization of the universities included in the dataset

Figure n. 2 - GDPC of the municipality where the university is located (logarithmic scale)