RESEARCH, KNOWLEDGE TRANSFER AND INNOVATION: THE EFFECT OF ITALIAN UNIVERSITIES’ EFFICIENCY ON THE LOCAL ECONOMIC DEVELOPMENT 2006-2012

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JEL Classification: I21, E01

Keywords: Higher education; knowledge spillovers; local economic development; efficiency of universities
Research, knowledge transfer and innovation: the effect of Italian universities’ efficiency on the local economic development 2006-2012

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Abstract

In this paper, we test whether there is a link between the performance of universities and the local economic development of the territory where they operate. The performance of academic institutions is measured through an efficiency concept, estimated by means of an innovative Stochastic Frontier Analysis (SFA), and considering indicators of teaching, research and ‘third mission’ as outputs. A system generalized method-of-moments (Sys-GMM) dynamic panel estimator, instrumented with time lags and differences is estimated over the period from 2006 to 2012 to solve the potential endogeneity of the explanatory variables. Our findings reveal that the presence of efficient universities fosters local economic development, and that knowledge spillovers occur between areas through the geographical proximity to the efficient universities.

Keywords: 
Higher education; knowledge spillovers; local economic development; efficiency of universities

JEL Codes:  
I21 - Analysis of Education  
E01 – Measurement of Data on National Income and Product Accounts and Wealth

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1. INTRODUCTION, MOTIVATION AND RESEARCH QUESTION

The assumption that universities should contribute to the social, economic and cultural development of the territories in which they operate is widely accepted nowadays. Several theoretical paradigms have been inspired by the positive role that Higher Education Institutions (HEIs) can play in the interaction with key stakeholders, with the final aim of transferring knowledge, disseminating culture and foster economic competitiveness.

Among the first attempts of defining the “external” role of HEIs, the famous Clarke’s triangle (Clark, 1986) stands as a model for interpreting the performances of higher education systems. In the author’s view, the activities and results of universities are not only the fruit of the academic quality and willing, but are instead also influenced by the interplay with the “State” (i.e. the government that regulates the system) and the “market”, intended in its inclusion of various actors, from students/families to public and private entities of the territory. At the same time, the outcome of the various actors’ operations is not confined to the boundaries of academia, but exerts a positive/negative influence (depending on its quality) on wider society and economy. Later in the literature, a clear indication emerges: that it is possible to theoretically define a specific “external” impact of teaching and research on the community – and, such impact can actually be measured empirically. Bornmann (2013), for example, reviews two decades of studies that attempt at estimating the “societal impact” of research, defining the concept as the ability of transforming knowledge into economically relevant products, services and processes. Even more compelling becomes the notion that universities can contribute to the improvement of human capital, which in turns can stimulate and foster economic growth – see, for example, Benhabib and Spiegel (1994) and Barro (2001). The most recent development in the field is the formalization of the specific role of universities in sustaining local development into a stand-alone new “mission” that must be added to the traditional two (teaching and research). Researchers often use the terms “third mission” (Laredo, 2007) or “knowledge transfer” (Bekkers and Freitas, 2008) to identify the new set of activities which, all together, constitute the various channels through which HEIs interact with the communities where they are immersed, and contribute to their economic and social development.

Quality of operations matters, however. While early indicators of “third mission” tried to capture the amount of teaching and research conducted in a given territory, and to correlate it with indicators of economic growth, the approach is substantially different now. The availability of new reliable and more complete datasets, coupled with advancements in theoretical frames, allows the analysts to describe much more precisely the channels through which HEIs influence the territorial social and economic development. First, measures of human capital development and research can be collected at the level of single institutions, and not only at a more aggregated level as district, province, region, country. This constitutes a great opportunity for integrating microeconomic insights within the analysis of a macroeconomic topic. Second, several databases also include indicators about the kind of actions that universities conduct with respect to third mission, thus enabling the inclusion of this area of activities into the wider picture of HEIs’ performance. Third, the studies about higher education activities

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1 In the remainder of the paper, we adopt the expression of “third mission” (or TM) as the preferred one, for guaranteeing homogeneity and univocal naming in the discussion of results.
highlighted how HEIs tend to operate inefficiently in many cases, in other words using more resources than needed to obtain the observed levels of output – if the resources themselves would be used in their most productive way (a discussion is in Johnes, 2006). In this perspective, more precise information about the role of universities in developing human capital should consider not only their performance levels, but also the level of efficiency at which they operate, in other words the ratio at which they are able to convert inputs (human and financial resources) into outputs (as for instance graduation rates, publications, technology transfer initiatives). There are few examples of studies that take into consideration these potential advantages for empirical analyses. For instance, Branwell and Wolfe (2008) conduct a case study to show how a specific university acts in fostering economic growth in the Region where is located. On a related ground, Etzkowitz (2003) formulates a theory about how specifically the third mission of universities can contribute to the economic development (‘entrepreneurial university’), and many subsequent works demonstrate the empirical validity of the intuition. Barra and Zotti (2016) use the number of Italian graduates and universities’ efficiency scores as (institution-level) indicators of human capital, and demonstrate their positive effect on the areas where HEIs operate. This latter paper constitutes a natural key reference, as our study moves from it to extend and improve the preliminary analysis presented in that occasion.

In this research, we contribute to the advancement of the literature by proposing an empirical analysis about the impact of Italian universities’ performance on local gross domestic product (GDP) rise. Specifically, we address the following research question: is there a statistical link between the performance of universities and the economic development of the geographical area where they operate? We provide an answer to the research question by employing an econometric analysis, which uses a dynamic panel model for the period 2006-2012. Data refer to 53 public universities, clustered into 46 Italian Provinces. Performance of HEIs is conceptualized in efficiency terms; the efficiency of universities is estimated by means of an innovative and robust Stochastic Frontier Analysis, and takes into account indicators of all the three missions – teaching, research and third mission. Such a measurement of efficiency makes it more complete than the one proposed by Barra and Zotti (2016), in which the dimension of third mission is completely ignored.

The topic addressed in this paper is of particular, timely interest in the current situation of Italian economy. On one side, Italian governments struggled for decades in searching for policy interventions to improve the competitiveness of the country. Our findings point at the use of the educational instrument for fostering economic development, by reinforcing the nexus between human capital – favoured by universities’ performances – and economic development. On the other side, the recent public debate has been centred on raising the efficiency of public spending (Agasisti et al., 2015), and higher education sector was also included in this wider effort – indeed, public expenditure in the sector amounts almost 1% of GDP (OECD, 2016). The results of our empirical analysis demonstrates that it is not only universities’ performance that matters for

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2 Provinces are administrative geographical units, that include several municipalities and represent quite homogenous socio-economic realities, within. There are around 100 Provinces in Italy, but universities are not located in all of them, while in some of them there are more universities operating.
positively affecting the economy of territories where they are immersed, but especially their efficiency, i.e. their ability of making the most with the available resources.

The remainder of the paper is organized as follows. Next section §2 discusses the theoretical insights about the relationship between universities’ activities and economic development. The section §3 outlines the various steps of our methodological approach. Section §4 reports the main results obtained through our empirical analyses, including a battery of robustness checks. Section §5 concludes, also formulating some suggestions and deriving some implications for policy-making.

2. UNIVERSITIES’ ACTIVITIES, THEIR EFFICIENCY AND ECONOMIC DEVELOPMENT

2.1 How universities’ activities affect economic development – existing evidence

The impact of universities on regional development has been the object of intense debate in the last years in order to underline whether the economic development and prosperity of regions could be (directly or indirectly) attributable to the presence of a university. Several are the contributions that universities can make in order to increase local economic development such as the knowledge transfer through education and human resources development (i.e. human capital of students and graduates), knowledge creation and regional innovation through research (i.e. publications) and technology transfer (i.e. third mission) activities, all leading to spillover effects and regional competitiveness (Drucker and Goldstein, 2007).

A key contribution of the universities to local development is related to the teaching mission of the universities which may lead to important and strong territorial effects to the extent that higher education institutions play a role in providing knowledge spillovers through human capital embodied in graduating students as they move from universities to firms. Indeed, highly skilled and well-educated individuals are one of the main outputs of universities and are considered as an important drive of economic development (Florida et al. 2008) as well as one of the most relevant channels for propagating and commercializing knowledge from the academia environment to local high technology industry (Varga, 2000; Robert and Eesley, 2009; Stephan, 2009). 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) find that the most significant positive contribution made by the universities to innovation, and to generating and transmitting knowledge, are attributable to university graduates. Graduates 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 (Rothaermal and Ku, 2008). Full-time highly-skilled employees are key factors for increasing the number of spin-offs and innovative companies which, in turn, positively affect local development (Algieri et al. 2013). As a consequence, regions that increase the average level of education of their employees tend to introduce novelties in their existing industrial texture and become more innovative (Chi and Qian, 2010; Gumbau-Albert and Maudos, 2009). 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”, also attracting educated workforce from
other geographical areas. Importantly, such supply skilled labour benefit is, to a certain degree, localised as the mobility of graduates is limited and knowledge spillovers are shaped by geographic proximity (Boschma, 2005; Salter and Martin, 2001). Indeed, as a high proportion of graduates look for a job in the geographical region where they receive education, firms which are situated close to universities may have easy access and take advantage of the knowledge generated (Felsenstein, 1995; Glasson, 2003; Breschi and Lissoni, 2009).

Knowledge spillovers from universities to firms involve also research published in scholarly journals (i.e. codified knowledge). Although this kind of knowledge can be easily transferred at low cost (i.e. download from internet) and therefore can act orthogonally to firm location, the proximity to high output universities may important for accessing research networks (Audretsch and Lehmann, 2005). The higher is the quality of academic research, the larger is the contribution to industrial innovations (Mansfield, 1995) and to firms’ technological performance, even though considerable industry differences are measured (Leten et al. 2014). Scientific research results in knowledge that could lead to firms’ innovation activities (Bercovitz and Feldman, 2007; Autant-Bernard, 2001) or create and extend economic activities (Cohen et al. 2000). 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 confirms the importance of university research for corporate innovation performance (Mansfield, 1995, 1997; Cohen et al. 2002; Veugelers and Cassimian, 2005).

Universities, in addition to the traditional teaching and research activities, try to attain a high interaction with the society by building a link between research and business through the so-called ‘third mission’, which includes patents, business incubators, collaboration agreements and spin-offs (Shane, 2002). The contribution of universities to local development is always more frequently 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. Indeed, universities are investing specific resources to these activities in order to promote knowledge transfer and as, a consequence, the university-industry relationship has become more important due to the role played by technological progress in the development of an area (Algieri et al. 2013; Muscio, 2010; Guldbrandsen and Smeby, 2005). The establishment of new companies based on technologies derived from university research is a well-recognized driver of regional economic development (Hayter et al. 2016). 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). Incubators developed by higher education institutions are effective in supporting new entrepreneurial initiative (Auricchio et al., 2014) and innovative start-ups are also an effective way to facilitate technology transfer from the university to the
economy (Boh et al., 2015). Maietta (2015) describes the channels through which university–firm research and development (R&D) collaboration impacts upon firm product and process innovations, and Caniëls and van den Bosch (2010), illustrate the role of HEIs in building regional innovation systems.

Whatever the specific form of the collaboration between HEIs and the economy, the spatial pattern of knowledge (i.e. the importance of geographic location) plays an important role; indeed, the knowledge flows tend to be restricted to the area where the university is located, and firms’ likelihood of innovating is positively affected by their proximity to a university (Piergiorgioanni and Santarelli, 2001). This pattern is confirmed by empirical evidence that shows how firms tend to locate their production in proximity of universities as they as easier access to the knowledge generated by tertiary education. In other words, geographical proximity is a channel through which knowledge and technology could be transferred from the universities to the industry sector, representing an important contribution to regional economic development (D’ Este et al., 2012; Abramovsky and Simpson, 2011).

2.2 Why universities’ efficiency is important for local economic development: a conceptual framework

In the previous section, we discussed the existing evidence about the role that universities’ various activities (teaching, research and ‘third mission’) can have in fostering the local economic development. In this paragraph, we illustrate the set of reasons for which it would be important to consider efficiency of universities and not only their absolute level of output as a key driver for the territorial economic development. This discussion constitutes a key element of innovation because, while the literature about the nexus between HEIs’ outputs and growth is very well developed and abundant of contributions, the study of the role of HEIs’ efficiency in this area is still in its infancy.

It is important to define the concept of ‘efficiency’ in this context. Following the literature in this field (Johnes, 2006), we can define a university as efficient if it is able to produce the maximum of outputs (teaching, research and third mission) given the available inputs (such as human and financial resources) – or, conversely, which is able to minimize the inputs necessary for the production of a given amount of outputs. In the following section §3.2 we provide details about how we operationalize this measurement in an econometric perspective, but it is here worthwhile to clarify some theoretical aspects. Efficiency is a ‘relative’ concept. Whilst the measurement of output is linked to an absolute level of performance (how much of output is produced), the efficiency calculates how the production of outputs by an institution is far from its optimality, when compared with similar institutions and/or with a pre-defined optimal production function. Efficiency measurement is then theoretically very distinct from the straight measurement of performance; indeed, the former involves productivity considerations, in which the assessment is based on making the most with the available resources, and so fostering innovation and improvements in the technology of production.

The first argument for considering efficiency is that different universities, which produce the same amount of output, can have a heterogeneous impact on local development depending on the intensity of their inputs’ usage. For instance, if a university is employing less individuals for their operations, for a given level of output,
then these individuals could be employed in the same territory for more productive alternative occupations, so stimulating local economic development. In this perspective, it should be noticed that some Italian universities behaved as ‘social welfare interventions’ in the past, hiring more people than necessary (especially in the South), with the implicit aim of sustaining local economy by reducing unemployment. Such an approach, paradoxically, could have had even a contrary effect, if employing such people did reduce the opportunity of making them working more productively in local companies, and contributing to local economy through this channel.

A second aspect of the story about universities’ efficiency is reputational. If institutions are well respected by the society due to their reputation of ‘efficient organizations’, they can induce positive mechanisms of relationships with important stakeholders’ activity in the territory. This positive climate can result in the generation of new partnerships, ideas and collaborations that can then find their effect on new economic opportunities for local companies. If instead an academic institution, although able to produce teaching and research of a great quality, is deemed to be ‘inefficient’, companies and local entities would be more reluctant in exploring concrete partnerships with it.

A third relevant consideration is about the stimulus towards the efficiency of other institutions that interact with universities. If the university is productive at its maximum level (i.e. is efficient in the technical sense), it should have an approach of relationship with other institutions based on high expectations for efficiency. If the economic and social activity that is mediated by the university is relevant enough, then also its stakeholders would necessarily act in an efficient way. Following one of the points above, this can free human and financial resources (inputs) to be used in alternative productive activities with a direct and positive effect on local economy.

Finally, efficient universities can produce more output for a given amount of inputs, all else equal – for the very definition of efficiency. To the extent that the outputs of universities are positively affecting local economic development, the higher-than-proportional production from efficient universities can have a positive effect on local development, higher than that by those areas where universities operate in a less efficient way. Although part of this effect can be captured in empirical modelling by employing universities output levels in the regression for economic development, efficiency indicators provide a more valuable and direct measure of the ‘productivity mechanism’ that is behind that production.

The use of measures for the efficiency of universities in the estimation of economic development’s determinants is innovative and is inserted within a new strand opened by Barra and Zotti (2016). This methodological choice changes the traditional way of interpreting the results about the role of universities, as it moves the analyst from considering how graduates and research foster economic competitiveness, towards taking also into account the rate at which inputs are transformed to get these outputs, that is from an angle which considers universities’ productivity as a key input *per se* for local development.
3. EMPIRICAL STRATEGY

3.1 Modelling the determinants of local economic development

In order to analyse the relationship between the efficiency of universities and local economic development, we specify the following dynamic panel model (Barra and Zotti, 2016):

\[
\ln GDPC_{i,j,t} = \alpha \ln GDPC_{i,j,t-1} + \beta_1 \ln EFF_{i,j,t} + \beta_2 \ln EFF_{i,j,t} \times W + \beta_3 \ln GDPC_{i,j,t} \times W + \beta_4 \ln MK_{i,j,t} + \beta_5 LG \\
+ \mu_{i,j} + \tau_t + \epsilon_{i,j,t}
\]  

(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 workers in each area where the university is located\(^3\)) explained by \(GDPC_{t-1}\) (its lagged value), by \(EFF\) (efficiency of universities), by \(EFF \times W\) (HEIs’ efficiency estimates of universities located in neighbour geographical areas, with the aim of taking care of spillover effects due to the efficiency of universities’ operations), by \(GDPC \times W\) (spatial lagged value of the \(GDPC\)), 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 region, included for capturing the potential effects due to the presence of more concentration or competition between universities) and by \(LG\) (number of employed individual at time \(t\) minus the number of employed individual at time \(t-1\)); \(\mu\) is the unobserved area-specific effect, \(\tau\) are year dummies controlling for time-specific effect, and finally \(\epsilon\) are the disturbance errors. Subscripts \(i, j\) and \(t\) refer to the unit of analysis (universities), area where the university is located (provinces) and time periods (years), respectively. 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 to the economic development of a small geographic area. More specifically, GDPC and LG 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). Two are the main advantages of using some data at such disaggregated level. First, 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. Second, 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 LG 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 development. In this sense, our variable for geographical influence is

\(^3\) GDP per worker is constructed by updating the SLL value-added data from ISTAT through the period of 2006 to 2012 with data from the Bureau van Dijk AIDA data set (similar to Barra and Zotti, 2016) (AIDA is a database providing balance sheets and other information about Italian firms with a turnover of at least one million euro. See for further information: http://aida.bvdep.com/).
based on a socio-economic construct, which is much more precise and institutionally relevant than a purely administrative classification of the geographical space. Moreover, the idea of such disaggregated territorial level is not completely new in the literature, but is used for the first time in the context of HE. McHenry (2014), with the aim of investigating the geographic distribution of human capital in US, uses 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 considers 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. This means that, for each university in the sample, we are able to match a value of GDPC and LG corresponding to the municipality where the university is located. MK is also measured at university level, in other words is measures the “market share” of each i-th university in the j-th territory in which it operates (at any time point t).

The main threat to the correct estimation of the causal effect of HEI’s performance on the local economic development stems from the likely endogeneity of such relationship. In particular, the areas can show higher levels of economic developments (and dynamics in this variable) because of reasons others than universities’ efficiency, but somehow correlated to our measure of such performance. This eventuality is absorbed, in our specification, by the effect \( \mu_i \), and can make our estimation invalid if not taken properly into account. To eliminate \( \mu_i \), the unobserved area-specific effect, in the dynamic panel specification of the model (where the areas’ effects can change over time), we use the two-step system GMM estimator with Windmeijer (2005) corrected standard error in dynamic panel specification developed by Holtz-Eakin et al. (1990), Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). Moreover, in order to deal with suspected endogeneity problem between the efficiency of the universities and economic development (i.e. for instance changes in the economic conditions could lead to an increase in the demand or supply of graduates) we adopt an instrumental variable (IV) approach, instrumenting EFF by including lagged levels and differences until orthogonality is reached (the efficiency level of the universities is specified as endogenous variable). The use of instruments is necessary in order to deal with suspected endogeneity of the explanatory variables and with the problem that the error term is correlated with the lagged depend variable. The GMM dynamic panel estimator is specifically designed to address the econometric problems induced by unobserved effects (in our case university-specific) and joint endogeneity of the explanatory variables in lagged-dependent-variable models, such as growth regressions employed in the paper (see Levine et al., 2000, who examine whether the exogenous component of financial intermediary development influences economic growth). The GMM is based on the use of lagged observations of the explanatory variables as instruments (i.e. internal instruments). More specifically, we difference the regression equation to remove any omitted variable bias created by unobserved university-specific effects, and then instrument the right-hand-side variables using differences of the original covariates to eliminate potential parameter inconsistency arising from simultaneity bias (this is the difference dynamic-panel estimator, developed by Arellano and Bond, 1991 and Holtz-Eakin et al. 1990). As showed by Alonso-Borrego and
Arellano (1996) and Blundell and Bond (1998), when the explanatory variables are persistent over time, the lagged levels of these variables are weak instruments for the regression equation in differences; therefore, in order to reduce these potential issues when using the difference estimator, the system GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) is used, improving the quality of instruments also using the regression in levels (in addition to the regression in differences). In other words, first-differencing is used to eliminate the unobserved effect, and then differences and lags two and beyond are used as instrumental variables for the differenced lagged dependent variable (i.e. as instruments for EFF). Consistency of the GMM estimator depends on the validity of the instruments used. We check the correctness of the model through the Sargan test of over-identifying restrictions for the overall validity of the instruments; the Arellano-Bond test is, instead, used for testing the autocorrelation between the errors terms over-time (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998) – we anticipate that all these tests point at demonstrating the validity of the approach proposed here.

In order to examine whether geographical space has an impact on the relationship between the efficiency of the 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 \( j \); in other words, we take into account that the development in area \( j \) depends systematically on the human capital development in neighbouring areas \( j \in J \), where \( J \) is the set of all areas (Anselin, 1988). Is so doing, we use an inverse distance weighted matrix to weight EFF of all neighboring areas. In matrix notation, \( EFF \times W \) is the weighted average of university efficiency 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 parameters we are most interested in are two:

- \( \beta_1 \) which measures how economic development at community level is directly influenced by the efficiency of universities that operate in the territory of influence;
- \( \beta_2 \) which measures whether economic development at community level indirectly benefits (\( \beta_2 > 0 \)), suffers (\( \beta_2 < 0 \)) or is independent (\( \beta_2 = 0 \)) from the university efficiency (due to the presence of the universities with a high level of efficiency) of neighbours.

\( GDPC \times W \) is the weighted average GDPC proxies across \( J_j \) areas neighbouring area \( j \) and is included to control for spillovers due to the economic development of neighbour areas.

See Table 1 below for a description of the variables used for modelling the determinants of local economic development. In estimating the GMM model we rely on STATA 12\(^4\).

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\(^4\) 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. HCQ and GDPC, was built using the module so called "splagvar" by Jeanty (2010b).
3.2 Estimating the efficiency of universities

We calculate a university’s relative efficiency in converting inputs into a production set while maximizing outputs. As described in the previous sections, the idea is that an area in which universities comply with their functions (i.e. producing highly skilled and well-educated individuals, highly rated research and knowledge transfer) with the utilization and the combination of different resources is on average more efficient than other areas and should benefit in terms of development because they contribute more productively to increasing local human capital. In the literature, two main methods have been extensively applied for measuring efficiency: non-parametric⁵ and parametric⁶. There is no general consensus about which method is to be adopted to measure higher education institutions efficiency. 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 under-estimated 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 is not sensitive to extreme values because imposes some assumptions on the error distribution, but must deal with the necessary assumptions for decomposing the error term. In particular, SFA, proposed by Aigner et al. (1977), Meusen and Van den Broeck (1977) and Battese and Corra (1977), assumes that the error term is composed by two components with different distributions (see the discussion in Kumbhakar and Lovell, 2000). 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. In this paper, we opt 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. Apart from the strict statistical distinctions between the two types 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, 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

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⁵ 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).

⁶ 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).
the human capital development on local development. 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 SFA. Specifically, in order to calculate the university’s performances, we apply the recent and innovative model suggested by Kumbhakar et al. (2014) which splits the error term into four components: university fixed effects, time-varying inefficiency, time-invariant (so called ‘persistent’) inefficiency, and a stochastic component capturing random shocks. This model captures the fact that academic institutions may eliminate certain sources of their short-run inefficiency over time, while other sources may have a more permanent nature. The model is represented by the following set of equations:

\[ y_{it} = f_{it}(x_{it}, \beta_{it}) + \varepsilon_{it} \]  
\[ \varepsilon_{it} = \nu_{it} - u_{it} + \alpha_{i} + E(u_{it}) + \alpha_{0}^{\nu} \]  
\[ \alpha_{i} = \mu_{i} - \eta_{i} + E(\eta_{i}) \]  
\[ \alpha_{0}^{\nu} = \alpha_{0} - E(\eta_{i}) - E(u_{it}) \]  
\[ \nu_{it} \sim i.i.d. \mathcal{N}(0, \sigma_{\nu}^2) \]  
\[ u_{it} \sim i.i.d. \mathcal{N}(0, \sigma_{u}^2) \]  
\[ \mu_{i} \sim i.i.d. \mathcal{N}(0, \sigma_{\mu}^2) \]  
\[ \eta_{i} \sim i.i.d. \mathcal{N}^+(0, \sigma_{\eta}^2) \] 

where \( y \) denotes the output of the \( i \)-th university (in our case number of graduates, number of publications and spin-offs; all outputs are normalized by total number of students weighted by the quality of freshmen. See Section 3.3 for more details on how we calculate a composite index out of these three outputs), \( x_{i} \) represents 1xk vector of input (number of academic and non-academic staff normalized by total number of students weighted by the quality of freshmen), \( \beta \) is kx1 vector of unknown parameters to be estimate, \( \eta_{i} \) represents persistent inefficiency, \( u_{it} \) denotes the short-run inefficiency distributed by each unit as a half normal, \( \sigma_{u}^2 = z_{i} \delta \), where \( z \) is a (1 x m) vector of exogenous variables (for more details on these determinants of efficiency see section 3.3) associated with technical inefficiency of production of units and \( \delta \) is a (m x 1) vector of unknown coefficients, \( \mu_{i} \) captures university fixed effects and \( \nu_{it} \) is a stochastic component, where in the variance are included the same determinants as in the variance of short-run inefficiency component. This model is estimated in three steps. First, equation (2a) is estimated using standard fixed effects estimation. Second, time-varying inefficiency \( u_{it} \) is obtained. Lastly, persistent inefficiency \( \eta_{i} \) is estimated (Kumbhakar et al., 2014).

3.3 Production set, choice of variables and specification of the models

Referring to the literature on this subject, the production technology is specified, with one input: 1 – number of academic and non-academic staff divided by total number of students weighted by the quality of freshmen. More specifically, the input takes into account what we call the equivalent personnel (EQUIV_PERS), namely the
total number of academic and non-academic staff\(^7\); it is a measure of a human capital input and it aims to capture the human resources used by the universities for teaching activities\(^8\) (see Johnes, 2014; Agasisti and Dal Bianco, 2009). The total number of students measures the quantity of undergraduates in each university. Moreover, among the inputs that are commonly known to have effects on students’ performances there is the quality of the students on their arrival at university; indeed, there is strong evidence that pre-university academic achievement is an important determinant 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). To take this quality differential into account, we weight the number of students by a proxy of the knowledge and skills of students when entering tertiary education, namely the percentage of enrolments with a grade higher than 9/10 in secondary school (STU\_weigh)\(^9\). Thus, this input aims to capture both the quantity and the quality of students. There are no measures of capital inputs (such as library, computing, buildings) which might have a role in determining university outputs. This is confirmed by a recently published paper by De Witte and López-Torres (2015) in which they reviewed the literature regarding the efficiency in education. In describing the inputs in the education production function, only a very small amount of paper included those inputs in the analysis in higher education.

Three measures of outputs are included in the model reflecting the teaching, research and ‘third mission’ functions of HEIs: 1 – number of graduates; 2 – number of academic publications; 3 – spin-offs. The first output is the number of graduates weighted by their degree classification (GRAD\_MARKS), in order to capture the quantity and the quality of teaching and to treat in the same way quantity and quality in both the student input and output\(^10\) (see Kuah and Wong, 2011; Agasisti and Perez-Esparrells, 2010; Thanassoulis et al. 2011; Duh et al.

\(^{7}\) We also consider non-academic staff in order to take into account the administrative staff who support the academic staff and the students.

\(^{8}\) The academic staff has been decomposed into three categories, namely professors, associate professors and researchers. 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 (Madden et al. 1997) and assuming that a professor is expected to produce more teaching work than an associate professors and so on (Carrington et al. 2005). To the non-academic staff has been assigned the lower weight. Similarly to Halkos et al. (2012) we use the following aggregate measure of human capital input: Equivalent personnel (EQUIV\_PERS)=1*professors+0.75*associate professors+0.50*researchers +0.25* non-academic staff. The weights have been chosen so that the distance between two ranks is 1/4=0.25. A potential limitation of this choice is represented by the decision to assign different weights. Therefore, for robustness, we also further test how alternative weights given to this variable would change the results, to avoid a severe discounting of researchers and non-academic staff. In all cases results (available on request) are similar.

\(^{9}\) A similar measure is also used in Agasisti and Dal Bianco (2009). For robustness, we also weight total number of students by the percentage of enrolments from a Lyceum (i.e. non-vocational secondary school which are more academic oriented and specialized in providing students the skills needed in order to enroll in the university). Results, available on request, are similar.

\(^{10}\) 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 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 task assigned to university is to produce graduates with the utilization and the combination of different resources, and Madden et al. (1997) used the number of graduates under the hypothesis that the higher is the number of graduates, the higher is the quality of teaching. An increase in the human capital stock generate positive effects to the regional economy; indeed, highly skilled and well-educated individuals are one of the main output of universities and are considered as an important drive of economic development (Florida et al. 2008). The second output is a measure of research performances of universities (PUB). Different proxies have been used in the literature in order to measure academic performances such as the number of citations (Agasisti et al. 2012; Bonaccorsi et al. 2006), the number of publications (Wolszczak-Derlacz and Parteka, 2011; Lee, 2011; Duh et al. 2014) and grants for research (Thanassoulis et al. 2011; Johnes et al. 2008). We use the number of publications in Web of Science, which is a proxy for the overall quality of research productivity, which in turn can have an effect on the regional propensity to innovation. Finally, the third output aims to measure the third mission of the universities being the number of university spin-offs established (SPINOFFS). Indeed, spin-offs have an important role in explaining the transfer of frontier knowledge from university to the society (Laredo, 2007; Bathelt et al. 2010; Caldera and Debande, 2010; Berbegal-Mirabent et al. 2013). Spin-offs are the most complex way of commercializing academic research, compared to patents and R&D collaborations, but have the highest potential impact on local context (Iacobuzzi and Micozzi, 2015). In other words, they are one of the main way of transferring research results to the market as well as an important driving force in renewing industrial structures (Calcagnini et al. 2016). We are aware that the third mission of universities include several other activities such as various forms of knowledge transfer and public engagement, but the number of spin-offs appears a good proxy for the phenomenon under the lens of this study, namely the impact of universities in the economy of the area where the operate. All the outputs are normalized by total number of students weighted by the quality of freshmen.

To rank universities, we construct a composite index consisting of the three output variables described above. The composite indicator avoids the common subjectivity on the weight selection. We do so by proposing an endogenous weighting mechanism, which exploits the differences among universities. Variables where a university has a comparative advantage in (for instance in the production of graduates) are more heavily weighted than variables where a university has a lower comparative advantage or even a comparative disadvantage in. On those variables, a lower weight is assigned. More specifically, the applied and endogenously determined weights of the model provide useful insights in why universities rank high or low in rankings. For example, University $X$, which ranks the first place in a ranking which is based on the efficiency scores calculated using academic research as an output, might perform relatively poorly on the production of graduates, instead. Therefore, in an endogenous weighting, the output number of graduates will be assigned a lower weight in the weighting scheme. In contrast, outputs where it performs relatively well, for instance the number of publications, will obtain a higher weight. In a similar model the weights are observation specific, which contrasts previous

the results as follows. We have also used just the number of graduates without weighting by their degree classification. In all cases results (available on request) are similar.
literature and practices. The idea corresponds to the benefit of the doubt (BoD) model, a concept that was first developed by Melyn and Moesen (1991). Using BoD, each university gains its own weights that maximize (or minimize) the impact of the criteria where the university performs relative good (or poor) compared to the others (see De Witte and Rogge, 2011; and De Witte and Hudrlikova, 2013 for an application of such method in higher education.) In this paper, the BoD scores are used as composite output in measuring the efficiency of universities, while the estimation of efficiency scores is conducted completely in a parametric way (SFA).

Moreover, it seems inadequate to assume that the variability of the efficiency behavior is the same for each university. Indeed, each institution can react in very different ways to the context in which they operate, and can also interact heterogeneously with various environmental variables. Therefore, given that several exogenous variables are available, the use of a heteroscedastic stochastic frontier model is particularly suitable for our analysis, to adequately measure the effects of exogenous characteristics on university inefficiency, and take them into account for estimating efficiency scores more precisely. Therefore, the vector of exogenous variables ($z$) included to analyze correlations with the variance of inefficiency is composed by:

- **YEAR\textsubscript{FOUND}** is the year of foundation of the university as a proxy for the level of tradition of a given HEIs as, according to Wolszczak-Derlacz and Partek (2011), it is often perceived that HEIs with a longer tradition have a better reputation, but it could also be the case that younger HEIs have more flexible and modern structures, assuring a more efficient performance;

- **MED\textsubscript{SCHOOL}**, being a dummy variable equal to 1 if the university has a Medical School and 0 otherwise 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\textsuperscript{11} (Kempkes and Pohl, 2010). Also, it can happen that higher costs associated with intense laboratory activity does impact efficiency negatively;

- **TTO\textsubscript{AGE}** being the number of years since a technology transfer office opened in the university in order to control for the knowledge context in which the firms operate (in terms of research, education and technology transfer-related activities at local universities) as the universities’ technology transfer offices are used as proxies of academic policies that are oriented towards the commercial exploitation of research results (see Muscio and Nardone, 2012, and Maietta, 2015 for previous use of such variable);

- **INACT\textsubscript{STU}** is the percentage of dropouts by the end of the 1\textsuperscript{st} year in order to take into account how much students’ knowledge changed throughout their courses, and at the same time take into account the change in the profile of students along the course following Zoghbi et al. (2013);

- **FFO** is the ordinary financing fund that the central government transfer to each university (i.e. a global lump-sum fund) that can be managed by universities autonomously. This variable is included in order to take

\textsuperscript{11} 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 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.
into account the budget transferred for teaching and research activities, as its amount and criteria for allocation can have an effect for incentivising the productivity of institutions.

Finally, dummy variables associated to the dimension of the universities (DIM1, DIM2, DIM3 and DIM4) have been also added obtained by dividing the number of students in quartiles, in order to control for the size of the institutions influencing their own technology. Time dummies (T1-T7) have also been included to capture two different effects: (i) technical change over time when it is included in the production function and (ii) inefficiency change over time when it is included in the variance of inefficiency term. Table 1 above contains the descriptive statistics of the variables used in the production set while Table 2 specify the outputs, inputs and the exogenous factors combinations in the empirical models.

(Tables 2 around here)

3.4 Data sources and descriptive statistics

The dataset refers to 53 Italian public universities from years 2006 to 2012. Data were obtained not without some difficulties in the collection derived from the absence of a single database and the non-comparability of certain data. Unfortunately, a longer period of data was not available to us. A drawback is represented by the fact that the years included in the analysis are recession years, whose consequence could affect university output in terms of, for example, research grants funded by private firms in the South of Italy. We exclude all private sector universities, owing to the absence of comparable data on various dimensions; this leaves us with a sample of 53 universities, each of which yields data over the period, so we have a total of 212 observations. Our sample is very representative of the higher education system in Italy, corresponding to almost 90% of the total number of public universities in the country. Confirming the representativeness of the sample used, in the 53 universities included in the empirical analysis are enrolled 88% of the students enrolled in the entire higher public education system in Italy. The variables included in the production set of the universities, such as EQUIV_PERS, STUD_WEIGHT, GRAD_MARKS, YEAR_FUND, MED_SCHOOL, INACT_STU, and FFO have been collected from the National Committee for the Evaluation of the University System (CNVSU) website (http://www.cnvsu.it; specifically, data have been collected by the Italian Ministry of Education, Universities and Research Statistical Office). SPINOFFS as well as TTO_AGE have been obtained from NETVAL which is the Italian association for the valorization of results from public research. The number of publications (PUB) were extracted from Thomson Reuters’ ISI Web of Science database, (being a part of the ISI Web of Knowledge) which lists publications from quality journals in all scientific fields; we count all publications (scientific articles, proceedings papers, meeting abstracts, reviews, letters, notes etc.), with at least one author declaring as an affiliate institution the HEI under consideration. Finally, the environmental variables used in order to estimate the local economic impact of HEIs, such as GDPC and LG, are, instead, taken from the Italian National Institute of Statistics (ISTAT) website.
A glance to the descriptive statistics reveal some interesting features of the Italian context which are interesting to be commented. Let us consider first the variables for the estimation of economic development. GDP is much higher in the North than in the South Italy; these well-known characteristic influences various aspects of the economic and social life of the country, and in this paper is would be worthwhile to study how this affects (or is affected by) differences in universities’ efficiency across the country. The market structure of the provision of HE, as measured through MK (the market share of each university in its Region) reveals more concentration in South areas, while the universities in the North are more subject to within-region competition – this is especially true for those located in the North-West. Lastly, the dynamic of the labour market appears as substantially stable in the period under scrutiny (2006-12), with the slight increases in the Northern and Central Italy being offset by a reduction of the number of workers in the South. Turning the attention to the variables that deal with the inputs and outputs of universities, it can be noted that the average of employees in Italian universities is around 1,000, with more personnel in the universities located in Norther and Central Italy. On the contrary, universities are somehow bigger in the South, and this leaves them with worse students-teachers ratios than they counterparts in the North. On the output side, universities in the North have a quite higher number of graduates, although the substantial differences come from the number of spinoffs and academic publications, which are more than double for universities in the North than in the South. Such difference in descriptive statistics strongly suggest that some important differentials in universities’ efficiency do exist, and that it must be necessary to consider such differences when analyzing the impact of their activities to the local economic development. Lastly, also the controls inserted in the empirical analysis of universities’ efficiency show a high degree of heterogeneity across macro-regions. For example, the lump-sum funding provided by the Ministry of Education (FFO) is much higher for the universities in the North, as well as the ‘experience’ in the development of technology transfer activities – as approximated by the ‘age’ of the Technology Transfer Office (TTO). The number of inactive students, instead, is higher in the universities located in the South.

4. RESULTS

4.1 The efficiency of universities

The estimated parameters of the stochastic education frontier, employed for measuring the efficiency of universities, are presented in the Table 3. From a methodological perspective, the null hypothesis that there is no heteroscedasticity in the error term has been tested and rejected, at 1% significance level, using a Likelihood Ratio Test (LR), giving credit to the use of some exogenous variables, according to which the inefficiency term is allowed to change. In other words, the validity of heteroscedastic assumption has been confirmed, leading to the significance of the inefficiency term. The coefficients show that the input variable has a positive and statistically significant effect on the indicator for the composite output of the universities.
The patterns of efficiency scores are worth of a comment. When looking at the (average) technical efficiency scores by geographical area (see Table 1 above)\textsuperscript{12}, the estimates reveal that HE institutions in the Central-North area (North-Western, North-Eastern and Central) outperform those in the Southern area; this result is consistent with previous evidence, as for instance that reported by Agasisti and Dal Bianco (2009), Agasisti, Barra and Zotti (2016) and Barra and Zotti (2016). Overall, universities could expand their production of output of about 25% without increasing their inputs; this number is lower for those located in the North (20%) and substantially higher for those in the South (around 28%).

\textit{(Table 3 around here)}

\textbf{4.2 The (direct) effect of universities’ efficiency on local economic development}

The GMM estimates of the local economic growth model are presented in Table 4 (Mod_1 and Mod_2). We use both GDPC and EFF as time-lagged predictors in order to estimate our growth model (Mod_1). Following Barra and Zotti (2016), we also use the GDPC as the only time-lagged predictor by specifying a SYS-GMM reduced-form growth model as a dynamic panel model in order to focus on a more short term effects on the economy and on the local GDP per capita (Mod_2). The results of the Arellano-Bond test confirm the appropriateness of the 2nd-order autoregressive specification while the Hansen tests is always insignificant, corroborating 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 (EFF) has a positive and significant effect on local development. An increase by 1 percent in technical efficiency of universities increases the local development by about 0.051 percent (see Table 4, Mod_1) and by about 0.013 percent (see Table 4, Mod_2). In other words, we find evidence that the presence of more efficient universities foster local economic development, through a direct channel of influence. To take into account how the socioeconomic environment plays a role in shaping the relationship between universities’ performance and economic development, we control for a measure of the evolution of the job market (LG) and 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 that the higher is the concentration of the universities (i.e. less competition between them) the lower is the local economic development. 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 partly 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 development 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

\textsuperscript{12} 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.
of choice 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 labour according to desired knowledge and skill sets, and thus have a positive impact on economic development, when compared with situations where there are not universities located nearby or institutions which act in a monopolistic way. All these possible interpretations provide a clue towards the expansion of pro-competitive policies in the Italian higher education sector (see Barra and Zotti, 2016). Indeed, such policies can help efficiency of universities’ operations which, in turn, are positively related with the positive effects on local economy.

(4.3 Extending the analysis of the (indirect) relationship between universities’ efficiency and local development: the role of spillover effects)

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 4, Mod_3 to Mod_8). We consider two measures of spatial dependence such as Efficiency * Spatial (EFF * W), being a spatially lagged regressor which measures whether the average economic development is higher for those areas close to areas where the most efficient universities are located (see Table 4, Mod_3 and Mod_4) and economic development * Spatial (GDPC * W), being a spatially lagged dependent variable which, instead, tests the effects for an area, in term of economic development, being close to a prosperous area (see Table 4, Mod_5 and Mod_6).

First of all, when we introduce the specification of the spatially weighted covariates, the efficiency estimates do not change and remain statistically significant. Not only the introduction of the spatial effects does not alter our previous results, but we also detect a significant and statistically positive effect of the spatially weighted variables. In the Mod_3 and Mod_4, we find evidence that the average economic development is higher in areas that are supported by closeness to areas when universities well-contribute with their missions. This suggests the presence of knowledge spillovers exerted by areas in which virtuous institutions operate. Moreover, when instead the spatially weighted dependent variable has been included (Table 4, Mod_5 and Mod_6), we do not find evidence of a positive effect for an area, in terms of economic development, being closer to a prosperous area. Results provide more information when both the spatially weighted efficiency of the university and the spatially weighted dependent variable have simultaneously been included (see Table 4, Mod_7 and Mod_8). Indeed, the findings show that an area benefits, in term of economic development, from being close to a high economic developed area; additionally, and more importantly, the results show the presence of spillover effects meaning that when efficient universities operate in a certain area, also other neighbour areas indirectly benefit in term of economic development. This result is in line with the idea that knowledge flows decreases as the
geographic distance between HEI’s and regions increases (Paci and Usai, 2009) and that knowledge spillovers take place within a specific geographic range (Moreno et al. 2005).

4.4 Sensitivity tests about the robustness of empirical results

We performed a number of sensitivity tests to check the robustness of our results.

Firstly, we examine whether the results depend on the distribution of the measure of the university’s performances used in the analysis, by dividing the universities’ efficiency scores (obtained through the procedure described in Section 3.2) in quartiles (see Tables 5 and 6). The idea is to further explore whether the main results are driven by the university with the lowest or highest efficiency level, i.e. at the tails of the efficiency distribution. Specifically, we repeat the analysis first removing from the sample those universities with an efficiency score in the first quartile, that is, taking out the less efficient universities (see Table 5) and then we remove those universities with an efficiency score in the fourth quartile, that is, taking out the most efficient universities (see Table 6). Results are generally confirmed, and starting from the models when the spatial dependence is not taken into account (see Table 5, Mod_1 and Mod_2; Table 6, Mod_1 and Mod_2), we still find that efficiency of universities has a direct positive and significant effect on local economic development (still significant at 1 percent level) especially when the efficiency of the universities has been included as an additional time-lagged predictor. We then consider the case when, instead, the potential geographical spillovers have been considered. Table 5, Mod_3 to Mod_8 summarize the results when the less efficient universities are excluded from the sample; the empirical evidence shows the statistical significance of the spatially weighted efficiency of the university and the spatially weighted dependent variable are both used (Table 5, Mod_7 and Mod_8). Table 6, Mod_3 to Mod_8 summarize, instead, the results when the most efficient universities are excluded from the sample; both the measures of spatial dependence are positive and highly statistically significant in all models. In other words, there is still evidence that the existence of knowledge spillovers is particularly evident when both the upper and lower quartiles of the distribution are considered. In other words, geographical space has an impact on the relationship between the efficiency level of the universities and local economic development even when the highest and lowest HEIs’ efficiency scores are not taken into account. This additional empirical evidence supports the idea that the presence of universities in a certain area might imply a higher development of the economy also of neighbour areas independently from the distribution of the HEIs’ efficiency scores considered.

(Tables 5 and 6 around here)

Secondly, we examine whether the results depend on the distribution of the measure of the economic development used in the analysis by dividing the territory according to the gross domestic product per capita (GDPC) in quartiles (see Tables 7 and 8). The idea is to further explore whether the main results are driven by

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13 Data constraints do not allows us to perform the analysis on each quartile.
the fact that some universities are located in area characterized by a high level of economic development while other are positioned in areas with a low level of economic development. Specifically, we repeat the analysis first removing from the sample those areas with a GDP per capita in the first quartile, that is, taking out the areas with low economic development levels (see Table 7) and then we remove those with a GDP per capita in the fourth quartile, that is, taking out those areas which grow the most (see Table 8). Results still show that efficiency of universities has a direct positive and significant effect on local economic development, particularly when the efficiency of the universities has been included as an additional time-lagged predictor. Table 7, Mod_3 to Mod_8, and Table 8, Mod_3 to Mod_8, summarized the results when the spatially weighted efficiency of the university and the spatially weighted dependent variable are used, when the areas with lowest and highest level of economic development are excluded from the sample, respectively. Interestingly, geographical space has an impact on the relationship between the efficiency level of the universities and local economic development especially when the analysis has been performed when the areas with the lowest level of GDP have been excluded; this suggests that not only economic gains are larger in neighbour areas to those in which efficient universities are located, but also that this effect is higher when areas with already a good level of development is taken into account. In this vein, the findings point at illustrating the existence of virtuous circles, where economic development coupled with the efficiency of universities operating in the territory fosters subsequent economic performance.

(Tables 7 and 8 around here)

Finally, in order to examine whether a different measure of the presence of the university al local level affects the analysis, we use the same composite index consisting of the three output variables (see Section 3.3) as measure of the university performances (UNI_PERF) without calculating the ratio at which they are able to convert inputs into outputs. In other words, we do not calculate the level of efficiency at which they operate, but only the association between universities’ output level and local economic performance. The results, showed in Table 9, reveal that the measure of the performances of the universities has still a positive but not statistically significant effects on local economic development when we take the spatial dimension into account (Table 9, Mod_3 to Mod_8). The findings provide further evidence in favour of using the universities’ efficiency estimates as a measure of university’s performances, instead of only absolute indicators of output production.

(Table 9 around here)

5. CONCLUDING REMARKS AND IMPLICATIONS

This article examines the role of universities in sustaining local development, under the hypothesis that the presence of a university in a specific area might have a positive influence on its economic activities. Academic institutions contribute to economic development through the production of highly skilled graduates and consequently of a highly educated workforce; universities research productivity transforms knowledge into
economically relevant products. Moreover, transfer of knowledge, the product development and services for the industry sector must be taken into account. Although the idea that universities could contribute to the social economic and cultural development of the area in which they are located has been widely discussed in the literature, to the best of our knowledge, only a few quantitative estimates of the “external” impact of teaching, research and knowledge transfer operations on the community are present (see for instance Carre et al. 2014; Calcagnini et al. 2016). Although this paper does not fully resolve all methodological concerns, it uses data and econometric procedures that directly confront the potential biases induced by simultaneity and omitted variables, that have not been fully taken into account in previous empirical work on the specific external impact of university activities on the community economic development. In this perspective, the insights that we are proposing here can be considered as illustrative of a tentative causal effect of HEIs’ efficiency on local economic development.

To shed more light upon this relevant topic, we have focused on the Italian experience and tried to quantify the impact of universities’ performances on local economic development, using highly territorially disaggregated data. Following the approach proposed by Barra and Zotti (2016), we consider the level of efficiency at which universities operate as an indicator of quality of human capital production and of transfer of knowledge and technology. We justify our conceptual approach by considering that more productive universities can exert a positive role in the territory, in several ways: (i) by saving human and financial resources to be used for alternative economic activities, (ii) by producing more teaching and research outputs, for a given level of inputs, and (iii) by stimulating new ideas and opportunities, to be developed in the territory that can appreciate the university’s reputation as an efficient organization. Efficiency scores are estimated via an innovative Stochastic Frontier Analysis taking into account all the three university missions – such as teaching, research and knowledge transfer – and then a growth model is tested through a Sys-GMM model estimator, to evaluate the link between the performances of universities and the economic development of the geographical area where they operate. The importance of geographical spillovers has also been highlighted in order to examine whether part of the effects related to the presence of a university spill over the neighboring areas.

The results show that universities’ efficiency turns out to be a positive and statistically significant determinant of economic development, meaning that the presence of efficient universities directly fosters local GDP per capita. Also, we show the presence of spillovers meaning that the geography of production is affected; indeed, we find evidence of a positive effect for an area, in terms of economic development, being closer to a prosperous area. Moreover, spillover efficiency effects are present meaning that when efficient universities operate in a certain area, also neighbor areas are positively affected and benefit in term of economic development. Results are robust to a battery of robustness checks.

Several implications derive from our analyses.

First, confirming the findings provided by Barra and Zotti (2016), the empirical evidence validates the use of university efficiency as an instrument able to capture the impact on the community of the ability of universities of making the most with the available resources. This is a specific contribution to the literature on economic
growth, that can represent a substantial improvement in understanding the mechanisms behind the role of academic institutions.

Second, results confirm the importance of measuring the development of human capital and skills, the technology transfer activities, new product development and research activities to better understand the mechanisms behind the local economic development (in other words, to explicitly consider “third mission” activities). Such a broader concept of universities goals should then be considered when developing incentives and funding model that acknowledge and takes into account the multiple mission of universities. This in line with the idea that universities not only supply knowledge outputs such as graduates and research papers but are also involved in collaborations with private firms through licensing and spin-offs (see Carree et al. 2014; Calcagnini et al. 2016; Shubert, 2014; Thanassoulis et al. 2011 and Johnes et al. 2008).

Third, the results support the necessity to take into account the presence of spatial dependence, when explaining regional income per capita and development differences; in other words, the proximity to university leads to an expansion of the knowledge base available for firms and increases the university-industry partnership (Muscio, 2013; Carboni, 2013; Cardamone et al. 2014). The importance of spatial effects gives credit to policy interventions and investments in tertiary education, to the extent that the activities performed in such institutions foster economic competitiveness and increase the interest in measuring the contribution that universities directly have on the area where they are located and, indirectly, on neighbor areas.

Fourth, some issues arise for the specific Italian case when policy makers must decide what doing for favoring positive collaborations between academia and local institutions and industries. The findings from our analyses reveal that presence of “virtuous circles” characterized by highly efficient universities, located in the territories which grow more, which in turn stimulate to reach higher levels of operations’ efficiency. Such conditions are very unevenly distributed across Italy, and they constitute another potential explanation of the North/South gap. In this perspective, a policy devoted to improve the performance of universities in the South Italy (like ad hoc incentives, targeted funding, etc.) can be justified in the long run under the idea of building the economic capacity at local level. Nevertheless, this approach can also be risky and wasteful if local industries are not culturally ready to accept the challenge of benefiting from highly-skilled human capital and innovative research developed in neighbor academic institutions. The nature of this challenge is even reinforced by the findings about the positive (spillover) effects of the local economic development of neighbor areas. In this vein, even a positive move from a single university or local territory would be insufficient; instead, a more systemic approach based on grouping different areas in a positive effort would be more successful. If nothing is attempted in this direction, however, the geographical patterns depicted here would work towards widening the gap between geographical areas characterized by different starting points of the local economic development – as it is the Italian case with its North/South gap.

Fifth, when turning the attention to the other determinants of local economic development, another finding is worth of specific attention. The variable that captures competition between universities (MK, that can be interpreted as a local ‘market share’ of the academic institutions) is positively correlated with the territorial
economic development. In other words, economic development at local level benefits from an environment where universities compete more between them. This finding adds to existent evidence of positive effects for university performances induced by competition (see Agasisti, 2009) and future research should be devoted to disentangling how much of the benefit for economic development is channeled indirectly through higher efficiency of universities.

This research opens the way to future interesting extensions. One immediate is to test the validity of the relationship between universities’ activities and local economic development not only at national, but also at a European level. Can we assume that part of the regional differentials across Europe stem from the differences between universities’ productivity and their geographical localization? The use of disaggregated EUROSTAT data at regional level, together with recent data of single European HEIs (https://www.eter-project.com), could be eventually used for this purpose, in future research projects.
References


Lassibille, G. (2011). Student progress in higher education: what we have learned from large-scale studies.” *The Open Education Journal*, 4, 1–8.


Table 1 – Variables for estimating economic development and the production set for estimating universities’ efficiency: descriptive statistics (mean values by geographical areas)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>North-Western</th>
<th>North-Eastern</th>
<th>Central</th>
<th>Southern</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFF</td>
<td>Efficiency of universities</td>
<td>0.8142</td>
<td>0.7808</td>
<td>0.7376</td>
<td>0.7269</td>
<td>0.7576</td>
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<tr>
<td>GDP</td>
<td>Gross domestic product normalized by workers (sum of the gross values added of all units)</td>
<td>61.102</td>
<td>58.776</td>
<td>56.116</td>
<td>52.751</td>
<td>56.383</td>
</tr>
<tr>
<td>MK</td>
<td>Market share (# of enrolments university/total enrolments region)</td>
<td>0.256</td>
<td>0.387</td>
<td>0.333</td>
<td>0.400</td>
<td>0.352</td>
</tr>
<tr>
<td>LG</td>
<td>Labour growth (# of employed individuals at time t minus the # of employed individuals at time t-1)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.005</td>
<td>-0.005</td>
<td>0.0001</td>
</tr>
<tr>
<td>EQUIVPERS</td>
<td># of academic and non-academic staff</td>
<td>990.91</td>
<td>1064.43</td>
<td>1169.22</td>
<td>873.01</td>
<td>1000.66</td>
</tr>
<tr>
<td>STUWEIGH</td>
<td>Number of total students weighted by the percentage of enrolments with a score higher than 9/10</td>
<td>14036.85</td>
<td>13605.46</td>
<td>17627.07</td>
<td>15238.35</td>
<td>15221.73</td>
</tr>
<tr>
<td>GRADMARKS</td>
<td># of graduates weighted by their degree marks</td>
<td>3627.32</td>
<td>3873.38</td>
<td>4330.58</td>
<td>31230.26</td>
<td>3641.63</td>
</tr>
<tr>
<td>SPINOFFS</td>
<td># of spin-offs</td>
<td>15.935</td>
<td>17.357</td>
<td>12.976</td>
<td>8.250</td>
<td>12.633</td>
</tr>
<tr>
<td>PUB</td>
<td># of publications</td>
<td>1632.84</td>
<td>1469.07</td>
<td>1535.00</td>
<td>752.642</td>
<td>1247.63</td>
</tr>
<tr>
<td>YEARFOND</td>
<td>Years of existence of university</td>
<td>205.812</td>
<td>403.1</td>
<td>404.166</td>
<td>180.65</td>
<td>278.452</td>
</tr>
<tr>
<td>MEDSCHOOL</td>
<td>Presence of medical school</td>
<td>0.727</td>
<td>0.800</td>
<td>0.583</td>
<td>0.700</td>
<td>0.698</td>
</tr>
<tr>
<td>INACTSTU</td>
<td># of inactive students</td>
<td>5020.182</td>
<td>4961.957</td>
<td>7392.036</td>
<td>6457.55</td>
<td>6088.62</td>
</tr>
<tr>
<td>FFO</td>
<td>University Ordinary Financing Funding</td>
<td>1.33e+08</td>
<td>1.36e+08</td>
<td>1.47e+08</td>
<td>1.09e+08</td>
<td>1.28e+08</td>
</tr>
<tr>
<td>TTOAGE</td>
<td>Age of TTO’s</td>
<td>5.727</td>
<td>4.400</td>
<td>5.166</td>
<td>2.5</td>
<td>4.132</td>
</tr>
</tbody>
</table>

Note: 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 number of GDP is reported in the descriptive statistics. In the analysis it is divided by the workers in each area where the university is located.

The variables EFF, GDP, MK and LG have been included in the two-step system GMM estimator in order to analyse the relationship between the efficiency of universities and local economic development. EQUIVPERS and STUWEIGH are used as inputs, GRADMARKS, SPINOFFS and PUB as outputs in specifying the university production technology while the variables YEARFOND, MEDSCHOOL, INACTSTU, FFO and TTOAGE have been included in the variance of the inefficiency term in the Stochastic Frontier Analysis when calculating the university’s relative efficiency.

In order to get an easy and comprehensible measure, the total number of academic and non-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). Descriptive statistics are reported separately for both EQUIVPERS and for STUWEIGH while in the analysis the ratio between the two variables has been used.
Table 2 – Estimating universities’ efficiency – specification of outputs and inputs and exogenous factors

<table>
<thead>
<tr>
<th>Models</th>
<th>Input</th>
<th>Outputs</th>
<th>Explaining the inefficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model A1</td>
<td>EQUIVPERS/STUWEIGH</td>
<td>GRADMARKS; SPINOFFS; PUB</td>
<td>YEARFOUND; MEDSCHOOL; INACTSTU; FFO; TTOAGE</td>
</tr>
</tbody>
</table>

Notes (1):
- EQUIVPERS: Weighted # of academic staff and non-academic staff
- STUWEIGH: Total number of students weighted by the % of enrolments with non-vocational secondary school
- GRADMARKS: # of graduates weighted by their degree classification
- SPINOFFS: # of spin-offs
- PUB: # of publications
- YEARFOUND: Years of existence of university
- MEDSCHOOL: Presence of Medical school
- INACTSTU: # of inactive students
- FFO: University Ordinary Financing Funding
- TTOAGE: age of TTO’s
### Table 3 – Estimating the universities’ efficiency – result from Stochastic Frontier Analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQPERS/STUWEIGH</td>
<td>0.745*</td>
<td>(2.55)</td>
</tr>
<tr>
<td>T1</td>
<td>-0.144</td>
<td>(-1.62)</td>
</tr>
<tr>
<td>T2</td>
<td>-0.280***</td>
<td>(-3.33)</td>
</tr>
<tr>
<td>T3</td>
<td>-0.326***</td>
<td>(-4.29)</td>
</tr>
<tr>
<td>T4</td>
<td>-0.357***</td>
<td>(-7.31)</td>
</tr>
<tr>
<td>T5</td>
<td>-0.337***</td>
<td>(-6.61)</td>
</tr>
<tr>
<td>T6</td>
<td>-0.247***</td>
<td>(-3.54)</td>
</tr>
<tr>
<td>DIM1</td>
<td>1.466***</td>
<td>(16.49)</td>
</tr>
<tr>
<td>DIM2</td>
<td>0.435***</td>
<td>(5.47)</td>
</tr>
<tr>
<td>DIM3</td>
<td>0.114**</td>
<td>(2.66)</td>
</tr>
<tr>
<td>VAR(U)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YEARFOUND</td>
<td>0.00122**</td>
<td>(2.76)</td>
</tr>
<tr>
<td>MEDSCHOOL</td>
<td>-0.822**</td>
<td>(-2.86)</td>
</tr>
<tr>
<td>INACTSTU</td>
<td>0.000117**</td>
<td>(3.23)</td>
</tr>
<tr>
<td>FFO</td>
<td>-3.33e-09</td>
<td>(-1.55)</td>
</tr>
<tr>
<td>TTOAGE</td>
<td>-0.101*</td>
<td>(-2.28)</td>
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<tr>
<td>T1</td>
<td>-2.420***</td>
<td>(-6.84)</td>
</tr>
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<td>-2.669***</td>
<td>(-5.35)</td>
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<tr>
<td>T3</td>
<td>-2.122***</td>
<td>(-3.98)</td>
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<tr>
<td>T4</td>
<td>-1.930***</td>
<td>(-3.65)</td>
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<td>T5</td>
<td>-1.730**</td>
<td>(-2.86)</td>
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<td>T6</td>
<td>-1.097</td>
<td>(-1.64)</td>
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<td>N</td>
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</table>

Notes. t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01
<table>
<thead>
<tr>
<th></th>
<th>Mod_1</th>
<th>Mod_2</th>
<th>Mod_3</th>
<th>Mod_4</th>
<th>Mod_5</th>
<th>Mod_6</th>
<th>Mod_7</th>
<th>Mod_8</th>
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<tbody>
<tr>
<td>GDPC(t-1)</td>
<td>0.707***</td>
<td>0.718***</td>
<td>0.709***</td>
<td>0.714***</td>
<td>0.704***</td>
<td>0.716***</td>
<td>0.698***</td>
<td>0.705***</td>
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<tr>
<td></td>
<td>(0.014)</td>
<td>(0.016)</td>
<td>(0.015)</td>
<td>(0.001)</td>
<td>(0.011)</td>
<td>(0.001)</td>
<td>(0.015)</td>
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<tr>
<td>EFF (t-1)</td>
<td>0.051***</td>
<td>0.013***</td>
<td>0.047***</td>
<td>0.0555***</td>
<td>0.049***</td>
<td>0.016***</td>
<td>0.011***</td>
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<tr>
<td></td>
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<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.003)</td>
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<tr>
<td>EFF (t)</td>
<td>0.013***</td>
<td>0.010**</td>
<td>0.016**</td>
<td>0.016***</td>
<td>0.387***</td>
<td>0.011***</td>
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<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.123)</td>
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<tr>
<td>EFF*W (t-1)</td>
<td>0.258***</td>
<td>0.258***</td>
<td>0.257***</td>
<td>0.257***</td>
<td>0.379***</td>
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<tr>
<td>EFF*W (t)</td>
<td>-0.007***</td>
<td>-0.007***</td>
<td>-0.008**</td>
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<td>-0.008***</td>
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</tr>
<tr>
<td>GDPC*W (t)</td>
<td>-0.033***</td>
<td>-0.033***</td>
<td>-0.032***</td>
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<tr>
<td>MK (t)</td>
<td>-0.044**</td>
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<td>-0.050**</td>
<td>-0.050**</td>
<td>-0.051**</td>
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<td>LG (t)</td>
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<td>-0.032***</td>
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<tr>
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<tr>
<td>T6</td>
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<td>CONST</td>
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<td>0.402</td>
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<td>Hansen</td>
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</tr>
</tbody>
</table>

Notes: Standard errors in brackets; * p < 0.1, ** p < 0.05, *** p < 0.01
Table 5– The effect of universities’ efficiency on local economic development – Without and with spatial spillovers using quartile university efficiency scores – Excluding the lowest efficiency universities

<table>
<thead>
<tr>
<th></th>
<th>Mod_1</th>
<th>Mod_2</th>
<th>Mod_3</th>
<th>Mod_4</th>
<th>Mod_5</th>
<th>Mod_6</th>
<th>Mod_7</th>
<th>Mod_8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GDPC (t-1)</strong></td>
<td><strong>0.871</strong>*</td>
<td><strong>0.799</strong>*</td>
<td><strong>0.874</strong>*</td>
<td><strong>0.771</strong>*</td>
<td><strong>0.870</strong>*</td>
<td><strong>0.794</strong>*</td>
<td><strong>0.860</strong>*</td>
<td><strong>0.783</strong>*</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.026)</td>
<td>(0.020)</td>
<td>(0.025)</td>
<td>(0.022)</td>
<td>(0.026)</td>
<td>(0.023)</td>
<td>(0.034)</td>
</tr>
<tr>
<td><strong>EFF (t-1)</strong></td>
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Notes: Standard errors in brackets; * p < 0.1, ** p < 0.05, *** p < 0.01
Table 7– The effect of universities’ efficiency on local economic development – Without and with spatial spillovers using quartile of GDPC – Excluding the areas with the lowest GDPC values

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Notes: Standard errors in brackets; * p < 0.1, ** p < 0.05, *** p < 0.01
Table 8 – The effect of universities’ efficiency on local economic development – Without and with spatial spillovers using quartile of GDPC – Excluding the areas with the highest GDPC values

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<th>Mod_6</th>
<th>Mod_7</th>
<th>Mod_8</th>
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<td>GDPC (t-1)</td>
<td><strong>0.530</strong>* (0.014)</td>
<td><strong>0.518</strong>* (0.018)</td>
<td><strong>0.522</strong>* (0.019)</td>
<td><strong>0.518</strong>* (0.020)</td>
<td><strong>0.544</strong>* (0.017)</td>
<td><strong>0.547</strong>* (0.022)</td>
<td><strong>0.549</strong>* (0.024)</td>
<td><strong>0.553</strong>* (0.025)</td>
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<tr>
<td>EFF (t-1)</td>
<td><strong>0.023</strong>* (0.005)</td>
<td><strong>0.020</strong>* (0.006)</td>
<td><strong>0.024</strong>* (0.005)</td>
<td><strong>0.024</strong>* (0.006)</td>
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<tr>
<td>EFF*W (t-1)</td>
<td>0.114 (0.115)</td>
<td>0.092 (0.117)</td>
<td><strong>0.682</strong>* (0.179)</td>
<td><strong>0.736</strong>* (0.175)</td>
<td>0.397 (0.455)</td>
<td><strong>0.799</strong>* (0.239)</td>
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<tr>
<td>GDPC*W (t)</td>
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<td></td>
<td>0.092 (0.117)</td>
<td><strong>0.682</strong>* (0.179)</td>
<td><strong>0.736</strong>* (0.175)</td>
<td>0.397 (0.455)</td>
<td><strong>0.799</strong>* (0.239)</td>
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<tr>
<td>MK (t)</td>
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<td>-0.001 (0.003)</td>
<td>-0.002 (0.003)</td>
<td>-0.002 (0.002)</td>
<td>-0.003 (0.002)</td>
<td>-0.001 (0.002)</td>
<td>-0.003 (0.002)</td>
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<tr>
<td>LG (t)</td>
<td>-<strong>0.064</strong>* (0.021)</td>
<td>-<strong>0.043</strong>* (0.021)</td>
<td>-<strong>0.069</strong>* (0.022)</td>
<td>-<strong>0.052</strong>* (0.024)</td>
<td>-<strong>0.072</strong>* (0.023)</td>
<td>-<strong>0.052</strong>* (0.023)</td>
<td>-<strong>0.063</strong>* (0.023)</td>
<td>-<strong>0.046</strong>* (0.023)</td>
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<tr>
<td>T3</td>
<td>-<strong>0.031</strong>* (0.002)</td>
<td>-<strong>0.029</strong>* (0.002)</td>
<td>-<strong>0.031</strong>* (0.002)</td>
<td>-<strong>0.030</strong>* (0.002)</td>
<td>-<strong>0.033</strong>* (0.002)</td>
<td>-<strong>0.032</strong>* (0.002)</td>
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<td>-<strong>0.044</strong>* (0.001)</td>
<td>-<strong>0.045</strong>* (0.001)</td>
<td>-<strong>0.045</strong>* (0.001)</td>
<td>-<strong>0.046</strong>* (0.001)</td>
<td>-<strong>0.047</strong>* (0.001)</td>
<td>-<strong>0.046</strong>* (0.001)</td>
<td>-<strong>0.047</strong>* (0.001)</td>
</tr>
<tr>
<td>T5</td>
<td>-<strong>0.012</strong>* (0.001)</td>
<td>-<strong>0.012</strong>* (0.001)</td>
<td>-<strong>0.012</strong>* (0.001)</td>
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<td>-<strong>0.011</strong>* (0.001)</td>
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<td>-<strong>0.049</strong>* (0.002)</td>
<td>-<strong>0.049</strong>* (0.002)</td>
<td>-<strong>0.050</strong>* (0.002)</td>
<td>-<strong>0.050</strong>* (0.002)</td>
<td>-<strong>0.051</strong>* (0.002)</td>
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<td>-<strong>0.051</strong>* (0.002)</td>
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<td>T7</td>
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<td>-<strong>0.058</strong>* (0.002)</td>
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<td>-<strong>0.059</strong>* (0.002)</td>
<td>-<strong>0.054</strong>* (0.002)</td>
<td>-<strong>0.058</strong>* (0.002)</td>
<td>-<strong>0.053</strong>* (0.002)</td>
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<td>1.942*** (0.076)</td>
<td>1.974*** (0.101)</td>
<td>1.972*** (0.0986)</td>
<td>4.593*** (0.710)</td>
<td>4.792*** (0.692)</td>
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<td>5.106*** (1.016)</td>
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Notes: Standard errors in brackets; * p < 0.1, ** p < 0.05, *** p < 0.01
Table 9 – The effect of universities’ performances on local economic development – Using the composite index consisting of the teaching, research and knowledge transfer missions

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<th>Mod_6</th>
<th>Mod_7</th>
<th>Mod_8</th>
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Notes: Standard errors in brackets; * p < 0.1, ** p < 0.05, *** p < 0.01