



FULL ARTICLE

Direct and indirect effects of universities on European regional productivity

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Abstract

Universities are fundamental in driving economic performance as they generate human capital, research and knowledge diffusion. We propose a novel analysis by investigating their effects on European regions' total factor productivity (TFP) over the period 2000–2016. We distinguish between *direct* effects, due to universities societal role (“third mission”), and *indirect* ones originating from human and technological capital creation. Our contribution is threefold. First and foremost, we provide evidence that the presence of universities has a sizeable impact on regional TFP. Second, this impact spreads across regional boundaries. Third, universities effectively drive human and technological capital growth, thus indirectly fostering productivity enhancements.

KEYWORDS

human capital, regional Total factor productivity, technological capital, Universities' third mission, university

JEL CLASSIFICATION

I23, I25, J24, O31, O47

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1 | INTRODUCTION

Universities are fundamental actors in the current knowledge-based economy, not only for the generation of high-level human capital, the creation and diffusion of new knowledge and technological enhancements, but also for actively contributing to regional social and economic development. The awareness that universities play an essential role explains why higher education institutions (HEIs) worldwide have significantly increased since the first university was founded in Bologna in 1088. The World Higher Education Database in 2021 records 20,000 HEIs in 196 countries worldwide, almost 3,000 in Europe. These numbers have been growing steadily, especially in the post-Second World War period, when the total of world HEIs has quadrupled, and Europe almost tripled.

The literature has remarked that the functions carried out by universities are complex and highly differentiated as their roles have been changing over time to respond both to academic and societal needs in a multifaceted interplay with local and international stakeholders and institutions. The list of universities' functions is long, and it has been institutionalized in three missions: teaching, research and "third mission". While the first two are traditional functions, the latter has mainly developed in the last three decades, and it is still an evolving concept characterized by a high degree of heterogeneity and vagueness. The third mission includes a wide range of activities, like know-how and technological transfer, regional leadership, a hub of knowledge networks, entrepreneurship development, public engagement (Drucker & Goldstein, 2007; Goldstein et al., 1995).

As is well known, the first two functions generate an expansion of human capital and technological capital. According to several scholars (refer, among others, to Griliches, 1979; Mankiw et al., 1992; Romer, 1990b), these two intangible factors are the key drivers of economic growth, although the literature has not focused on the role played by HEIs as their main "supplier". This is especially the case in lagging regions, where R&D activities are almost entirely carried out by public universities due to the scarcity of large innovative firms. While an extensive theoretical and empirical literature has documented the effects of both human and technological capital, studies on the impacts of the third mission functions are still in their infancy because of the difficulties in providing clear definitions that allow for a rigorous empirical assessment (Brekke, 2021; Uyarra, 2010; Varga, 2009; for a recent ample review). Thus, universities accomplish a complex, diversified and growing set of societal functions combining the outcomes of their first two missions—teaching and research—with the provision of development-promoting services to the society.

Hence, the need to assess the overall comprehensive impact exerted on the local economy by universities' presence, over and above the one already accounted for by human capital and technological capital. This is the main aim of our study, which is posited at the intersection of two main streams of literature with the specific purpose of bridging them and thus providing a novel contribution that enhances the understanding of the role played by universities at the local level.

The empirical literature on the impact of HEIs has mostly developed along two main research avenues: the first focusing on the effects on GDP, and the second emphasizing the supply-side impact by using a knowledge production function (KPF). Among the former, a few articles have explicitly investigated the universities' influence on local economic performance, measured mainly by GDP and employment, with a specific attention to regions within one country. Goldstein and Drucker (2006), Lendel (2010), Hausman (2012), Drucker (2016) focus on the US counties and states; Schubert and Kroll (2016) on German NUTS 3 regions; Agasisti et al. (2019) on Italian labour market areas. To the best of our knowledge, only two empirical studies employ extensive cross-country comparisons to thoroughly investigate the contribution of HEI to regional development. The seminal contribution by Valero and Van Reenen (2019), who consider 1,500 regions globally, and Agasisti and Bertolotti (2022) on 284 regions in Europe. Both studies assess the impact of the universities' presence on regional GDP *per capita* growth.

The second stream of the literature concentrates on the universities' effects on firms' and local systems productivity growth within the KPF framework. At the beginning, the main research purpose was to explicitly identify the extent to which university R&D spills over firms within the regional system of innovation (Acs et al., 1994; Varga, 2001). More recently, Buesa et al. (2010) have generalized the analysis by considering, not only R&D, but a



broader set of indicators. Finally, Ponds et al. (2010) and Wanzenböck and Piribauer (2018) have extended the KPF model by including networks of different nature: university–industry collaborations and EU funded R&D partnerships, respectively.

So far, the two approaches on the role of HEI have mainly developed independently of each other. In this paper, we propose to bridge them by taking advantage of the merits of both and analysing how universities can act as a key driver of total factor productivity (TFP) growth at the regional level. As TFP is a comprehensive measure of economic performance that encompasses the efficiency enhancing effects of knowledge-related processes, it allows us to focus on the long-run supply-side productivity effects that universities exert on the local economy. TFP is widely recognized as the main driver of economic growth, especially in mature economies (Easterly & Levine, 2001). We follow a recent research line of research, started with Marrocu et al. (2013), which investigate TFP differentials in European regions by introducing the potential productivity-enhancing role of universities.

We contribute to the literature in several ways as depicted in the conceptual framework in Figure 1. First, for the first time we assess the role of HEIs on TFP dynamics for a very ample sample of European regions (270) at the NUTS 2 level over the period 2000–2016. This allows us to provide a thorough picture of regional productivity disparities in Europe, which, notwithstanding some convergence in the last two decades (EU Commission, 2017), are still a central issue (Iammarino et al., 2019; Rodríguez-Pose & Crescenzi, 2008). We then empirically assess the effect of HEIs on TFP dynamics, once we account for human and technological capital, as well as a wide array of local characteristics that may affect the regional performance, such as the quality of the institutions, the territorial features, and the production structure.

Second, we provide novel evidence on disentangling the three effects that universities exert on the regional system in which they are located. The first two indirect effects are related to the creation of human capital and innovations by providing higher education and basic research. It is worth highlighting that local universities, especially in advanced territories, contribute to the enhancement of human capital jointly with external HEI thanks to graduate mobility (Corcoran & Faggian, 2017) and to the development of technological capital through universities–firms’ collaborations. The third effect is entirely due to the existence of the university itself; we can deem this as a “direct” university effect, which has no substitutes and does not exist in territories with no universities. It is intrinsically related to the core institutional features of the universities. As they carry out the ever-evolving third-mission functions, universities are able to leverage multidimensional skills and capabilities, create synergies, promote value co-creation and, ultimately, act as a proper economic and cultural engine.

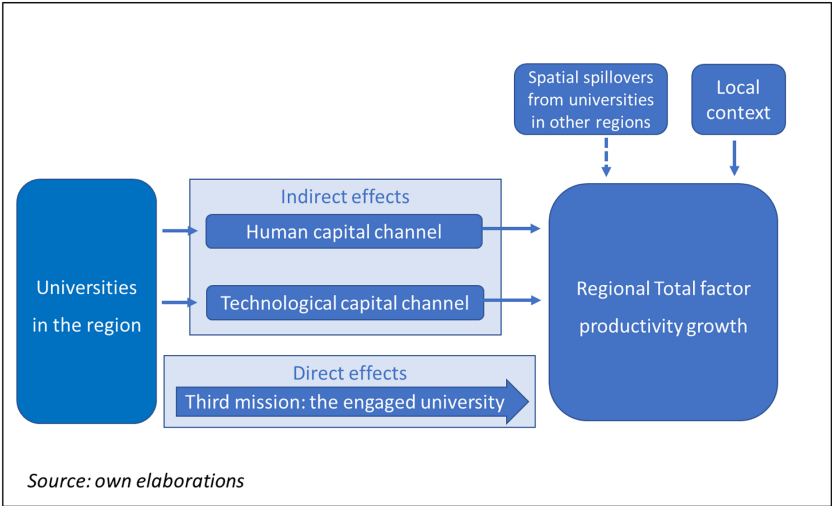


FIGURE 1 The long-run supply-side productivity-enhancing effects of universities



Third, in assessing the three possible university effects described above, we also investigate the role played by external factors that can influence regional productivity growth due to university knowledge spillovers from “proximate” regions. The existence of such externalities has relevant implications for both academic and public policies as far as university funding and the creation of new HEI are concerned.

Finally, we also contribute to the extant literature by investigating the two transmission channels through which universities contribute to human and technological capital enhancement and, consequently, to productivity growth at the regional level.

Main results indicate that the impact of universities on regional productivity growth is positive and sizeable. It proves robust to the inclusion of other factors, such as institutional capital, agglomeration forces and production structure. This direct effect goes along with the more traditional “indirect” effects exerted by human and technological capital. Moreover, we have found robust evidence that the universities positively affect the regional growth rate of human and technological capital. These intangible assets represent, in turn, the key determinants of local productivity growth. Thus, universities play an essential role in enhancing, directly and indirectly, the productivity of regions in Europe. Finally, we show that the positive impact of universities may spread across regional boundaries, and it is thus reinforced by spatial positive externalities from neighbouring territories.

The paper proceeds as follows. Section 2 outlines the literature background and offers the basic rationale of our research. Section 3 presents the dataset and the methodology for the TFP computation. Section 4 discusses the results of the baseline empirical analysis along with the robustness exercises. Section 5 examines the transmission channels through which universities influences the regional growth rates of human and technological capital. The final section summarizes the findings and discusses their broader implications.

2 | LITERATURE REVIEW AND CONCEPTUAL BACKGROUND

Since the Second World War, there has been a considerable increase in higher education demand and the number of universities and HEIs worldwide. This ever-increasing process is because universities are core agencies in contributing to economic growth and social development by forming human capital and high-quality skills, as well as prompting technological change by knowledge creation and diffusion. At the beginning of the 1900s only one in a hundred young people enrolled in universities; during the twentieth century, this proportion increased to one out of five. Over the years, the university density has also increased considerably. Nowadays, at least one university is located in almost every country globally, even though the distribution is remarkably skewed. Seven countries (United States, Brazil, Philippines, Mexico, Japan, Russia and India) are home to more than half of all existing universities.

It is widely recognized (Drucker & Goldstein, 2007; Goldstein et al., 1995) that universities play differentiated and complex functions, although all universities do not necessarily carry them out simultaneously. Over the last three decades, five different university engagements models have been identified (Uyarra, 2010), each advocating a different set of roles, various spatial aspects of interactions, as well as other mechanisms of university commitments.¹ Besides the institutional functions related to higher education and basic research, universities are involved in knowledge and technological transfer, in producing knowledge infrastructures and participating in related networks, in promoting entrepreneurship development, regional leadership, cohesion and democratic dialogue.

The literature has extensively examined the growth-enhancing effects of higher education, basic research and innovation, even though the university role as the main “supplier” of such assets is often remained behind the scenes. Several studies carefully examined the impact of human capital endowments on the economic growth processes (Benhabib & Spiegel, 1994; Gennaioli et al., 2013, 2014; Mankiw et al., 1992; Romer, 1990a). At the same time, the knowledge-capital model (Griliches, 1979) has underlined the positive impact of technological capital on

¹The five models identified by Uyarra (2010) are: knowledge factory, relational university, entrepreneurial university, systemic university, engaged university.



economic performance. As technology is, at least partly, a public good, higher investments in technological capital endowments increase local firms' productivity and, consequently, regional economic performance (Audretsch & Feldman, 2004; Fischer et al., 2009; Rodríguez-Pose & Crescenzi, 2008; Romer, 1990b).

As for the other functions, which constitute the variegated and evolving third mission of HEIs, the role played by universities in the last decades has changed considerably, and so have the expectations of policymakers and stakeholders. The rapid expansion of university education, the limited public funding, the increased competitiveness between universities, the challenges posed by the global emergences summarized in the Sustainable Development Goals and, more recently, by the COVID-19 pandemic are increasingly engaging universities for innovative modes of territorial intervention. Universities, therefore, have multiple impacts, not only on the production system but also in areas such as culture, environment, tourism, development and regeneration of local communities.² Engaged universities are complex organizations that operate as nodes within multi-level institutional networks (international, national and local). They are supposed to integrate teaching and research activities with the territory's needs in a global-regional innovation system (Arbo & Benneworth, 2007; Bathelt et al., 2004; Benneworth & Hospers, 2007). As a result, universities are significantly differentiated entities, even within the same national system, in terms of size, status, history, specialization and organization. These differences also make the ways and intensity with which universities play the role of growth-enhancer much diverse.³ The evolution and transformation of universities, the high number of models they can select, and the heterogeneous nature of the regional economic and social environments that host these institutions have recently motivated a new wave of studies (see Bonaccorsi et al., 2019 and Brekke, 2021, for recent reviews).

We identify two broad approaches within the empirical literature. The first focuses mainly on the overall impact and therefore analyses macroeconomic outcome measures, such as GDP and employment at the regional level. The second emphasizes universities' long-run supply-side impact and focuses on technological advances and knowledge creation measures, such as patents. We refer to them as the *GDP* and the *KPF* approach, respectively.

Among the first stream, Goldstein and Renault (2004) explicitly investigate universities' impact on local economic performance. They employ a quasi-experimental approach to explain differentials in average earnings changes due to universities across 312 metropolitan statistical areas (MSAs) in the USA. The same geographical setting is the focus of Goldstein and Drucker (2006), who study the influence of universities on local economic performance by explicitly differentiating their functions. They suggest that the presence of universities has the most substantial impact in small- and medium-sized regions and that such impact spills over neighbouring regions. Lendel (2010) follows this research track by introducing the business cycle dynamics into the analysis. She finds that research universities positively affect regional employment growth in the expansion period, while only top universities can still positively impact during the contraction. Moreover, results suggest a minimal necessary scale of university R&D expenditures to impact regional employment significantly. Drucker (2016) reconsider previous contributions to the USA by incorporating all degree-granting institutions and comparing multiple economic outcomes, including GDP, employment and entrepreneurship. As expected, the impact varies by outcome measures, but is substantially less relevant than in previous studies. There is evidence of spillovers across MSAs but only up to almost 100 km. Overall, by distinguishing universities' functions, the findings confirm that the traditional university missions of research and teaching are still crucial, together with general policies promoting entrepreneurship to support local economic performance.

More recently, the analysis has been extended to a few country studies in Europe. Schubert and Kroll (2016) use spatial panel-data models to investigate the impact of HEIs on GDP *per capita* and unemployment in NUTS 3 German regions. They manage to identify cross-regional long-term effects of HEIs on knowledge generation, which go

²For example, Budyldina (2018), within the Russian context, analyses 20 HEIs in the Saint Petersburg region and finds that their local impact extends far beyond tangible outputs, and include outcomes such human capital attraction and detention, formation of entrepreneurship capital and informal networks.

³Dj Berardino and Corsi (2018) study the Italian university system and observe a specific positive impact of third mission activities on the local ecosystem performance. On the contrary, Atta-Owusu et al. (2021), in the Norwegian context, show that universities that pursue success in research quality do not necessarily facilitate local growth, as the pursuit of research excellence tends to weaken their links with local and national firms.



beyond direct demand-side effects. Moreover, they find that HEIs contribute in the long run to the reduction of regional unemployment. Agasisti et al. (2019) analyse the contribution of universities to economic growth for a selection of Italian labour market areas. They find a positive association between universities' efficiency and the economic development of the local production system in which the university operates, as well as in nearby regions accruing spillovers benefits.

All these studies focus on one country with the same institutional setting and other common specific features. This focus implies that results are not necessarily applicable to different situations. In the European context, a first partial attempt to go beyond country borders is the contribution by Lilles and Roigas (2017). They investigate the relationship between HEIs (measured by students in tertiary education) and economic growth in NUTS 2 regions in Europe. Results highlight the importance of the indirect effects of human capital creation on knowledge-intensive sectors. More recently, Agasisti and Bertoletti (2022) investigated the impact of the dynamics of regional higher education systems (HESs), rather than universities, on economic growth in 284 NUTS 2 European regions from 2000 to 2017 paying specific attention to HES heterogeneity.

The seminal article by Valero and Van Reenen (2019) offers a more comprehensive assessment of universities' impact on GDP *per capita* growth differentials from 1950 to 2010 for 1,500 regions in 78 countries. They find that increases in the number of universities are associated with higher GDP *per capita* at the regional level, with positive spillover effects from universities to neighbouring regions. These positive spillovers are mediated by increasing human capital, innovation and stronger pro-democratic attitudes.

Within the second stream of literature, the KPF approach, one pioneering contribution is Acs et al. (1994). They show that university research and development positively impact local small firms' performance, especially in specific sectors. Varga (2001) documents the importance of local agglomeration economies in allowing technology-intensive firms to take advantage of university research. Varga (2009) explores the themes of the geography of economic knowledge transfers mechanisms (both at regional and interregional levels) and university-based regional development. Ponds et al. (2010) and Wanzenböck and Piribauer (2018) follow this research avenue by extending the KPF model to consider the importance of networks in channelling knowledge spillovers across regions. The former focus on university-industry collaborations, while the latter analyses the role of EU funded R&D partnerships. Finally, Buesa et al. (2010) use a comprehensive set of variables to analyse the determinants of knowledge production in European regions. They offer robust empirical evidence that regional innovation systems consist of multiple and interconnected elements among which universities are crucially important.

In this paper, we propose a novel empirical framework which integrates the merits of the two approaches described above by focusing on the TFP enhancing effects of universities. Being a more comprehensive measure, TFP is considered a superior indicator of economic performance in European regions (Cortinovis & van Oort, 2019). It encompasses all the changes resulting from creating, transmitting and absorbing knowledge, organizational and institutional changes, shifts in societal attitudes, or gains due to more efficient factor allocation (Del Gatto et al., 2011; Isaksson, 2007), which affect the long-term structure of the economy and, therefore, its ability to grow persistently.

From an empirical point of view, Rodríguez-Pose and Crescenzi (2008) and later Rodríguez-Pose and Ganau (2022), show that innovative and productivity performance in European regions result from a complex interaction between research, human capital, socio-economic conditions and institutional quality. Beugelsdijk et al. (2018), with development accounting techniques, find that the large and persistent differences in economic development across regions in the European Union can primarily derive from differences in TFP. Recently various papers have investigated these TFP differentials and their evolution in EU regions. Marrocu et al. (2013), Männasoo et al. (2018) and Siller et al. (2021) show that human capital endowment has a fundamental impact on TFP growth and that more robust TFP growth is associated with a significant productivity gap. Moreover, they all prove that spillovers are a relevant component of TFP dynamics. Cortinovis and van Oort (2019) specify that such spillovers are channelled through three proximity networks: trade, co-patenting and geography. Finally, Ouwehand et al. (2022) find that both urban size and structure can influence TFP dynamics. We move along this research avenue by focusing on the



role played by European universities in enhancing productivity, and consequently long-run growth, in a regional context.

Figure 1 attempts to provide a synthesis of the complex set of mechanisms and channels (Conway et al., 2009; Uyarra, 2010) that link universities' activities to the final economic performance. This synthesis uses the distinction introduced by Florax (1992), who discriminate short-term, expenditure-based demand-side effects from long-term, knowledge-based supply-side effects. The core of our econometric analysis assesses the impacts of universities on TFP dynamics (Johansson & Arano, 2016; Pastor et al., 2018) while accounting for local characteristics, like the quality of the institutions, the territorial features, and the production structure. Universities can affect local economic performance along three channels. The channels of human capital and new knowledge are mainly indirect or a two-step process: universities form new graduates and produce basic and applied knowledge which only in a later moment produce an impact on productivity. The channel of the third mission, on the contrary, may prove more direct because it is mainly related to knowledge transfer to the local ecosystem and may straight affect its productivity. Nevertheless, we recognize that the third mission may also produce indirect effects on productivity dynamics (i.e., industry collaboration, knowledge dissemination). Both direct and indirect mechanisms can be reinforced by external factors due to knowledge spillovers from "proximate" regions (D'Este et al., 2013; D'Este & Iammarino, 2010). Our study aims to provide a thorough analysis of the supply-side effects considering together the three channels through which universities may affect regional productivity.

3 | DATA AND METHODS

This section presents in detail the database used in our analysis. It refers to 270 NUTS 2 regions in 28 European countries and comprises data to compute regional TFP levels, universities' activities variables and economic, social and territorial characteristics of the regions. Table A1 in the Appendix provides a complete description of all the variables and data sources.

3.1 | Total factor productivity growth

The empirical evidence suggests that countries and regions, especially the most advanced ones, do not differ just in traditional factor endowments (labour and physical capital) but mainly in productivity, knowledge and technology (Isaksson, 2007). Beugelsdijk et al. (2018) found that the large and persistent divide across regions in Europe is mainly due to differences in TFP. Therefore, it is crucial to provide an adequate measure of this phenomenon, both from a static and a dynamic perspective.

TFP is a measure of economic performance that focuses on both efficiency and technology. Its use is often hindered by missing data for the computation of capital stocks at the regional level. Nonetheless, there have been some recent studies on EU regions, such as Männasoo et al. (2018) and Siller et al. (2021), who use TFP regional measures following the pioneering research by Marrocu et al. (2013). We build upon this contribution by using the JRC EU Commission's Knowledge4Policy (K4P) platform.⁴ The first step is to compute the annual stock of physical capital at time t by applying the perpetual inventory method to the flows of gross fixed capital formation in the previous year while assuming a yearly depreciation rate equal to 10%. The capital stock value for the initial year 1999 is considered equivalent to the cumulative sum of investment flows over the ten years from 1990 to 1999.

⁴This platform (<https://knowledge4policy.ec.europa.eu/>) builds upon another database created by the Cambridge Econometrics and provides a set of time series on regional value added, labour and capital formation disaggregated by sector.



TABLE 1 Total factor productivity in the EU countries

	Centre-North	South	New accession	European Union
Index TFP level, EU = 100				
2000	119	101	51	
2008	119	93	57	
2016	120	90	58	
TFP average annual growth rate				
2000–2016	0.67	–0.08	1.69	0.74
2000–2008	0.96	–0.06	2.62	1.12
2008–2016	0.36	–0.08	0.62	0.33

Notes: South: Italy, Spain, Greece, Portugal.
 New: 12 new accession countries (Malta is excluded).
 Centre-North: remaining 11 Western Central and Northern countries.

We then compute TFP levels by following a quasi-growth accounting approach. We do not impose factor endowment elasticities, but we estimate them within a traditional Cobb–Douglas production function model. This is reported in (1) in its panel log-linearized form:

$$\ln(VA_{it}) = \beta_K \ln(K_{it}) + \beta_L \ln(L_{it}) + \alpha_i + \delta_t + \varepsilon_{it}, \quad (1)$$

where $i = 1, \dots, N = 270$ regions; $t = 2000, \dots, 2016$ (17 years); VA is value-added, K is capital stock, and L are units of labour; α_i are regional fixed effects, δ_t are times dummies, and ε_{it} is the error term. To deal with the usual production function endogeneity problem, we apply the fixed effects two stage least squares (2SLS) estimation method; as instrumental variables we employ the one year lagged input factors.⁵ Estimated elasticities have the expected value based on theoretical and empirical literature: 0.34 for the capital stock and 0.60 for the labour input.

In the next step we calculate the TFP levels at the regional level for the years 2000–2016 by applying the growth accounting method using the estimated factors elasticities, assumed invariant over the period considered. Table 1 summarizes the main results for different macro-regions and sub-periods. More specifically, we split our sample into the two sub-periods, 2000–2008 and 2008–2016, to analyse the effect of the financial crisis that hit the global economy in 2008. Moreover, we partition the regions into three groups. The first group includes the 13 new accession countries, which entered the EU in 2004–2013 (11 Eastern countries plus the Mediterranean islands of Cyprus and Malta).⁶ The second group comprises the regions of the four Southern countries (Greece, Italy, Spain and Portugal), which have most severely suffered the sovereign debt crisis at the beginning of the century's second decade. The third group includes the regions of the remaining 11 countries in the West Centre and North Europe.

Some interesting results emerge. Considering the TFP index levels, with the European average equal to 100, the productivity divide still appears quite remarkable (see Figure 2). The “old” prosperous Europe (West Centre and Northern regions) shows a TFP index equal to 120 in 2016 whilst the “new” Europe is slightly below half of that value with 58. However, there is a critical divide even within the “old” Europe: Northern countries have a lead of 20% with respect to Southern countries in 2000, which widens in the following 16 years up to almost 30%.

Therefore, from a dynamic perspective, European productivity follows a triple path with diverse speed. Centre-North countries show a stable TFP index and maintain their lead with respect to the average EU region in terms of the TFP level. Eastern new accession countries move along a convergence path: their TFP average growth rate over

⁵We have also considered longer lags and the results remained broadly unchanged.

⁶Malta is excluded from the econometric analysis due to the lack of data on value added.

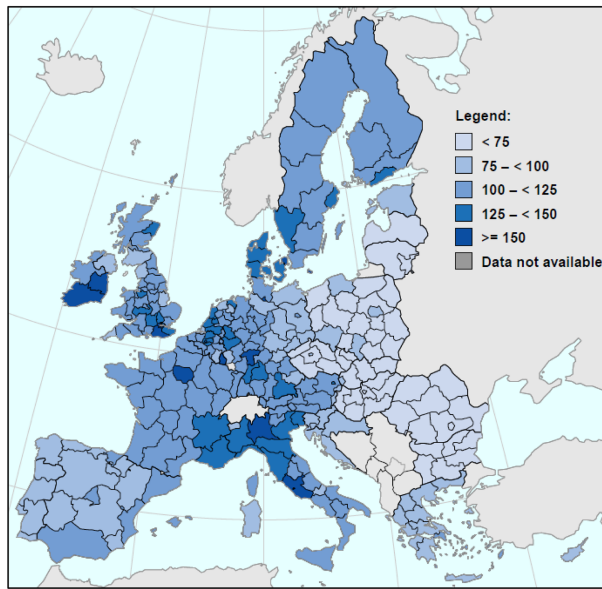


FIGURE 2 TFP levels. Index EU = 100. Year 2000

the entire period is 1.69%, more than double compared to the Centre-North countries (see Figure 3), although their TFP level is still half the Centre-North average. Especially in the pre-crisis years, the New Europe has outperformed the Old Europe by growing at an average rate of 2.62 vs 0.96. Finally, Southern countries show a negative trend in their total productivity over the entire period (−0.08%), and in the final year 2016 they end up well below the European average. Most importantly, Southern countries have fallen behind more in the first years of the new century than after the financial breakdown in 2008: a sign of a structural rather than a contingent crisis. Thus, in the econometric analysis, we take these divergent TFP growth patterns—across space and over time—into account by estimating specific regressions for macro-regions and sub-periods.

3.2 | Measures for the presence of universities

Our analysis utilizes the European Tertiary Education Register (ETER) dataset, which gives information on 2,764 HEIs in 36 countries between 2000 and 2016. Notwithstanding the Bologna process, the national university systems are very different among the European countries. Therefore, the nature and classification of the HEI vary substantially across countries. For instance, Germany established a binary HEI, comprising both universities and *Fachhochschulen* (School of applied sciences), whose primary goal is to provide high professional training. On the other hand, Italy does not include these professional schools within the HEIs (Agasisti & Gralka, 2019). Therefore, to provide comparability across countries, we restrict the analysis to the core category “universities”, thus excluding the “universities of applied sciences” listed in the ETER database.⁷

Figure 4 reports the evolution of the universities in Europe over time, indicating specifically the years where the total number of universities doubled. One hundred of them are very ancient institutions, created well before the nineteenth century starting with the first university, Alma Mater Studiorum, established in Bologna in 1088. Most of

⁷We have also excluded other typologies of HEIs in Italy (the online universities) and Poland (the Academies of National Defence Ministry, Maritime and Theological) given their specificities.

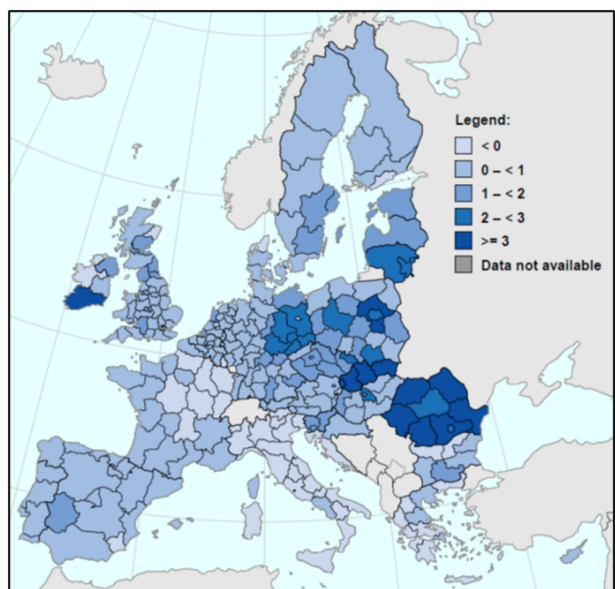


FIGURE 3 TFP annual average growth rates: 2000–2016

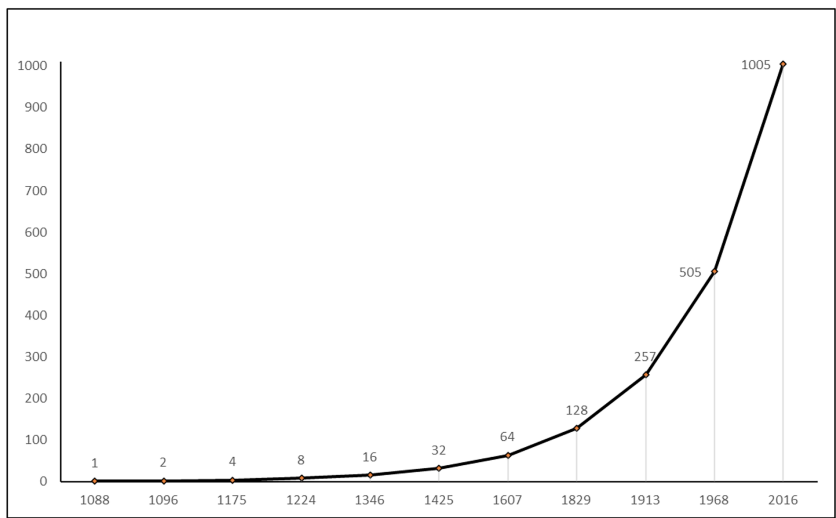


FIGURE 4 Number of Universities in Europe: 1088–2016

these early institutions are located in Italy, Germany, Spain and the United Kingdom. From 1800 to 1944, 250 new universities were founded, spreading in most European countries. The reinforcement process of HEI has rapidly increased at the end of the Second World War. Universities show an outstanding growth over the last 45 years, when have been established half of the 1,005 institutions active in 2016 in the 28 EU countries.

From the ETER dataset, we use the foundation year of each university to select the number of active institutions in year 2000, the initial time of our analysis, and in the following years until 2016. In the year 2000, the number of active universities in the 28 EU countries was 881. Most of them (72%) are public, while 16% are formally private but still dependent on government financing, while the remaining 12% are entirely private. In 2016 the number of



universities increased by 12%, reaching the total number of 1,005. It is worth remarking that new universities arise nowadays in all European countries, signalling the vitality and the central role of this longstanding institution. To perform our econometric analysis, we have aggregated the universities individual data at the regional level. In 2000, among the 270 territorial units considered, only 23 regions lacked universities. Interestingly, the largest number of HEIs is in Yugozapaden, the region of Bulgaria's capital city Sofia (20), followed by Inner London West (18) and Lisboa Metropolitan area (18). In 2016, at the end of the period considered, seven more regions had established a new university and therefore only 16 territorial units have remained without a higher education institute. These regions are, in general, small areas (1.9% of total EU population) contiguous to regions with well-established universities.

There are noticeable differences among the universities in terms of size, nature and quality, and the “university presence” variable described above is not able to account for these features. Therefore, in the econometric analysis, we try to control these differences by using additional information from the ETER database, which also contains data on staff, finances, educational offer, research, students, Erasmus mobility. Unfortunately, these variables present several missing data, and thus, we can use only a small set of additional indicators. We consider the research universities, the number of staff (both academic and administrative), the number of students and graduates (5–7 ISCED), PhD graduates (8 ISCED) and the incoming Erasmus students.

3.3 | Transmission channels

As discussed in the previous sessions, universities indirectly influence regional economic performance through two channels. As for the first one, universities contribute to the formation of human capital by providing graduates and postgraduates individuals. Thus, we measure human capital by the share of the population, aged 25–64 years, with tertiary education (ISCED 5–8) over the total population. In the second transmission channel, universities are the leading producer of basic research and innovation, which contribute to increase the endowment of technological capital in the economy and, consequently, its productivity. The technological capital of each region is measured in terms of R&D expenditure over GDP. Although we also considered the stock of patents, we prefer to account for technological capital by means of R&D, an innovation input rather than an output one, because it is a more comprehensive measure of firms' innovative efforts, tacit knowledge exchange and collaborative interactions between firms and universities (Uyarra, 2010). Moreover, patenting activity is rare in regions with economic structures characterized by small businesses (Santarelli & Sterlacchini, 1990) or specialized in traditional low-tech productions.

3.4 | Regional contextual variables

The extent to which universities' activities affect regional economic performance depends on several other local system characteristics. To control for these factors, we include three sets of contextual variables: the intangible assets, the production structure, and the geographical features.

Among the intangible assets, given that human capital and technological capital are already included to account for the indirect universities' effects, we consider the regional institutional capital. More precisely, we include the quality of the local institutions using the European Quality of Government Index, computed by Gothenburg University (Charron et al., 2015). This measure is a composite index based on three main dimensions: high impartiality, public service delivery quality and low corruption.

The literature has also emphasized how differences in the production structure impact regional performance (Marrocu et al., 2013). Therefore, we include an indicator that measures the relative importance of traditional sectors, and it is based on the Revealed Comparative Advantage (RCA) index in low-technology manufacturing (LTM). We expect that regions specialized in LTM show a relatively lower productivity growth. In the econometric analyses



we also consider other indexes based on the relative specialization in high- and medium high-technology manufacturing and knowledge-intensive services.

The last set of controls are related to the geographical characteristics of the regions. We consider the Settlement Structure Typology (SST) index, which distinguishes six categories of regions according to two dimensions, density and city size. The less densely populated areas without centres take value one, while the densely populated regions with large centres take a maximum value of six. In the preliminary analysis, we have also considered other territorial controls, like an accessibility measure, the population density, and the country's capital. However, they were consistently outperformed by the SST index, which represents a more comprehensive measure.

3.5 | Spatial spillovers

The literature has highlighted the importance of spatial spillovers,⁸ which make the growth process in one region dependent on the performance of the other proximate regional systems. Therefore, the productivity growth rate of a specific region may be affected by the presence of other universities in nearby areas, which may favour human capital mobility and the transmission of knowledge externalities (D'Este et al., 2013; Drucker & Goldstein, 2007; Valero & Van Reenen, 2019).

We account for university spatial spillovers by considering as additional regressors the spatial lag of the corresponding explanatory variables. Spatial lags are computed by means of a weight matrix whose elements are given by the inverse of the Euclidean geographical distance for any pair of regions in our sample. For robustness we also consider a first-order contiguity matrix. Following Kelejian and Prucha (2010), all matrices are max-eigenvalue normalized; such normalization avoid the imposition of strong undue restrictions, preserves symmetry and the absolute, rather than relative, notion of distance.

4 | EXPLAINING THE REGIONAL PRODUCTIVITY GROWTH PROCESS

This section discusses the main results of the econometric analysis. In subsection 4.1 we focus on the long-term supply-side model of TFP growth, which allows us to provide novel evidence on the role of universities as key drivers of regional productivity. In subsection 4.2 we extend the analysis to account for university heterogeneity in terms of size and quality, whereas in subsection 4.3 we perform a sub-sample analysis to assess the robustness of our main results with respect to the different TFP patterns documented in section 3.

4.1 | The baseline spatial model of productivity growth

The most general specification of our productivity growth model is formulated as:

$$\Delta TFP_i = \beta_0 + \beta_1 university_i + \beta_2 hk_i + \beta_3 tk_i + \beta_4 ik_i + \beta_5 TFP_i + \beta_6 W_univ_i + controls_i + v_i, \quad (2)$$

where the dependent variable (ΔTFP_i) is the annual average growth rate of regional TFP computed over the period 2000–2016 for 270 territorial units. The initial level of TFP and all the explanatory variables – number of universities in the region (*university*), human capital (*hk*), technological capital (*tk*) and institutional capital (*ik*) refer to the year

⁸We are aware that in spatial econometrics it is customary to refer to spatial spillovers effects as “indirect” effects, as opposed to the “direct” ones which are due to changes in one's territorial unit own variables. In this paper to avoid confusion with the university direct/indirect effects we will refrain from using them when referring to spatial spillovers.



TABLE 2 Universities and regional efficiency growth. Baseline results

Dependent variable: growth rate of TFP, annual average 2000–2016					
Model	(1)	(2)	(3)	(4)	(5)
Spatial matrix	NO	NO	distance	distance	contiguity
Number of universities	0.302 *** (0.072)	0.309 *** (0.079)	0.403 *** (0.076)	0.411 *** (0.085)	0.296 *** (0.080)
Human capital	0.573 *** (0.128)	0.335 ** (0.137)	0.303 ** (0.126)	0.294 ** (0.137)	0.398 *** (0.137)
Technological capital	0.234 *** (0.066)	0.151 ** (0.060)	0.137 *** (0.051)	0.132 ** (0.063)	0.148 ** (0.058)
Institutional capital		0.603 *** (0.220)	0.512 ** (0.209)	0.493 ** (0.211)	0.561 ** (0.231)
TFP initial level	−1.795 *** (0.208)	−2.294 *** (0.207)	−2.184 *** (0.198)	−2.143 *** (0.210)	−2.237 *** (0.199)
Spatial lag of universities			0.727 *** (0.156)		0.250 *** (0.089)
Spatial lag 0–300 km of universities				0.540 *** (0.158)	
Spatial lag 300–600 km of universities				0.264 * (0.137)	
Actual-fitted values square correlation	0.418	0.418	0.548	0.548	0.523
(a) Controls for production structure	NO	YES	YES	YES	YES
(b) Controls for geographical features	NO	YES	YES	YES	YES

Notes:
Number of regions 270.
Estimation method: Least squares.
Robust standard errors in parentheses; *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Exogenous variables are defined for year 2000 and are in natural logs.
(a) RCA for Low technology manufacturing.
(b) Settlement structure typology.
See Table A1 for variables' definition.



2000 and are log-transformed.⁹ Following Elhorst (2014), we account for university spillovers, by including the variable W_Univ_i , which is the spatial lag of the number of universities, computed as explained in subsection 3.2.¹⁰

The TFP growth model is a difference equation, where the coefficient (β_5) of the initial level of TFP is expected to be negative in order to rule out divergent dynamics. An extensive empirical literature has estimated models such as (2) for the growth of GDP *per capita* starting from seminal contributions as the one by Mankiw et al. (1992), who operationalized the output-per worker growth models by assuming that aggregate output is determined by Cobb–Douglas production function. In this study, we focus on TFP growth because, differently from labour productivity growth, being a more comprehensive measure of economic performance is robust to the production restructuring processes that have been going on in Europe in the last decades and that have entailed a reduction in the labour input in order to gain in terms of efficiency. Model (2) can be considered a long-run relationship and the estimated elasticity can be cautiously interpreted as causal effects, as long as the model is adequately specified.

The major issue with growth regression is possible endogeneity arising from reverse causality or region-specific heterogeneity. As all the explanatory variables in (2) are considered at their initial period value (2000), this is expected to rule out reverse causality. Regional heterogeneity is dealt with by including a wide array of controls that, as discussed above, account for territorial differences in terms of geography, production structure, demography and institutional features. As it is often the case with empirical models, there could be remaining heterogeneity, which we cannot account for due to data limitations. For this reason, the results have to be interpreted with caution.

Table 2 reports our baseline results. In column (1), we propose the simplest model that includes the three productivity-enhancing channels previously discussed: the university, human capital and technological capital. As expected, the university variable shows a positive and significant effect on regional efficiency growth with an estimated coefficient equal to 0.30. This is a remarkable result because, also in the case of productivity, we find evidence of a direct effect of universities, which is additional with respect to the well-documented effects due to the two indirect channels—human and technological capital. All three growth-enhancing channels are effective in driving regional economic productivity. The initial level of the dependent variable is negative, signalling a convergence process among the European regions: regions, which are initially less efficient, show a higher growth rate.

Column (2) includes the institutional quality variable and two controls for the production structure and the region's geographical features. The institutional capital shows the expected positive impact on regional productivity growth, while other results are maintained. The third model of Table 2 accounts for the possibility of regional cross border effects by including the spatial lag of universities. Results show that this variable exhibits a positive and significant coefficient (0.727), much larger than the own region's one (0.403).

It is important to remark that our variable of interest, the number of universities in the region, maintains a positive and significant effect in all the specifications. Considering our most general model of column (3), this implies that, on average, a 10% increase in the number of universities in a region produces a long-run impact on TFP levels equal to 1.8%. Moreover, when one considers the combination of the home region effect along with the one due to spatial externalities, an increase of 10% in the number of universities would produce a rise of around 5.2% in the TFP level. It is worth noting that such an effect would result if the 10% in the number of universities occurred in each region and a comparable increase has been recorded in Europe over the period 2000–2008.

Moreover, the other two indirect channels, related to the productivity-enhancing impact of the universities, are also positive and significant. All the three channels are therefore effective: in addition to the indirect effects through education and the scientific research activity, the presence of universities in a region favours its economic growth, supporting the diffusion of the innovations, entrepreneurship promotion, leadership formation and the cultural enhancement.

⁹The number of universities is augmented by 1 to also keep the regions with zero universities when taking logs.

¹⁰Model 2 is a parsimonious SLX (spatial lag of X) specification, which allows for a straightforward estimation and identification of the spatial spillovers, as these correspond to the estimated coefficient of the spatially lagged explanatory variables (Elhorst, 2014). This is remarkable advantage with respect to spatial autoregressive counterparts which entail more stringent requirements on the weight matrix to achieve spillovers identification.



Estimation results for the other explanatory variables are unchanged. More precisely, high institutional quality enhances local economic performance. Moreover, the territorial control variable SST is positive and significant, implying that a very densely populated area with large urban poles fosters regional productivity growth. When we look at the production structure, the estimation results indicate that specialization in low tech manufacturing is detrimental to productivity dynamics.

To examine in more detail the effect of spatial spillovers, we construct two spatial lags for the university variable. In the first case the inverse distance matrix exhibits a cut-off at 300 km, while in the second one the distances considered are in the range 300–600 km, in this way we account for universities located in long-distance regions without considering the too remote ones.¹¹ Results reported in column (4) allow us to assess how the impact of universities changes as the distance increases. Interestingly, the magnitude of universities spatially lagged coefficient is equal to 0.54 for a distance up to 300 km, while it decreases to 0.26 for those in the range 300–600. Moreover, as expected, the significance levels decline from 1% to 10% for the regions distant up to 600 km. After this threshold distance, the lagged value of the universities is no longer significant. This result confirms that spillovers are bounded in space, and their effect decay with distance. For robustness, in column (5) we report results for the model which includes the university spatial lag based on the first order contiguity matrix. The main results are qualitatively unchanged, thus confirming the spatially bounded nature of spillovers.

The spatial analysis indicates that the universities have an influence not only in the region where they are located, but also in nearby territories. This finding points out that not only there is no evidence of competitive processes among regional university systems but that beneficial externalities are reinforcing each region's own efforts. This spillover effect may be directly due to the university *per se* or it might also work through the channels of human capital and technological capital spatial interactions. We also estimated models including, alternatively, the spatial lag of these two intangible assets and they turn out to produce positive and significant externalities. Due to multicollinearity issues, arising because of the high correlation of spatially lagged variables (correlation coefficients above 0.92), we cannot include them in the same model.¹²

Finally, for comparison with previous literature, we have estimated Equation 2 replacing TFP with *per capita* GDP. The results, reported in Table A2 in the Appendix, show that the universities' variable has a positive and highly significant coefficient, signaling an impact on the overall local economic performance. All results are robust to the inclusion of production structure, territorial characteristics and spatial effects. Our results can be directly compared with those reported by Valero and Van Reenen (2019) in their estimation of a Barro long-run relationship. They state that a 10% increase in the number of universities generates a 1.6% increase in long-run GDP *per capita* at the world level. In our estimates for the European regions, the long-run impact (1.9%) is slightly lower. Moreover, when we consider the total effect, which also includes the spatial spillovers, the overall impact goes up to a remarkable 6.8% higher GDP *per capita* in the long run.

4.2 | Size and quality of universities

As we have previously discussed, the number of universities in a specific region is a simple proxy for the complex role of universities. However, this measure is the only one that is consistently available for the largest possible number of EU regions. If the analysis is focused on reduced samples of regions, we are able to account also for some specific university features by considering additional indicators. Namely, the number of universities' graduates, enrolled students, academic and administrative staff, the attractiveness for the Erasmus programme students, and the

¹¹To choose the spatial ranges length, we have considered that our benchmarks of 300 and 600 km represent approximately the first quartile and the median of the distance distribution across the EU regions.

¹²Estimations are available from authors.



TABLE 3 The role of universities' quality and size

Dependent variable: growth rate of TFP, annual average 2000–2016					
Model	(1)	(2)	(3)	(4)	(5)
Number of regions	261	259	258	258	261
Number of universities					0.359 *** (0.076)
Number of students	0.038 *** (0.010)				
Number of research universities		0.379 *** (0.070)			
Number of students in research universities			0.035 *** (0.010)		
Number of PhD graduates in research universities				0.083 *** (0.021)	
University attractiveness - Erasmus students					−0.005 (0.047)
Spatial lag (c)	0.063 *** (0.020)	0.693 *** (0.151)	0.065 *** (0.021)	0.117 *** (0.036)	0.653 *** (0.145)
Actual-fitted values square correlation	0.515	0.560	0.511	0.520	0.556
(a) Controls for production structure	YES	YES	YES	YES	YES
(b) Controls for geographical features	YES	YES	YES	YES	YES

Notes:

Estimation method: Least squares.

Robust standard errors in parentheses;

*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.

Exogenous variables are defined for year 2000 and are in natural logs.

(a) RCA for Low technology manufacturing.

(b) Settlement structure typology.

(c) The spatial lag is computed with respect to the specific university variable included in each model; it is not included for the Erasmus student variable.

See Table A1 for variables' definition.



prevailing specialization in research activities.¹³ Table 3 reports the results for models including these additional indicators of universities' activities.

We start the analysis by replacing the number of universities in the region with their overall size. This can be measured, alternatively, in terms of the number of enrolled students, graduates or university staff. Since the three variables are highly correlated (correlation coefficient in the range 0.82–0.90), in order to avoid multicollinearity, they are considered one at a time along with the other explanatory variables and controls (the same as for model 3 in Table 2) and their spatial lag.

In column (1) of Table 3 we report the results obtained when we include the overall number of students. The coefficients of both the new variable (0.038) and of its spatial lag (0.063) exhibit the expected positive sign and are highly significant. Although the sample reduces to 261 observations, the results corroborate the evidence on the role of universities as effective drivers of TFP dynamics. Similar results are obtained when the size is accounted for by including the number of graduates or the number of university staff.¹⁴ As for the magnitude of the estimated coefficients, it is worth highlighting that, when compared to the ones reported in Table 2, they are smaller and imply that a 10% increase in the number of students in the focal region would result in a long-run increase in the TFP level of 0.18%; this could reach 0.49% when accounting also for university spillovers. Since the regional average of students is around 47,000, a 10% increase amounts to nearly 5,000 additional students: a change in the number of students that is much smaller than the one implied by the establishment of a new university. At the same time, an increase of 10% in the number of students, although sizeable, could be obtained at a regional level in a relatively short period of time if effective academic and higher education policies are in place, whereas an increase in the number of universities is more complex and requires a longer period of time.

It is important to highlight that the creation of a new university implies a long run effect on the level of the regional TFP that is higher than the one associated with the implied increase in the number of regional university students (or graduates, or staff). To clarify this point, it is useful to consider a numerical example: suppose a new university, with a number of students equal to the average size of the university included in our sample, around 15,000, is created in a region that already hosts three universities (the sample average is 3.26), all having a size in terms of students equal to the average one. In this specific case, the percentage increase in the number of universities and in the number of regional students is 33.3%. These changes, on the basis of the results reported in Tables 2 and 3, entail a much higher effect due to the increase in the number of universities when compared to the increase in the number of students. The effects due to a size increase would be higher only if a region has a very large number of small universities and the new university starts its activity with a very large number of students.

Although the number of universities is a rough measure, based on our results, we can cautiously state that the existence *per se* of a university entails a multifaceted, comprehensive effect on the local economy which is not entirely accounted for by its size.¹⁵ As already noted above, the birth of a new university is a rare event at short and medium time horizons, so that gains in TFP—although smaller—can be much more easily accrued by increasing the size of the existing universities.¹⁶ This is why in the following sections we prefer to keep model (3) of Table 2 as our baseline model, thus using the universities' count as explanatory variable.¹⁷

In the subsequent columns of Table 3, we report the results of the models that attempt to account for university quality. In columns (2) and (3) quality is proxied by the number of research universities and by the number of students in research universities, respectively. As the number of observations is reduced, the estimated coefficients (0.379 and 0.035)—both positive and highly significant—cannot directly be compared with their counterparts reported in model

¹³According to ETER database, research universities are defined as those universities with a Ph.D. program.

¹⁴In the latter case the sample reduces further to 235 observations. Results are not reported to save space but are available from the authors.

¹⁵We have also estimated a model, which includes both the number of universities and the number of students, however, due to multicollinearity issues, the latter variables had a not significant coefficient. Higher quality data at the regional level are needed to enhance the analysis.

¹⁶It is worth noting that our results are obtained from log–log specifications, as the coefficient for university size is in the range (0,1), as the size variable increases the absolute change in TFP decreases. The same applies when we consider the number of universities as the main explanatory variable.

¹⁷It is worth remarking that the other two studies with a cross-national setting (Agasisti and Bertolotti, 2022 and Valero & Van Reenen, 2019) both use universities' count in their models.



TABLE 4 Robustness for time periods and territorial samples

Dependent variable: growth rate of TFP, annual average					
Model	(1)	(2)	(3)	(4)	(5)
Growth rate years	2000–2008	2008–2016	2000–2016	2000–2016	2000–16
Territorial sample	All	All	Centre-North	South	New
Number of regions	270	270	155	55	60
Number of universities	0.428 *** (0.138)	0.339 *** (0.079)	0.333 *** (0.071)	0.243 ** (0.113)	0.628 ** (0.279)
Human capital	0.484 ** (0.244)	0.433 ** (0.175)	0.541 *** (0.151)	0.319 * (0.164)	−1.101 ** (0.456)
Technological capital	0.220 ** (0.092)	0.083 (0.071)	−0.003 (0.050)	0.075 (0.107)	0.574 *** (0.207)
Institutional capital	0.368 (0.409)	0.679 *** (0.123)	0.452 (0.291)	0.630 *** (0.224)	0.227 (0.217)
Initial level of TFP	−3.172 *** (0.310)	−1.467 *** (0.304)	−1.875 *** (0.394)	−1.375 *** (0.407)	−2.045 *** (0.681)
Actual-fitted values square correlation	0.491	0.194	0.398	0.512	0.467
(a) Controls for production structure	YES	YES	YES	YES	YES
(b) Controls for geographical features	YES	YES	YES	YES	YES
(c) Controls for spatial dependence	YES	YES	YES	YES	YES

Notes:
Number of regions 270.
Estimation method: Least squares.
Robust standard errors in parentheses; *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Exogenous variables are defined for year 2000 and are in natural logs.
(a) RCA for Low technology manufacturing.
(b) Settlement structure typology.
(c) Spatial lag of universities, distance matrix.
South: Italy, Spain, Greece, Portugal.
New: 12 new accession countries (Malta is excluded).
Centre-North: remaining 11 western central and northern countries.
See Table A1 for variables' definition.



(3) of Table 2 and the model (1) of Table 3. Therefore, we have re-estimated the latter models on the sample of observations available for research universities. In the first case the coefficient for the number of universities is 0.357, which turns out to be slightly lower with respect to the one reported in column (2), equal to 0.379 suggesting that research universities are also effective drivers of TFP. However, the coefficient for the number of students remains 0.038 even when the model is estimated using the same sample as for the number of students in research universities. As in this comparison, research university seem unexpectedly less effective, we have investigated further the issue by including the number of Ph.D. graduates (column (4)), which are supposed to be one of the valuable outcomes of research universities. The results indicate that the Ph.D. graduates have more than twice the effect (0.083) of the number of students. Thus, confirming research universities as more powerful agencies in driving TFP dynamics.

Finally, we have also considered another dimension of university quality, the ability to attract foreign students through the Erasmus programme. However, as evident from the results in column (5), the variable turned out to be not relevant when included in the model featuring the number of universities; we found consistently the same result even when the attractiveness variable was included in the other specifications reported in Table 3.

It worth noting that all the other explanatory variables and controls turned out to be fairly robust for all the models of Table 3. The same was the case for regional spillovers, whose coefficient, highly significant throughout the different specifications, changed in magnitude depending on the university variable included in the model. This provides robust evidence on the positive role of university externalities and, possibly, also on the integration of the European higher education system. Although national systems are still very differentiated, universities are capable of exerting their effect beyond the boundaries of their own region through international networks of collaboration.

4.3 | Sub-sample analysis by time and geography

As highlighted in Section 3, TFP growth patterns are differentiated in Europe over time and across macro-areas. In this section we present the robustness analysis carried out to check the stability of the baseline results on the universities' impact on regional productivity. The robustness analysis is thus performed for model (3) of Table 2. We consider two periods sub-samples by splitting the observations to account for the structural break of the global financial crisis in 2008. The first two columns of Table 4 report the results for the 2000–2008 and 2008–2016 sub-periods, while the last three columns refer to the macro-regions, namely Centre-North, South and New.¹⁸

The most important result is that our variable of interest, the number of universities, exhibits a positive and significant coefficient across all periods and macro-regions. However, relevant differences in the magnitude of its impact among countries emerge. More specifically, the enhancing growth effect of the universities is more substantial for the new accession countries where the coefficient reaches the value of 0.63. In this model, the human capital coefficient is significant with a negative sign. This result, although might be due to the reduced sample size, could also suggest that the universities direct effect on the productivity growth of their own area is more effective than the indirect effect via the endowments of a highly educated population. Apart from the new accession countries, the human capital variable confirms its positive and significant role in all other specifications. The technological capital appears to positively affect the regional efficiency growth in the first period, before the financial crises. Moreover, looking at the geographical breakdown, it shows a positive impact for the new accession countries.

The local institutions' quality coefficient, which was positive and significant in the preferred model for the whole period (model (3) of Table 2), now appears not significant in the pre-crisis years, when the market forces worked more effectively. Nonetheless, it turns out to be highly significant in the post-crisis period when the need for a public intervention in the economy to assure the recovery phase was essential. Among the other determinants, it is worth remarking that we corroborate a convergence process of the TFP levels in all models, even though with some notable differences. More specifically, the convergence process is almost halved in the post-crisis period.

¹⁸Due to the low number of observations for the South (55) and New (60) countries the estimation results have to be interpreted with caution.



5 | UNIVERSITIES AND THE TRANSMISSION CHANNELS

As discussed in the previous sections, HEIs in a specific region directly foster productivity growth, and we have provided novel and robust evidence on such an impact. At the same time, universities contribute to generate highly skilled graduates and scientific research, consequently increasing the region's human and technological capital endowments. These two intangible factors, in turn, enhance regional efficiency growth, as we have shown in the previous sections. Therefore, in the following two sections, we further investigate the mechanisms that connect universities' presence with the human and technological capital dynamics at the regional level.

5.1 | The human capital channel

Table 5 presents a model where the dependent variable is the regional growth rate of human capital over 2000–2016. Our variable of interest is, as before, the number of universities because we aim at testing the functioning of this transmission channel. As usual, we also include the initial level of human capital to control for convergence dynamics.

Column (1) reports the estimation results of a simple specification for the entire sample of the 270 EU regions. As expected, the number of universities exerts a positive and significant impact on the subsequent growth of the graduates share with a relatively high coefficient at 0.52. Moreover, the initial level of human capital shows a negative coefficient, implying a catch-up process in the high education endowments.

A region's capacity to increase the share of graduates may also be positively influenced by the quality of local institutions that oversee the educational system, which exhibits a positive and significant coefficient, meaning that local institutions with a higher quality promote human capital accumulation. Although graduates' endowments in a specific region might be affected by the geographical spillovers coming from other areas, results in columns (2) and (3) indicate no significance evidence of such externalities for both cases considered, all neighbouring regions allowing for distance decay or just the contiguous ones.¹⁹ Remarkably, the effect of the universities maintain its positive influence and shows an even higher coefficient (0.75) with respect to the models for the TFP growth. Considering model (2), a 10% increase in the number of universities produces a long-run home impact on human capital levels equal to 1.5%, while the spillovers effect are not effective in this case.

In columns (4)–(6) we report the results by macro-regions. Although results have to be interpreted with caution due to the reduction in sample size, the most important finding is that the university positive effect on human capital accumulation is generally confirmed. The only exception is model (4) for the Centre-North regions, where the university coefficient is not significant (*p* value 0.150). A possible explanation is that we use the number of graduate residents in the region to measure human capital. These more advanced Centre-North regions often attract a relevant part of their graduates from universities located in other areas and countries.²⁰ Interestingly, the Southern and the New accession regions show a high impact of universities on human capital accumulation with a coefficient equal, respectively, to 0.61 and 1.35. The results for the other regressors are maintained in most specifications.

5.2 | The technological channel

The second transmission mechanism of the university effects on productivity growth is the technological capital channel. Universities are one of the most important creators of basic research and technological innovation,

¹⁹The results are confirmed also in the case of the inverse distance matrices computed for the 0–300 and 300–600 distances.

²⁰In addition, in the case of the macro-regions models we find no evidence of spatial externalities. A more sophisticated model with graduates' migration flows is needed to control for regions' different levels of attractiveness (see, for example, Abreu et al., 2014 for UK and Giambona et al., 2017 for Italy). This relevant issue is left for future research.



TABLE 5 Universities and human capital growth

Dependent variable: growth rate of human capital share, annual average 2000–2016						
Model	(1)	(2)	(3)	(4)	(5)	(6)
Territorial sample	All	All	All	Centre-North	South	New
Spatial matrix	NO	distance	contiguity	distance	distance	distance
Number of regions	270	270	270	155	55	60
Number of universities	0.519 *** (0.190)	0.722 *** (0.191)	0.750 *** (0.188)	0.318 (0.224)	0.611 ** (0.275)	1.353 *** (0.518)
Institutional capital		1.011 *** (0.398)	1.006 *** (0.380)	−0.406 (1.334)	3.564 *** (0.741)	1.180 ** (0.508)
Initial level of human capital	−4.234 *** (0.317)	−4.685 *** (0.369)	−4.793 *** (0.381)	−4.470 *** (0.614)	−5.487 *** (0.803)	−3.333 *** (0.821)
Spatial lag of universities		−0.232 (0.362)	−0.214 (0.262)	−0.419 (0.491)	−4.943 *** (1.655)	3.010 ** (1.330)
Actual-fitted values square correlation	0.519	0.542	0.543	0.383	0.691	0.418

Notes:

Estimation method: Least squares.

Robust standard errors in parentheses; *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.

Exogenous variables are defined for year 2000 and are in natural logs.

South: Italy, Spain, Greece, Portugal.

New: 11 new accession countries (Malta is excluded).

Centre-North: remaining 12 western central and northern countries.

See Table A1 for variables' definition.



TABLE 6 Universities and technological capital growth

Dependent variable: growth rate of R&D, annual average 2000–2016						
Model	(1)	(2)	(3)	(4)	(5)	(6)
Territorial sample	All	All	All	Centre-North	South	New
Spatial matrix	NO	distance	contiguity	distance	distance	distance
Number of regions	270	270	270	155	55	60
Number of universities	5,244 *** (0.914)	5,542 *** (1.128)	5,051 *** (1.105)	1,841 (1.293)	9,668 ** (4.428)	7,295 *** (2.691)
Human capital		2.154 (1.532)	3.401 ** (1.657)	−0.655 (1.887)	1.767 (3.138)	9.961 *** (3.586)
Institutional capital		−0.756 (1.656)	−0.825 (1.578)	4.170 (3.981)	1.235 (2.507)	0.650 (1.990)
Initial level of R&D	−3.387 *** (0.390)	−3.786 *** (0.516)	−3.664 *** (0.497)	−1.896 ** (0.977)	−4.951 *** (1.633)	−6.896 *** (1.671)
Spatial lag of universities		3.472 ** (1.556)	2.540 *** (0.968)	2.757 * (1.625)	12.202 ** (6.159)	11.009 * (6.725)
Actual-fitted values square correlation	0.375	0.395	0.398	0.096	0.346	0.346

Notes:

Estimation method: Least squares.

Robust standard errors in parentheses; *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.

Exogenous variables are defined for year 2000 and are in natural logs.

South: Italy, Spain, Greece, Portugal.

New: 11 new accession countries (Malta is excluded).

Centre-North: remaining 12 western central and northern countries.

See Table A1 for variables' definition.



especially in less advanced regions,²¹ where the production structure is often characterized by small firms. In advanced regions, universities contribute with private businesses to the accumulation of technological capital and hence to enhance local productivity growth. In this section, we aim to investigate the role of universities in promoting technological capital growth at the regional level. We start with a simple model where technological capital growth over the period 2000–2016 depends on the number of universities located in the region and the initial level of R&D expenditure to control for the convergence process.

Column (1) in Table 6 shows that universities exert a positive and significant effect on technological capital growth. This is in contrast with the non-significant role of universities found by Valero and Van Reenen (2019). It is worth noting that they proxied technological capital by the stock of patents, which—compared to R&D investments—is a too restrictive measure of innovative efforts as it accounts only for codified-higher quality inventions.

Our result is confirmed when we control for other explanatory variables. As for the human capital model, we include the quality of the local institutions since they play a role in setting the normative and regulatory framework. Moreover, following a standard approach in the literature on knowledge production function (Buesa et al., 2010; Romer, 1990b), we also include the initial level of human capital. A high endowment of graduates at the local level is expected to enhance the growth rate of regional innovative activity. Finally, we control for spatial spillovers by including the universities spatial lag alternatively based on the inverse distance matrix (model (2)) or the contiguity matrix (model (3)).

The initial level of human capital endowments appears positive and significant in model (3), while it is not significant (p value 0.160) in model (2). Institutional capital is never significant, contrary to the human capital growth model previously analysed. The educational system in Europe is mainly public, and therefore the role of local institutions is crucial for its expansion. On the other hand, the technological capital accumulation process features both local and international traits, the role of private firms is more decisive, and therefore there is less room for the quality of public institutions. The initial level of R&D expenditures is always negative, meaning that the convergence process in the technological endowments across the European regions is ongoing.

Finally, we find evidence of sizeable universities externalities (coefficient equal to 3.5 in the second column and 2.5 in the third one) which point to the relevance of research inter-regional networks in driving technological advances and the need for coordinated policies at the European level to make them larger, denser and more interconnected. Looking at model (2), a 10% increase in the number of universities generates a 14.6% increase in long-run R&D expenditure. If we also consider spatial spillovers, the total effect increases to a remarkable 23.8% higher R&D level in the long run.

In columns (4)–(6), we split our sample by the geographical breakdown. The main results are all confirmed. Most importantly, universities positively impact technological growth in all areas, with the partial exceptions of the Centre-North regions. The strong positive effect of the initial level of human capital on the technological accumulation in the New accession countries is worth noting.

6 | CONCLUDING REMARKS

The role of universities in enhancing regional development has evolved over the last decades in quantitative and qualitative terms. Along with a remarkable rise in university students and graduates associated with a sizeable proliferation and diffusion of universities worldwide, their role is being increasingly conceived as an essential engine to cultural, entrepreneurial and civic development (Mowery & Sampat, 2005; Uyarra, 2010). The literature has emphasized the impact of universities on the local economic performance stemming from their key functions of teaching

²¹In the EU over the years under examination, the average quota of R&D attributed to higher education institutions is around 40% in less developed regions, whilst it is below 30% in more developed regions (EUROSTAT).



and research. Namely, know-how and technological transfer, regional leadership, entrepreneurship development, public engagement (Drucker & Goldstein, 2007; Florax, 1992; Goldstein et al., 1995).

In this paper, we have proposed a new empirical framework that bridges the KPF and the GDP approaches mainly adopted in the extant literature to investigate the university effects. We focus on the supply-side effects by focusing on TFP and assessing the distinct influence of three universities' growth-enhancing channels: the two indirect channels through higher education and basic research and the direct channel of the third mission activities. Moreover, we also estimate growth models for human and technological capital to assess the university key role in enhancing the local stock of such valuable intangible assets.

The first important result of our analysis is that the long-run impact of universities on regional TFP is always positive and sizeable. This direct effect supplements the indirect one generated through human and technological capital. The university role proves robust to the inclusion of other variables, such as institutional capital, agglomeration forces and production structures indices. Moreover, we find that universities may spread their effects across regional boundaries, although with a significant distance decay. We show that a 10% increase in universities is associated with a 1.8% rise in the long-run TFP in a region. An expansion that rises to more than 5% when this internal impact is reinforced by the external ones accruing from neighbouring regions.

These results are based on the number of universities active in a region, which is an imperfect measure for the complex role played by the universities. However, it is the only one available for a large set of regions and therefore it has been used also in previous cross-national studies. For a reduced sample of regions, we have also considered alternative indicators as the number of universities students, graduates and staff. Overall, the results confirm the positive role of the universities as drivers of TFP dynamics although their impact is lower than the one estimated with the universities' number. Certainly, more research is needed to collect detailed and homogeneous indicators on the university's activities. Nevertheless, our results seem to suggest that it is the existence *per se* of a university which generate a comprehensive effect on the local economy which is not entirely accounted for by its size.

Finally, we show that universities are essential drivers of local human and technological capital growth, thus confirming their productivity-enhancing indirect effects. Although expected and usually taken for granted, this last outcome was not always found in previous studies. Therefore, if in addition to the direct effect we also consider the indirect effects via human and technological capital and their spatial spillovers, the total effect of a 10% increase in the number of universities on the long run TFP level goes up to 6.8%.

In general, universities play an essential role in increasing the productivity of the European regions, which complements and integrates that of other growth determinants. We have also tested the relevance of universities in regional economic performance by employing the usual GDP model which indicates results compatible with previous research.

Overall, our findings remark the several and differentiated ways in which universities enhance economic performance and support the society as a whole. Universities facilitate the private and public agents engaged in innovation and production with novel entrepreneurship and organizational models. We offer robust evidence that universities produce beneficial externalities within and beyond the local economic system in which they are located. Even though this might appear an obvious conclusion, it is worth remarking that this outcome strongly calls for policies favouring more advanced education as a means towards vigorous productivity enhancements and enduring economic growth. Therefore, strong support of the higher education institutions represents a crucial policy to reduce the development gap across regions, which is still a primary objective of the European cohesion policies, especially now in a time of pandemics. It is worth remarking that the "Next Generation EU" aims at modernizing traditional policies to maximize their contribution to the Union priorities and, for this reason, allocates 60% of the resources to the heading of "cohesion, resilience and values."

Although we find clear evidence on the direct effect of university activities on local performance, further research is needed to disentangle this channel usually summarized under the heading of third mission: business-academy linkages, movements of researchers and other personnel, and other collaborations favouring knowledge



exchange and diffusion, regional leadership, and entrepreneurial culture. This research line requires homogeneous micro-data, which are not readily available for the whole of Europe.

Another critical area, which deserves further exploration, concerns the map of interactions among regions and universities. We have started exploring this map by focusing on geography. Still, we know that other dimensions may prove essential (Basile et al., 2012; Boschma, 2005; Paci et al., 2014), especially for the collaborations between universities and industry (Alpaydin & Fitjar, 2021), since spillovers may travel through many channels, such as student and researchers' mobility or collaborative networks within cognitive communities.

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APPENDIX A

TABLE A1 Data sources and definition

Variable	Primary Source	Years	Definition
Value added	JRC, EU science hub	2000–2016	Millions euros, constant price 2015
Units of labour	JRC, EU science hub	2000–2016	Thousands
Gross fixed capital formation	JRC, EU science hub	1990–2016	Millions euros, constant price 2015
Total Factor Productivity	Own calculation	2000–2016	Estimated levels
TFP growth rate	Own calculation	2000–2016	Growth rate tfp 2000–2016, % annual average
Capital stock	Own calculation	2000–2016	Millions euros, constant price 2015
GDP <i>per capita</i>	Eurostat	2000–2016	Real GDP <i>per capita</i> , thousands euro
GDP pc growth rate	Eurostat	2000–2016	Growth rate of GDP <i>per capita</i> , % annual average
University	ETER	2000–2012	Number of universities in the region
Research university	ETER	2000–2012	Number of universities with a Ph.D. program (ISCED 8) active in the region
University Graduates	ETER	2000–2012	University graduates (Isced 5–7) per thousand inhabitants
University Students	ETER	2000–2012	University students (Isced 5–7) per thousand inhabitants
University Staff	ETER	2000–2012	University staff (FTE) per thousand inhabitants
University attractiveness	ETER	2000–2012	Share of incoming Erasmus students over total enrolled students (Isced 5–7)
University size	ETER	2000–2012	Average number of enrolled students (Isced 5–7) over number of university in the region
Human Capital	Eurostat	2000–2016	Population aged 25–64 with tertiary education (Isced 5–8) over total population 25–64, %
Technological capital	Eurostat	2000–2016	R&D expenditure over GDP, %
Quality of Institution	Gothenburg University	2010	Index based on citizens' perceptions on impartiality, quality of public service, corruption.
HMM specialization	Eurostat, Labour forces	2000–2016	Normalized RCA, Employment in High- and Medium high- technology manufacturing
LTM specialization	Eurostat, Labour forces	2000–2016	Normalized RCA, Employment in Low-technology manufacturing
KIS specialization	Eurostat, Labour forces	2000–2016	Normalized RCA, Employment in Knowledge-intensive services
Population density	Eurostat	2000–2016	Population per km ²
Settlement Structure Typology	ESPON project 3.1 BBR	2000	1 = less densely populated without centres, 2 = less densely populated with centres, 3 = densely populated without large centres, 4 = less densely populated with large centres, 5 = densely populated with large centres, 6 = very densely populated with large centres
Accessibility by road, rail, air	ESPON project 2.4.2	2000	1 = highly below average; 2 = below average; 3 = average; 4 = above average; 5 = highly above average



TABLE A2 Universities and regional economic growth

Dependent variable: growth rate of GDP <i>per capita</i> , annual average 2000–2016			
Model	(1)	(2)	(3)
Number of universities	0.558 *** (0.159)	0.522 *** (0.179)	0.678 *** (0.182)
Human capital	1.095 *** (0.263)	1.077 *** (0.286)	1.032 *** (0.270)
Technological capital	0.382 *** (0.109)	0.378 *** (0.109)	0.353 *** (0.104)
Institutional capital	0.081 (0.509)	0.099 (0.515)	−0.049 (0.496)
Initial level of GDPpc	−2.784 *** (0.331)	−2.799 *** (0.347)	−2.707 *** (0.324)
Spatial lag of universities number			1.163 *** (0.365)
Actual-fitted values square correlation	0.573	0.573	0.592
(a) Controls for production structure	NO	YES	YES
(b) Controls for territorial features	NO	YES	YES

Notes:
Number of regions 270.
Estimation method: Least squares.
Robust standard errors in parentheses;
*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Exogenous variables are defined for year 2000 and are in natural logs.
Spatial lag computed with distance matrix.
(a) RCA for Low technology manufacturing.
(b) Settlement structure typology.
See Table A1 for variables' definition.



Resumen. Las universidades son fundamentales para impulsar el desempeño económico, ya que generan capital humano, investigación y difusión de conocimientos. La investigación de sus efectos en la productividad total de los factores (PTF) de las regiones europeas durante el periodo 2000–2016 constituye un análisis novedoso. Se distingue entre los efectos *directos*, debidos al papel social de las universidades ("tercera misión"), y los *indirectos*, originados por la creación de capital humano y tecnológico. La contribución de este estudio es triple. En primer lugar, se aportan principalmente pruebas de que la presencia de universidades tiene un impacto considerable en la PTF regional. En segundo lugar, este impacto se extiende más allá de las fronteras regionales. En tercer lugar, las universidades impulsan eficazmente el crecimiento del capital humano y tecnológico, lo que fomenta indirectamente la mejora de la productividad.

抄録: 大学は、人的資本、研究、知識の普及を生み出すものであり、すなわち経済活動の推進の基盤となるものである。本稿では、2000~2016年の期間に、大学が欧州地域の全要素生産性(TFP)に与えた影響を検討する、新たな分析を行う。ここでは、大学の社会的役割(「第3の使命」)による直接的な効果と、人的資本や技術的資本の創出に起因する間接的な効果とを区別する。本研究から以下の3つの知見が得られた。1)大学の存在が地域のTFPに大きな影響を与えていることを示すエビデンスが得られ、2)その影響は地域の境界を越えて広がっており、3)大学は人的資本と技術的資本の成長を効果的に促進し、間接的に生産性を向上させている。