Human capital development, knowledge spillovers and local growth: Is there a quality effect of university efciency?

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Human capital development, knowledge spillovers and local growth: Is there a quality effect of university efficiency?

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Abstract

In this paper, we test whether economic growth depends on human capital development using data disaggregated at territorial level and propose the use of efficiency estimates, measured using a non-parametric technique, as an alternative quality measure of higher education institutions (HEIs). The nature of knowledge spillovers is also taken into account to examine the existence of geographically localized spillovers, from the presence of efficient universities, on local growth. Results show that the efficiency of universities has a positive and significant effect on GDP per worker. Moreover, we find evidence that productivity gains are larger in areas in which the most efficient universities are located, suggesting that investment in tertiary education may affect geographical distribution of economic activity as well as its level.

Keywords: Human capital; Higher education; Knowledge spillovers; Local economic development; Non-parametric technique.

JEL-Codes: I21, I23; C14; C67

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1. Introduction

As Potì and Reale (2005) have underlined, higher education institutions (HEI) "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". Several are the contributions that universities can make in order to increase local economic development[1]. Among them, both knowledge creation and regional innovation through research and technology transfer[2] 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).

Most of the studies on the contribution of universities to local development are focused on the technology transfer channel, highlighting the importance of HEI's services for the industry sector and specifically for boosting the innovation activities of the firms. According to Goldstein et al. (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 (2004), 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 HEI's 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. 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 Ponds et al. (2010), D'Este et al. (2012) and Abramovsky and Simpson (2011).

We, instead, want to focus the attention on the 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 the amount of highly-skilled human capital is a good predictor of economic development (Florida et al. 2008) and that HEIs might strongly contribute to increase the local human capital (Etzkowitz, 2003). Moreover, highly skilled and well-educated individuals are one of the main outputs of universities and at the same time are considered as the ultimate drive of economic development (Florida et al. 2008). Indeed, among the main channels, above mentioned, through which the HEI's activities might contribute to sustain local economies (see also Abel and Deitz, 2011; Anselin et al. 1997), this paper focuses specifically on the university contribution, through the development of human capital and skills, to economic growth; in

[1] For instance, to be able to play their regional role, HEIs must do more than simply educate and research – they must engage with others in their regions, provide opportunities for lifelong learning and contribute to the development of knowledge-intensive jobs which will enable graduates to find local employment and remain in their communities. This has implications for all aspects of these institutions' activities – teaching, research and service to the community and for the policy and regulatory framework in which they operate (OECD, 2007).

[2] As pointed out by Abel and Duiz (2011), "such activities can also raise local human capital levels if there are spillovers into the local economy that increase the demand for human capital, whether such human capital is produced locally or not.

other words, economic performances might increase through the production of highly skilled graduates and consequently of a highly educated workforce. 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, 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). Evidence of the effects that the human capital stock (measured through the share of adults with a college degree) and the presence of higher education institutions (measured through the 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[3].

An important contribution of the paper is, relying on territorially disaggregated data at province level (corresponding to the NUTS[4] 3 category)[5], to investigate whether the efficiency level of HEI's affects local development in Italy, under the assumption that the presence of an efficient university in a specific area might have a positive influence on its growth. We suggest the use of efficiency estimates as quality measure of higher education institutions (HEIs). A similar approach has already been considered in the financial context (see Hasan et al. 2009, and Destefanis et al. 2014) where the 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. Specifically, the analysis is performed in two stages: firstly, we use Data Envelopment Analysis (DEA) 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 relationship between university efficiency and economic growth. Moreover, the nature of spatial spillovers is also taken into account to examine whether geographical space has an impact on the relationship between the quality of university (measured by the efficiency scores) and local economic development. 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, 1997). 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 most efficient universities[6].

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

[4] Nomenclature of Territorial Units for Statistics.

[5] In Italy there are nowadays 110 provinces (NUTS3 category) even though we used only 103 of them because some missing data make 7 provinces useless. We think the province level is the most appropriate level of disaggregation properly matching the geographical distribution of universities in Italy.

[6] The occurrence of such spillovers is assumed to decrease with geographical distance.

Results show a significant and statistically positive effect of the universities quality (i.e. being more efficient) on local GDP per worker. Moreover, we find evidence that productivity gains are larger in areas in which the most efficient universities are located, suggesting that investments in tertiary education may affect geographical distribution of economic activity as well as its level. 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 introduces the methodology and the data, Section 3 illustrates the results, Section 4 provides a sensitive analysis and finally Section 5 concludes.

2. Empirical Strategy

2.1. Local economic development

In order to analyse the relationship between the quality of higher education institutions 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):

$$\ln GDP_{i,t} = \alpha lnGDP_{i,t-1} + \beta_1 lnEFF_{i,t} + \beta_2 \ln EFF_{i,t} * W + \beta_3 \ln GDP_{i,t} * W + \beta_4 LG_{i,t} + \beta_5 PD_{i,t} + \beta_6 MK_{i,t} + \mu_i + \tau_t + \varepsilon_{i,t} \quad (1)$$

where ln is the natural logarithm, GDP is the rate of growth in GDP per worker explained by its lagged value, by EFF (efficiency estimates of the universities), by $EFF * W$ (spatial lagged value of the HEIs efficiency), by $GDP * W$ (spatial lagged value of the rate of growth in GDP per worker), by LG (labour growth measured as the difference between employees at time t and employees at time $t-1$, aiming at controlling for the labour market characteristics), by PD (population density calculated as the ratio between population and km^2, aiming at controlling for changes in the population), 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 area, included for capturing the potential effects due to the presence of more concentration or competition between universities); 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 and t refer to the NUTS3 areas and time periods (years), respectively. 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, to deal with suspected endogeneity problem between human capital development and economic growth, we include lagged levels and differences as instruments of EFF.

Specifically, in order to examine whether geographical space has an impact on the relationship between the level of efficiency of universities and local economic development we specify a spatial-lag model such that the efficiency levels of the HEIs can spill over to the area i; in other words, we take into account that growth in area i depends systematically on the human capital development in neighbouring areas $i \in I$, where I is the set of all areas (Anselin, 1988). We use an inverse distance weighed matrix to weight EFF of all neighboring areas[7]. In matrix notation, $EFF * W$ is the weighted average of human capital development proxies across I_i areas neighboring area i, and $GDP * W$ is the weighted average rate of growth

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

in GDP per worker proxies across I_i areas neighboring area i. 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.

In estimating the efficiency of universities, we rely on two packages based on the freeware R (FEAR 1.13, Benchmarking 0.18); the regression analysis performed through a GMM model has been, instead, carried out with STATA 12[8].

2.2. University efficiency

In the literature, the main methods used to calculate the efficiency are: non-parametric and parametric. In particular, the non-parametric methods, such as DEA (Data Envelopment Analysis) and FDH (Free Disposable Hull), proposed by Charnes et al. (1978) and due to the original contribution of Farrell (1957), are based on deterministic frontier models (see also Cazals et al. 2002)[9]. Specifically, DEA analysis is a suitable tool for assessing the performances in higher education, according to Bougnol and Dula (2006), and can handle some well-known problems concerning the computation of technical efficiency in a parametric multiple input-output set up (Greene, 1980). Moreover, DEA model, extended by Banker et al. (1984), is especially adequate to evaluate the efficiency of non-profit entities that operate outside the market, since for them performance indicators, such as income and profitability, do not work satisfactorily (for more theoretical details on DEA see Coelli et al. 1998; Cooper et al. 2006). Traditionally, DEA assumes non-negativity of the inputs and outputs; however, the application of efficiency analysis, dealing with negative data, has been increasingly taken into account in the literature (see Pastor and Ruiz, 2007 and Thanassoulis et al. 2008 for a review) even though, to the best of our knowledge, it is almost new in the higher education environment. In the last decades, the problem of interrupted careers (i.e. drop out, thus negative output) has become an increasing concern in tertiary education[10], given that a substantial number of students enter in the higher education system and leave without at least a first tertiary degree[11]. The idea is to estimate efficiency scores in the presence of negative data using a directional distance approach [12]. Specifically, we focus on technical efficiency using an

[8] The spatial matrix has been constructed using the module so called "spwmatrix" by Jeanty (2010). The geographic data (latitude and longitude) for the statistical units used in our analysis, i.e. NUTS3, have been extracted from the mapping of ISTAT (http://www.istat.it/it/strumenti/cartografia). The 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. EFF and GDP, was built using the module so called "splagvar" by Jeanty (2010).

[9] These methods do not require the building of a theoretical production frontier, although necessitate the imposition of certain a priori hypotheses about the technology such as free-disposability, convexity, constant or variable return to scale (for more theoretical details on DEA see Coelli et al. 1998).

[10] According to Lambert and Butler (2006), "High drop-out rates are a sign either that the university system is not meeting the needs of its students, or that young people are using universities as a convenient place to pass a year or two before getting on with their lives. In a mass access system with no selection and high youth unemployment rates, it may be quite rational for a student to sit around for a year or two before dropping out. But this is hardly an efficient use of public resources".

[11] On average 31% of students entering tertiary education leave without at least a first tertiary degree among the 18 OECD countries for which data are available in 2008 and even though dropping out does not always represent a failure of individuals or inefficiency of universities, a high dropout rate shows that the higher education system did not probably match the students' expectations and needs (OECD 2010). To see why it is important to analyse the student persistence in higher education, individuals with a tertiary level of education have a greater chance of finding a job, a lower unemployment rate, a higher possibility of having a full time contract and earn more than those who do not have a university degree (OECD 2011).

[12] In other words, the main purpose of directional distance functions, that represent an alternative or generalization of Farrell's proportional approach, where all inputs are reduced or all outputs are expanded by the same factor but not simultaneously, is to determine

output-oriented[13] DEA method, with variable return to scale (VRS)[14]. Details about the estimation strategy and about the inputs and outputs used in order to compute efficiency scores are reported in Appendix 2.

2.3. Data

The dataset refers to 72 Italian universities (61 of them are public and 11 are private) from academic year 2003/2004 to 2007/2008[15] and it has been constructed using data which are publicly available on the National Committee for the Evaluation of the University System (CNVSU) website[16] (see Table 1 in Appendix 1, for a description of the variables available by geographical areas and by ownership). GDP, LG and PD are, instead, taken from the Italian National Institute of Statistics (ISTAT) web site (see Table 2 in Appendix 1 for a description of the variables used as controls).

3. The Empirical Evidence

3.1. University efficiency

A directional distance function approach has been applied in order to estimate technical efficiency of 72 Italian universities using data from academic year 2003/2004 to 2007/2008 using Model 1 (see Table 3 in Appendix 1 for a description of the inputs and outputs used in the production function). The efficiency estimates are presented in Table 4 (by geographical areas and by ownership) and in Table 5 (by university) in Appendix 1. The results reveal 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. The mean efficiency of all universities, considering Model 1, is 0.7185 with around 50% of the universities having a level of efficiency over the sample mean. Three of the most important private institutions such as Milano Bocconi, Milano Cattolica and Roma LUISS are very efficient in almost all the models. Among the public institutions, Bologna, Roma La Sapienza, Milano Politecnico, Padova, Torino, Chieti e Pescara, Siena and Milano do perform particularly well. Still taking into account the geographical effects, some information could be gained also when we consider the big city areas where many universities are located. For instance, the Rome area (where Roma IUSM, Roma LUISS, Roma LUMSA, Roma La Sapienza, Roma Tor Vergata and Roma Tre are located), is particularly efficient with an average efficiency of 0.9063 among all the years. The Milan area (where Milano, Milano Bicocca, Milano Bocconi, Milano Cattolica, Milano IULM, Milano Politecnico and Milano San Raffaele are located) also shows good performances with an average of 0.8618 among all the years. Finally the Naples area (where Napoli Benincasa, Napoli Federico II, Napoli II, Napoli L'Orientale and Napoli Parthenope are located), shows lower performances with an average of 0.6678 among all the years.

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improvements in a given direction d, in addition to measure the distance to the frontier in such d-units. Generally speaking, its role (related to efficiency measure) is to simultaneously seek to contract inputs and expand outputs. The main advantage of this method, belonging to the class of non-radial approach, is the flexibility. In fact, it allows to handle negative data or undesirable outputs-inputs, especially in managerially oriented benchmarking models (as suggested also by Portela et al. 2004).

[13] Following Agasisti and Dal Bianco (2009) who claimed that "as Italian universities are increasingly concerned with reducing the length of studies, and improving the number of graduates, in order to compete for public resources, the output-oriented model appears the most suitable to analyse higher education teaching efficiency".

[14] Indeed, as suggested by Portela et al. (2004), "in the presence of negative data variable return to scale (VRS) technologies need to be assumed". Moreover, the VRS is probably the most reliable in our case as suggested by Agasisti (2011) who argued that the assumption of constant return to scale is restrictive because it is reasonable "that the dimension (number of students, amount of resources, etc.) plays a major role in affecting the efficiency".

[15] 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.

[16] Specifically, data have been collected by the Italian Ministry of Education, Universities and Research Statistical Office.

3.2. Human capital development and local growth

Table 6 in Appendix 1 reports the main results related to the effects of human capital development on local growth. The estimates suggest that the efficiency of universities has a positive and significant effect on local growth. An increase by 1% in technical efficiency of universities increases the local growth by 0.012% (see Table 6, column 1 in Appendix 1). In other words, we find evidence that the presence of more efficient universities fosters local economic growth.

To take into account further environmental variables, we control for measurement of population per square kilometers (PD), a measure of labor-force quality (LG) and finally for a measure of the concentration of the universities (MK). 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.

3.3. 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 7 in Appendix 1). We consider two measures of spatial dependence such as *Efficiency * Spatial (EFF * W)*, a spatially lagged regressor which measures whether the average productivity of labour is higher for those areas closer to the most efficient universities and *GDP * Spatial (GDP * 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. We firstly take into account these two measures separately (see Table 7, Columns 1 to 4 in Appendix 1) and then we include both in the analysis (see Table 7, Columns 5 and 6 in Appendix 1). First of all, when we introduce the specification of the spatially weighted regressors, 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. Specifically, considering Table 7, columns 5 and 6 in Appendix 1, when both the specification of the spatially weighted human capital development and spatially weighted dependent variable have been included, we firstly find evidence of a positive effect for an area, in term of economic development, being closer to a prosperous area. Secondly, and most importantly, we also find evidence that the average productivity of labour is higher for those areas closer to the most efficient universities, suggesting the presence of knowledge spillovers within areas having virtuous institutions.

In order to check whether the main results are sensitive to the calculation of the efficiency used as proxy of the human capital development, we repeat the analysis using a different combination of inputs and outputs (see Table 3, Model 2 in Appendix 1). The results (see Table 8 in Appendix 1) still confirm that efficiency of universities has positive and significant on local growth and the presence of geographical spillovers.

4. 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 (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 the local human capital level and the share of the population enrolled in college to quantify the presence of higher education institutions). The idea is that, based on the assumption that highly skilled and well-educated individuals are one of the main outputs of universities and at the same time are considered as the ultimate drive of economic development (Florida et al. 2008), the number of graduates weighted by their degree marks could be used as a proxy of the human capital development.

We again find (see Table 9 in Appendix 1 for the results) that that the number of graduates has positive and significant effects on local growth (lower in magnitude but still significant at 1% level). 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 with the highest number of graduates, is still positive and statistically significant at 1% level; in other words, when the human capital development is proxied through the number of graduates weighted by their degree marks, we still find that the average productivity of labour is higher in municipalities that are closer to the most efficient universities.

4.1. How the distribution of efficiency affects the estimates?

As a second robustness check, we examine whether the results depend on the distribution of the HEIs quality measures used in the analysis by using quartiles and then median values. Specifically, when the university efficiency estimates are used as a proxy of the quality of the HEIs, we divide these scores in quartiles (see Table 10, columns 1 to 4 in Appendix 1); then we repeat the main analysis firstly removing from the sample those universities with an efficiency score in the first quartile (i.e. we take out the less efficient universities) and secondly those universities with an efficiency score in the fourth quartile (i.e. taking out the most efficient universities). Then, we also consider only those universities with efficiency score above and then below the median value (see Table 10, column 5 in Appendix 1). We apply the same approach using the number of graduates weighted by their degree time as a measure of the quality of the HEI's. What we expect to find is that the higher is the qualitative measure of HEIs the higher is the influence on economic growth.

We firstly consider our benchmark analysis, when the university efficiency scores used as a proxy of the human capital development are obtained according to Model 1 (see Table 3 in Appendix 1). Eliminating from the sample those universities with an efficiency score in the first quartile (i.e. with efficiency scores lower or equal than 0.532) the results (see Table 11, columns 1 and 2 in Appendix 1) confirm, as predicted, that the efficiency of universities has positive and significant on local growth and that the average productivity of labour is higher for those areas closer to the most efficient universities; when, instead, we remove from the sample those universities with an efficiency score in the fourth quartile (i.e. with efficiency scores greater than 0.999), the results (see Table 11, columns 3 and 4 in Appendix 1), show a decrease of the effects in term of magnitude and the spatially lagged regressor, which measures whether the average productivity of labour is higher for those areas closer to the most efficient universities, is still positive but not statistically significant as before. The same evidence has been obtained when we repeat the analysis using only those universities with an efficiency score above (i.e. with efficiency scores greater than 0.692) and below (i.e. with efficiency scores lower than 0.692) the median value (see the results in Table 11, columns 5 and 6 and columns 7 and 8, respectively, in Appendix 1). These are interesting findings meaning that there is still evidence that productivity gains are larger in areas in which the most efficient universities are located but the existence of knowledge spillovers is particularly evident when the upper quartiles of the distribution are considered. In other words, geographical space has an impact on the relationship between the quality level of university and local economic development only when the highest quality HEIs are taken into account.

Results are similar (see Tables 12 and 13 in Appendix 1) when we finally use a different measure of the university efficiency scores (see Table 3, Model 2 in Appendix 1) and the number of graduates weighted by their degree as proxies of human capital development.

5. 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 (NUTS 3) in Italy. As far as we know this is the first study to explore the human capital-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 quality measure of the human capital development. Indeed, we use DEA 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 efficiency 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 the level of quality of universities (measured by the efficiency scores) and the local economic development.

Our 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 more efficient universities fosters local GDP per worker. 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 the most 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 that area; in other words, investment in tertiary education may affect geographical distribution of economic activity as well as its level. Results are robust to a more quantitative measure of the human capital development such as the number of graduates. Moreover, further robustness checks show that geographical space has an impact on the human capital-growth relationship only when the highest quality HEIs are taken into account. 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 quality measure of HEIs.

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 and that the basis for allocating core funding to HEIs has become more output-oriented. Future works is needed to incorporate the quality 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.

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Appendix 1 – Tables

Table 1 - The production set: descriptive statistics - Mean values by geographical areas and by ownership

		Mean values					
		North-Western	*North-Eastern*	*Central*	*Southern*	*Public*	*Private*
Inputs							
$ACAD_{STAFF}$[1]	*# of academic staff*	790.51 (741.63)	970.5 (845.36)	875.65 (1147.59)	766.54 (732.90)	948.85 (886.74)	193.65 (398.36)
ENR_{HSG}[2]	*% of enrolments with a score higher than 9/10 in secondary school*	5.34 (2.43)	4.82 (0.87)	4.88 (2.42)	4.90 (1.37)	4.77 (1.27)	6.20 (3.66)
ENR_{LYC}[2]	*% of enrolments who attended a lyceum*	8.44 (3.20)	6.70 (1.12)	7.36 (3.15)	7.07 (1.33)	7.06 (1.51)	9.35 (4.79)
STUD	*Total number of students*	21922.85 (18388.58)	26244.7 (25110.15)	25575.98 (30835.39)	26287.84 (22150.01)	28120.14 (24850.52)	8169.09 (10466.29)
Good Output							
$GRAD_{MARKS}$	*# of graduates weighted by their degree classification*	2566.32 (2079.30)	2800.01 (2800.69)	2094.63 (2336.90)	1646.77 (145457)	2342.73 (2189.07)	1199.38 (1543.03)
Bad Output							
DROU	*# of enrolments who drop out at the end of the 1st year*	-546.12 (556.23)	-855.31 (1028.61)	-867.55 (1102.54)	-1131.75 (1165.05)	-1010.75 (1067.87)	-163.81 (204.98)
$INACT_{ENR}$	*# of inactive enrolments at the end of the 1st year*	-514.57 (519.99)	-628.56 (746.91)	-885.21 (1327.23)	-1144.09 (1773.72)	-969.12 (1394.49)	-155.49 (269.82)

Note: Authors calculation on data collected by the Italian Ministry of Education, Universities and Research Statistical Office.

[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 and lectures).*

[2]*Both ENR_{HSG} and ENR_{LYC} are percentages of the total number of students enrolled.*

Table 2 - Environmental variables: descriptive statistics - Mean values by geographical areas

			Mean values			
			North-Western	*North-Eastern*	*Central*	*Southern*
GDP	*Gross Domestic Product per worker*	*Sum of the gross values added of all units*	52.35 (3.209)	50.61 (2.497)	47.35 (3.165)	39.24 (3.920)
LG	*Labour growth*	*Log of employees$_t$ – Log of employees$_{t-1}$*	0.0104 (0.015)	0.0103 (0.015)	0.0132 (0.019)	0.0040 (0.024)
PD	*Population density*	*Population / km^2*	304.87 (366.61)	255.16 (223.68)	206.35 (170.65)	224.67 (412.74)
MK	*Market share*	*# of enrolments university$_j$/total enrolemnts NUTS3$_i$*	0.084 (0.077)	0.060 (0.047)	0.048 (0.043)	0.076 (0.055)

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

Table 3 - Specification of outputs and inputs

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

Notes:

$ACAD_{STAFF}$: *Number of academic staff*
ENR_{HSG}: *% of enrolments with a score higher than 9/10 in secondary school respect to the total number of students*
ENR_{LYC}: *% of enrolments who attended a lyceum respect to the total number of students*
STUD: Total number of students
DROU: Number of enrolments who drop out at the end of the 1st year
$INACT_{ENR}$: *Number of inactive enrolments at the end of the 1st year*
$GRAD_{MARKS}$: *Number of graduates weighted by their degree classification*

Table 4 - Technical Efficiency - Directional distance efficiency scores by geographical areas and by ownership

	Model 1					Model 2				
	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Geographical areas										
North-Western	0.8011	0.7303	0.7477	0.7880	0.8073	0.7652	0.7262	0.7694	0.7931	0.7933
North-Eastern	0.7681	0.7380	0.7362	0.7358	0.7317	0.7860	0.7355	0.7566	0.7911	0.7649
Central	0.8410	0.7967	0.8215	0.8087	0.8029	0.8019	0.7682	0.8035	0.8060	0.7963
Southern	0.5553	0.5563	0.6049	0.6415	0.6414	0.5226	0.5628	0.5864	0.6315	0.6142
Ownership										
Public	0.6702	0.6542	0.6684	0.6945	0.6945	0.6418	0.6367	0.6645	0.7012	0.6891
Private	1.0000	0.8739	0.9711	0.9503	0.9657	0.9810	0.9302	0.9770	0.9540	0.9379

Notes: Estimates of the efficiency scores have been obtained through a directional distance approach. In model 1, academic staff ($ACAD_{STAFF}$), the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), the percentage of enrolments who attended a lyceum (ENR_{LYC}) and the total number of students (STUD) are used as inputs , while the number of enrolments who drop out at the end of the 1st year (DROU) and the number of graduates weighted by their degree classification ($GRAD_{MARKS}$) are used as outputs. In model 2, academic staff ($ACAD_{STAFF}$), the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), the percentage of enrolments who attended a lyceum (ENR_{LYC}) and the total number of students (STUD) are used as inputs, while the number of inactive enrolments at the end of the 1st year ($INACT_{ENR}$) and the number of graduates weighted by their degree classification ($GRAD_{MARKS}$) are used as outputs.

Table 5 - Technical Efficiency - Directional distance efficiency scores by university

		Model 1	Model 2			Model 1	Model 2
1	Aosta	1.0000	1.0000	37	Napoli Benincasa	1.0000	1.0000
2	Bari	0.8675	0.7899	38	Napoli Federico II	0.7545	0.7204
3	Bari Politecnico	0.3998	0.4025	39	Napoli II	0.6383	0.5718
4	Basilicata	0.4352	0.4056	40	Napoli L'Orientale	0.5224	0.5145
5	Bergamo	0.6152	0.5581	41	Napoli Parthenope	0.4239	0.4123
6	Bologna	1.0000	1.0000	42	Padova	0.9999	0.1.000
7	Bolzano	0.8696	0.9478	43	Palermo	0.6920	0.6822
8	Brescia	0.4322	0.4195	44	Parma	0.5769	0.5905
9	Cagliari	0.7490	0.7478	45	Pavia	0.7795	0.8288
10	Calabria	0.6949	0.6845	46	Perugia	0.6348	0.6182
11	Camerino	0.3920	0.3708	47	Perugia Stranieri	0.9348	0.9139
12	Casamassima - J.Monnet	0.8830	0.9803	48	Piemonte Orientale	0.5411	0.4409
13	Cassino	0.5809	0.5344	49	Pisa	0.8360	0.7132
14	Castellanza LIUC	1.0000	1.0000	50	Reggio Calabria	0.3580	0.3141
15	Catania	0.6489	0.6559	51	Roma IUSM	0.9672	1.0000
16	Catanzaro	0.3757	0.3442	52	Roma LUISS	1.0000	0.8984
17	Chieti e Pescara	0.9851	0.9852	53	Roma LUMSA	0.9249	0.8947
18	Ferrara	0.5411	0.6031	54	Roma La Sapienza	1.0000	1.0000
19	Firenze	0.9807	0.9752	55	Roma Tor Vergata	0.7035	0.7312
20	Foggia	0.3264	0.3638	56	Roma Tre	0.8423	0.7662
21	Genova	0.7662	0.7676	57	Salerno	0.5924	0.5684
22	Insubria	0.4692	0.4666	58	Sannio	0.3833	0.3072
23	Lecce	0.5751	0.5194	59	Sassari	0.4598	0.4147
24	L'Aquila	0.6016	0.6204	60	Siena	0.9844	0.9267
25	Macerata	0.8722	0.8968	61	Siena Stranieri	1.0000	1.0000
26	Marche	0.5258	0.6294	62	Teramo	0.5122	0.4671
27	Messina	0.5025	0.5123	63	Torino	0.9396	0.9744
28	Milano	0.7871	0.7756	64	Torino Politecnico	0.5974	0.6381
29	Milano Bicocca	0.7199	0.6421	65	Trento	0.5339	0.5279
30	Milano Bocconi	1.0000	1.0000	66	Trieste	0.9593	0.9640
31	Milano Cattolica	1.0000	0.9790	67	Tuscia	0.4757	0.4349
32	Milano IULM	0.9458	0.9122	68	Udine	0.5173	0.5317
33	Milano Politecnico	0.7286	0.7734	69	Urbino Carlo Bo	1.0000	1.0000
34	Milano San Raffaele	0.8512	0.9043	70	Venezia Cà Foscari	0.7296	0.7677
35	Modena e Reggio Emilia	0.6100	0.6246	71	Venezia Iuav	1.0000	1.0000
36	Molise	0.6202	0.6030	72	Verona	0.5677	0.6448

Notes: Estimates of the efficiency scores have been obtained through a directional distance approach. In model 1, academic staff ($ACAD_{STAFF}$), the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), the percentage of enrolments who attended a lyceum (ENR_{LYC}) and the total number of students (STUD) are used as inputs , while the number of enrolments who drop out at the end of the 1st year (DROU) and the number of graduates weighted by their degree classification ($GRAD_{MARKS}$) are used as outputs. In model 2, academic staff ($ACAD_{STAFF}$), the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), the percentage of enrolments who attended a lyceum (ENR_{LYC}) and the total number of students (STUD) are used as inputs , while the number of inactive enrolments at the end of the 1st year ($INACT_{ENR}$) and the number of graduates weighted by their degree classification ($GRAD_{MARKS}$) are used as outputs.

Table 6 - Human capital effects on local growth

	(1)	(2)
lnGDP$_{t-1}$	0.949***	0.954***
	(0.008)	(0.008)
EFF	0.012***	0.013***
	(0.003)	(0.004)
LG	-0.208***	-0.204***
	(0.039)	(0.040)
PD*10^4	0.02***	0.01**
	(0.008)	(0.007)
MK	-0.054**	-0.045**
	(0.022)	(0.022)
N	412	412
NUTS3	103	103
SARGAN	0.1002	0.1183
AR(2)	0.9155	0.9149

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_j$/total enrolments NUTS3$_i$. 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. Model (1) uses EFF variable measured at log-level. Model (2) uses EFF variable at linear-level. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 7 - Human capital effects on local growth - Spatial spillovers

	(1)	(2)	(3)	(4)	(5)	(6)
lnGDP$_{t-1}$	0.884***	0.889***	0.942***	0.943***	0.890***	0.885***
	(0.023)	(0.025)	(0.008)	(0.007)	(0.019)	(0.021)
EFF	0.016***	0.021***	0.014***	0.019***	0.016***	0.023***
	(0.003)	(0.005)	(0.002)	(0.003)	(0.002)	(0.004)
EFF *W	0.056**	0.085**			0.045***	0.073***
	(0.026)	(0.043)			(0.018)	(0.029)
GDP*W			0.054***	0.054***	0.053***	0.054***
			(0.014)	(0.013)	(0.014)	(0.014)
LG	-0.221***	-0.217***	-0.197***	-0.201***	-0.182***	-0.185***
	(0.040)	(0.041)	(0.032)	(0.033)	(0.032)	(0.033)
PD*10^4	0.05***	0.03***	0.02***	0.02***	0.07***	0.06***
	(0.01)	(0.01)	(0.06)	(0.006)	(0.01)	(0.01)
MK	-0.089***	-0.077***	-0.059***	-0.054***	-0.079***	-0.076***
	(0.025)	(0.024)	(0.018)	(0.017)	(0.020)	(0.019)
N	412	412	412	412	412	412
NUTS3	103	103	103	103	103	103
SARGAN	0.1452	0.2123	0.1962	0.2813	0.2094	0.3306
AR(2)	0.9275	0.9284	0.9748	0.9986	0.9172	0.9401

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_j$/total enrolments NUTS3$_i$. 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. Models (1), (3) and (5) use EFF variable measured at log-level. Models (2), (4) and (6) use EFF variable at linear-level. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 8 - Human capital effects on local growth and spatial spillovers - Alternative measure of efficiency using a different combination of inputs and outputs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*ln*GDP$_{t-1}$	0.934***	0.942***	0.898***	0.906***	0.931***	0.938***	0.892***	0.899***
	(0.008)	(0.008)	(0.021)	(0.019)	(0.008)	(0.007)	(0.017)	(0.015)
EFF	0.018***	0.021***	0.014***	0.018***	0.023***	0.028***	0.019***	0.026***
	(0.003)	(0.004)	(0.004)	(0.005)	(0.002)	(0.003)	(0.003)	(0.004)
EFF*W			0.039*	0.060*			0.040**	0.059**
			(0.022)	(0.032)			(0.016)	(0.023)
*ln*GDP*W					0.062***	0.059***	0.048***	0.058***
					(0.013)	(0.012)	(0.013)	(0.013)
LG	-0.206***	-0.203***	-0.213***	-0.228***	-0.197***	-0.205***	-0.178***	-0.198***
	(0.035)	(0.037)	(0.038)	(0.039)	(0.029)	(0.030)	(0.032)	(0.031)
PD*10^4	0.02**	0.01**	0.01*	0.02**	0.02***	0.01**	0.04***	0.03***
	(0.007)	(0.007)	(0.01)	(0.009)	(0.007)	(0.007)	(0.01)	(0.009)
MK	-0.077***	-0.068***	-0.085***	-0.074***	-0.081***	-0.071***	-0.090***	-0.078***
	(0.021)	(0.020)	(0.023)	(0.022)	(0.018)	(0.016)	(0.019)	(0.017)
N	412	412	412	412	412	412	412	412
NUTS3	103	103	103	103	103	103	103	103
SARGAN	0.1001	0.1118	0.11107	0.1508	0.2364	0.3311	0.2105	0.3169
AR(2)	0.9428	0.9859	0.9434	0.9959	0.7819	0.8647	0.7969	0.8431

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_i$/total enrolments NUTS3$_i$. 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. Models (1), (3) and (5) use EFF variable measured at log-level. Models (2), (4) and (6) use EFF variable at linear-level. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 9 - Human capital effects on local growth and spatial spillovers using the number of graduates weighted by their degree as a measure of HEIs quality

	(1)	(2)	(3)	(4)
*ln*GDP$_{t-1}$	0.940***	0.931***	0.926***	0.914***
	(0.009)	(0.009)	(0.008)	(0.008)
GR*10^4	0.01***	0.02***	0.02***	0.02***
	(0.005)	(0.004)	(0.04)	(0.003)
GR*W*10^4		0.2***		0.1**
		(0.006)		(0.005)
*ln*GDP*W			0.066***	0.064***
			(0.011)	(0.009)
LG	-0.205***	-0.201***	-0.188***	-0.196***
	(0.038)	(0.031)	(0.034)	(0.024)
PD*10^4	0.04**	0.03***	0.03***	0.01***
	(0.01)	(0.01)	(0.009)	(0.007)
MK	-0.112***	-0.142***	-0.138***	-0.159***
	(0.024)	(0.021)	(0.021)	(0.019)
N	412	412	412	412
NUTS3	103	103	103	103
SARGAN	0.1545	0.1122	0.2433	0.2653
AR(2)	0.8958	0.8946	0.9702	0.9836

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. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_i$/total enrolments NUTS3$_i$. 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. Models (1) and (3) use EFF variable measured at log-level. Models (2) and (4) use EFF variable at linear-level. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 10 - Proxy of HEIs quality: quartile and median values

	1st quartile	2st quartile	3st quartile	4st quartile	Median
	(1)	(2)	(3)	(4)	(5)
EFF (1)	0.043<EFF(1)≤0.532	0.532<EFF(1)≤0.692	0.692<EFF(1)≤0.999	EFF(1)>0.999	0.692
EFF (2)	0.049<EFF(2)≤0.522	0.522<EFF(2)≤0.715	0.715<EFF(2)≤0.980	EFF(2)>0.980	0.715
GR	9.200<GR≤1047.2	1047.2< GR≤2271.2	2271.2< GR≤3836.6	GR>3836.6	2271.2

Notes: EFF (1) refers to the university efficiency scores obtained according to Model 1 (see Table 3 in Appendix 1). EFF (2) refers to the university efficiency scores obtained according to Model 2 (see Table 3 in Appendix 1). GR indicates the number of graduates weighted by their degree used as a measure of HEIs quality.

Table 11 - Human capital effects on local growth and spatial spillovers using quartile and median university efficiency scores

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*ln*GDP$_{t-1}$	0.935***	0.920***	0.921***	0.885***	0.960***	0.964***	0.905***	0.911***
	(0.015)	(0.017)	(0.019)	(0.021)	(0.012)	(0.013)	(0.011)	(0.014)
EFF	0.009***	0.015***	0.005**	0.012***	0.008***	0.010**	0.006***	0.001
	(0.002)	(0.004)	(0.002)	(0.003)	(0.003)	(0.004)	(0.002)	(0.003)
EFF*W	0.032**	0.074***	0.017	0.057**	0.042***	0.072***	0.006	0.012
	(0.016)	(0.026)	(0.013)	(0.027)	(0.015)	(0.025)	(0.009)	(0.018)
*ln*GDP*W	0.077***	0.076***	0.065***	0.070***	0.053**	0.055***	0.008	0.012
	(0.014)	(0014)	(0.011)	(0.012)	(0.021)	(0.020)	(0.009)	(0.011)
LG	-0.113***	-0.092**	-0.183***	-0.252***	-0.227***	-0.237***	-0.192***	-0.161***
	(0.039)	(0.043)	(0.040)	(0.037)	(0.049)	(0.049)	(0.033)	(0.031)
PD*10^4	0.1***	0.1	0.008	0.03	0.01**	0.03	0.08*	0.05
	(0.01)	(0.03)	(0.07)	(0.07)	(0.03)	(0.03)	(0.04)	(0.05)
MK	-0.020	-0.036	-0.082***	-0.106***	-0.005	-0.000002	-0.138***	-0.128***
	(0.020)	(0.022)	(0.016)	(0.017)	(0.019)	(0.021)	(0.019)	(0.020)
N	316	316	310	310	213	213	199	199
NUTS3	100	100	101	101	92	92	89	89
SARGAN	0.6318	0.3380	0.1044	0.2592	0.5393	0.2407	0.6026	0.5445
AR(2)	0.6816	0.9713	0.3018	0.3963	0.5754	0.5677	0.1100	0.1110

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_j$/total enrolments NUTS3i. 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. Models (1), (3), (5) and (7) use EFF variable measured at log-level. Models (2), (4), (6) and (8) use EFF variable at linear-level. Models (1) and (2) are associated with university efficiency scores without the 1st quartile, Models (3) and (4) are associated with university efficiency scores without the 4st quartile, Models (5) and (6) are associated with university efficiency scores above the median value, Models (7) and (8) are associated with university efficiency scores below the median value. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 12 - Human capital effects on local growth and spatial spillovers using quartile and median university efficiency scores

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*ln*GDP$_{t-1}$	0.936***	0.923***	0.919***	0.918***	0.934***	0.932***	0.887***	0.890***
	(0.014)	(0.015)	(0.017)	(0.016)	(0.014)	(0.014)	(0.010)	(0.010)
EFF	0.015***	0.024***	0.009***	0.011***	0.008**	0.010**	0.005**	0.001***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.002)	(0.003)
EFF*W	0.026*	0.059**	0.016	0.032	0.042***	0.064***	0.011	0.016
	(0.015)	(0.025)	(0.015)	(0.023)	(0.008)	(0.014)	(0.007)	(0.014)
*ln*GDP*W	0.087***	0.091***	0.065***	0.067***	0.120**	0.125***	-0.001	-0.002
	(0.016)	(0017)	(0.012)	(0.012)	(0.018)	(0.017)	(0.010)	(0.011)
LG	-0.097**	-0.084**	-0.183***	-0.174***	-0.161***	-0.172***	-0.161***	-0.165***
	(0.039)	(0.039)	(0.036)	(0.038)	(0.060)	(0.059)	(0.025)	(0.024)
PD*10^4	0.04*	0.04*	0.06	0.05	0.03	0.06**	0.1***	0.1***
	(0.02)	(0.02)	(0.07)	(0.07)	(0.02)	(0.01)	(0.04)	(0.04)
MK	-0.025	-0.025	-0.102***	-0.092***	-0.064**	-0.061**	-0.122***	-0.125***
	(0.019)	(0.019)	(0.017)	(0.015)	(0.027)	(0.027)	(0.011)	(0.010)
N	313	313	298	298	208	208	204	204
NUTS3	100	100	100	100	95	95	95	95
SARGAN	0.2732	0.2593	0.1213	0.1280	0.3986	0.4749	0.5832	0.6083
AR(2)	0.8850	0.8672	0.3049	0.3051	0.5296	0.5240	0.8824	0.8709

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_j$/total enrolments NUTS3$_i$. 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. Models (1), (3), (5) and (7) use EFF variable measured at log-level. Models (2), (4), (6) and (8) use EFF variable at linear-level. Models (1) and (2) are associated with university efficiency scores without the 1st quartile, Models (3) and (4) are associated with university efficiency scores without the 4st quartile, Models (5) and (6) are associated with university efficiency scores above the median value, Models (7) and (8) are associated with university efficiency scores below the median value. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Table 13 - Human capital effects on local growth and spatial spillovers using quartile and median university efficiency scores - Number of graduates weighted by their degree used as a measure of HEIs quality

	(1)	(2)	(3)	(4)
*ln*GDP$_{t-1}$	0.927***	0.928***	0.938***	0.928***
	(0.006)	(0.005)	(0.004)	(0.003)
EFF*10^4	0.01***	0.01***	0.01***	0.01***
	(0.003)	(0.003)	(0.001)	(0.002)
EFF*W*10^4	0.02***	0.005	0.02***	0.009*
	(0.005)	(0.003)	(0.002)	(0.005)
*ln*GDP*W	0.056***	0.033***	0.069***	-0.039
	(0.008)	(0.009)	(0.008)	(0.005)
LG	-0.173***	-0.166***	-0.249***	-0.261***
	(0.032)	(0.021)	(0.024)	(0.021)
PD*10^4	-0.01	-0.02	0.04*	0.1***
	(0.03)	(0.02)	(0.02)	(0.03)
MK	-0.127***	-0.121***	-0.103***	-0.096***
	(0.018)	(0.011)	(0.014)	(0.009)
N	313	294	225	187
NUTS3	97	97	88	75
SARGAN	0.4653	0.3133	0.4628	0.8701
AR(2)	0.5740	0.9964	0.1110	0.5416

Notes: All equations are estimated through a two step system GMM estimator with Windmeijer (2005) corrected standard error (in brackets): the efficiency level of the universities (EFF) is specified as endogenous variable. GDP: Gross domestic product per worker. LG: Labour growth measured as Log of employees$_t$ – Log of employees$_{t-1}$. PD: Population density measured as Population / km^2. MK: Market share measured as # of enrolments university$_j$/total enrolments NUTS3i. 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. Models (1), and (3) use EFF variable measured at log-level. Models (2) and (4) use EFF variable at linear-level. Model (1) is associated with university efficiency scores without the 1st quartile, Model (2) is associated with university efficiency scores without the 4st quartile, Model (3) is associated with university efficiency scores above the median value, Model (4) is associated with university efficiency scores below the median value. *, **, *** stand for significant at 10%, 5% and 1% respectively.

Appendix 2: A description of the empirical strategy adopted in the paper

1.1. The model

Let assume $x = (x_1, \dots, x_N) \in \Re_+^N$ to be an input vector transformed to obtain an output vector $y = (y_1, \dots, y_M) \in \Re_+^M$. In this framework, the technology T can be described as follows:

$$T = \{(x, y): x \; can \; produce \; y\} \tag{2}$$

In this paper, we implement a specific procedure so called "directional distance function". In a generic form[17], following Chambers, Chung, and Fare (1998), this technique can be described as follows:

$$\overrightarrow{D_T}(x, y;\ g_x, g_y) = \sup\{\beta: (x - \beta g_x, y + \beta g_y) \ \in \ T\} \tag{3}$$

where $g = (g_x, g_y)$ denotes a directional vector. Assuming an arbitrary direction to be $d \in \Re_+^m$, the directional distance or excess function can be also defined in this way:

$$e = e(x, y; T, d) = \max\{e \in \mathbb{R}_+ | (x - ed, y + ed) \in T\} \tag{4}$$

where a high degree of excess reflects a high (in absolute value) amount of slack and a considerable amount of inefficiency. The main advantage of this method, belonging to the class of non-radial approach, is the flexibility. In fact, as already underlined in Section 2, it allows to handle negative data or undesirable outputs-inputs. However the applicability of this method imposes some fundamental requirements. One of the main condition concerns the choice's rule of the directional vector, since a wrong specification could lead to accept the infeasibility assumption. By definition, the direction of $g \in (-\Re_+^N) \times (\Re_+^M)$ is infeasible at $z = (x, y) \in T$ if $\Delta\,(z, g) = \{z + \delta g: \delta \in \mathbb{R}\} \cap T = \emptyset$. In other words, the directional distance function (so called $D_T(z; g)$) at point z and direction g is not well defined, i.e.$-\infty$. So, the optimal choice of direction vector assumes a high relevance in application and theory framework in order to determine the deviations from the boundary of technology. As shown by Briec and Kerstens (2009), in the case of more than two output dimensions and of a non-null output direction vector, the directional distance may be infeasible, but it's not our case.

However, to overcome the problem related to the "infeasibility", we follow the line suggested by Fare and Grosskopf (2000). In order to guarantee link and symmetry with the traditional distance functions, which are defined in the direction of the observed input or output mix for each observation, we impose the direction vector to be equal to the value of the observation (see Chambers, Chung, and Fare, 1998 and recently Bogetoft and Otto, 2011 for additional details about the choice of the directional vector). To the best of our knowledge, in higher education there are no works which make use of the directional distance function in order to assess technical efficiency of specific decision-making units (i.e. faculty, department or university). Our main contribution is then to implement this specific technique considering undesiderable outputs (in our case the number of dropouts), which is, instead, not allowed, using Farrell efficiency (radial approach).

For the purpose of this paper, we only formalize the output-oriented approach. Assuming $g = (0, g_y)$, the directional output distance function is reached as follows:

$$\overrightarrow{D_o}(x, y; g_y) = \sup\{\beta: (y + \beta g_y \ \in \ P(x) \subseteq \Re_+^M\} \tag{5}$$

[17] As a general specification, a constant return to scale (CRS) version of the procedure is presented even though a variable return to scale (VRS) assumption is finally assumed in the empirical analysis.

where $\overrightarrow{D_0}(x, y; g_y) = \overrightarrow{D_o}(x, y; 0, g_y)$. Using a directional distance function and assuming $g_x = x$ and $g_y = y$, it's possible to derive the conventional Shephard output distance function[18] as follows:

$$\overrightarrow{D_o}(x, y; y) = \frac{1}{D_0(x, y)} - 1 \tag{6}$$

The Shephard's distance function in the output-oriented context becomes:

$$D_0(x, y) = \inf\{\theta : \frac{y}{\theta} \in P(x)) \subseteq \Re_+^M\} \tag{7}$$

The conventional linear programming problem corresponding to the directional distance or excess function, i.e. e, in DEA-oriented output approach is formally described as:

$$max_{e,\lambda^1,\ldots,\lambda^K} \quad e \tag{8}$$

$$s.t. \quad x \geq \sum_{k=1}^{K} \lambda^k x^k \tag{9}$$

$$y + ed \leq \sum_{k=1}^{K} \lambda^k y^k \tag{10}$$

$$\lambda \in \Lambda^K(y) \tag{11}$$

1.2. The production set

The first input is the number of academic staff ($ACAD_{STAFF}$). It is a measure of a human capital input and it aims to capture the human resources used by the universities for teaching activities.[19]

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 (ENR_{LYC}), with respect to the total number of students enrolled. 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, Ahlburg, and McCall 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.

The first output is the number of enrolments who drop out at the end of the 1st year (DROU). As already pointed out in Section 2.2, a high number of leavers is considered a signal of a system that does not work perfectly. Consequently, it is used as an undesirable output. The second output is the number of inactive enrolments[20], meaning those freshmen who do not take any exam at the end of the first year ($INACT_{ENR}$). We use this measure as a proxy of the dropout and so as a bad

[18] Note that Shephard's distance functions have a multiplicative structure, while directional functions follow an additive framework.

[19] The variable $ACAD_{STAFF}$ indicates the number of total academic staff adjusting for the respective academic position (i.e. professors, associate professors and lectures). Unfortunately, we do not have information on the auxiliary staff such as the administrative staff.

[20] This choice is due to the fact that, according to the National Committee for the Evaluation of the University System (CNVSU) guidelines, among the weaknesses of the Italian higher education system there is also the high number of inactive students, meaning those students who do not pass any exam or acquire any credit during the 1st year.

output.[21]. The use of DROU and $INACT_{ENR}$ as outputs, results in some outputs being negative in most of the universities (see Table 1 in Appendix 1); this justifies the use of the directional distance function approach to cope with such data[22]. Moving to desirable outputs, according to Catalano et al. (1993) "the task assigned to universities is to produce graduates with the utilization and the combination of different resources" and Madden, Savage, and Kemp (1997) used the number of graduates under the hypothesis that the higher is the number of graduates the higher is the quality of teaching[23]. Also Worthington and Lee (2008) considered the number of undergraduate degrees awarded an obvious measure of output for any university. Thus, the fourth output is the number of graduates weighted by their degree classification ($GRAD_{MARKS}$)[24], in order to capture both the quantity and the quality of teaching[25].

1.3. Specification of the models

To reveal whether the results are sensitive to the specification of the outputs used in the analysis, we implement different models as summarized by Table 3 in Appendix 1. In the benchmark model (Table 3, Model 1, in Appendix 1), the academic staff ($ACAD_{STAFF}$), the percentage of enrolments with a score higher than 9/10 in secondary school (ENR_{HSG}), the percentage of enrolments who attended a lyceum (ENR_{LYC})[26] and the total number of students (STUD) are used as inputs[27], while the number of enrolments who drop out at the end of the 1st year (DROU) and the number of graduates weighted by their degree classification ($GRAD_{MARKS}$) are used as outputs. Keeping constant the input side, we then explore whether the number of enrolments who did not take any exam at the end of the 1st year ($INACT_{ENR}$) might be considered as a good proxy for the dropout phenomenon (see Table 3, Model 2, in Appendix 1). In estimating our models, we rely on two packages based on the freeware R (FEAR 1.13, Benchmarking 0.18).

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[21] These first two outcomes (DROU and $INACT_{ENR}$) are both measured at the end of the 1st year. This follows the Italian Ministry of Education, Universities and Research guidelines, according to which, universities are evaluated also on the base of indicators such as the number of students leaving university after the 1st year or the number of students who enroll in the 2nd year having acquired a certain amount of credits. In other words, the transition between the 1st and the 2nd year has been considered as the main checkpoint to evaluate the regularity of the educational path.

[22] As already argued, the number of enrolments who drop out at the end of the 1st year (DROU) and the number of inactive enrolments at the end of the 1st year ($INACT_{ENR}$) are negative numbers (see Table 1 in Appendix 1) and then are treated as bad outputs. However, some complementary variables could be used. For instance, a decrease in the number of dropouts is negatively correlated with an increase in the number of regular students (whatever the way in which they are measured), while a reduction in the number of inactive students is directly associated with an increase in the number of active ones. In this way, by using these (positive and/or desirable) variables a standard DEA can be easily implemented instead of directional distance functions. However, although, on average, the general results (geographical and ownership differences) are almost the same, the university efficiency scores are higher than the ones obtained through a directional distance approach. To avoid possible overestimation in our findings, we believe a directional distance approach is more suitable and consistent with the characteristics of the data under analysis.

[23] The liability of this measure is still not clear in the literature. See Kao and Hung (2008) and Abbott and Doucouliagos (2003) for a discussion.

[24] 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 marks between 66 and 90. The weights have been chosen so that the distance between two ranks is $1/4 = 0.25$.

[25] We've also used, for robustness check, just the number of graduates without weighting by their degree classification and the results are similar.

[26] Both ENR_{HSG} and ENR_{LYC} are percentages of the total number of students enrolled.

[27] 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 (STU). We use ENR_{HSG}, ENR_{LYC} as a measure of the quality of the enrolments and STU as a measure of the quantity of the students.