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On the Productivity Effects of Higher Education Supply: Evidence from Italian History

Abstract

This paper uses own built historical data to analyse the effects of higher education institutions on productivity, measured in terms of real Gross Value Added (GVA) per capita. We employ a fixed-effect instrumental variables estimator and use instruments à la Bartik to identify the productivity effects of higher education supply at the provincial level. We also take into account the influence that neighbouring provinces have in this context. Our analysis covers the period 1870-2010, which corresponds to the transition from elite to mass higher education in Italy. We find significant positive effects of higher education supply on productivity, particularly in synergy with industrialisation, contributing to Italy's transition to sustained growth. Further, we evaluate the estimated effects at 2001 supply levels, and suggest that a 10% increase in higher education supply (both within the province and neighbouring provinces) leads to an annual rise of 0.19% in per capita GVA. Our computations suggest that local supply accounts for approximately 58% of these annual returns, on average. The remaining 42% originates from faculties in nearby provinces. This positive externality persists even considering the local productivity loss caused by the negative displacement effects stemming from the supply of neighbouring areas.

JEL-Codes: I230, I280, N000, R100.

Keywords: productivity, higher education supply, neighbourhood effects, historical data, Unified Growth Theory.

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1 Introduction

The development of modern systems of higher education dates back to the outset of the second phase of the industrial revolution. By the end of the first phase, in the second half of the 19^{th} century, rising productivity resulting from the spread of industry generated a new demand for human capital that was needed to fuel further technological progress. This demand for skills triggered a long-term process of human capital formation that Unified theories regard as key for the transition to sustained economic growth (Galor, 2011). The translation of demand for skills into human capital, skills and competences that could feed industrial development called for a profound transformation of higher education supply. Higher education institutions had to gradually change from the elite status they held during the pre-industrial era to academic institutions favouring widespread higher education (Mokyr, 2002).

Not much is known about the economic effects of this historical process, which consists of establishing modern higher education institutions. We know that large stocks of human capital generate sizeable gains in GDP per capita, both in developed countries and developing countries (Hanushek and Woessmann, 2015). These gains are likely local, as workers and students have a limited geographical mobility. This may be reason why OECD countries engaged to tailor the expansion of their higher education supply to regional growth throughout the 20^{th} century (OECD, 2007; OECD, 2014). This regional perspective disregards the view that the economic benefits of higher education institutions may go well beyond regional boundaries. This is also true for their economic costs. Neighbouring regions insist on the same scarce resources (e.g., students and investments), so opening a higher education institution in a specific location may reduce the possibility of opening similar institutions nearby. Overall, quantifying the actual benefits and costs is a crucial task for evaluating the welfare effects of higher education institutions. From a policy perspective, it is a first necessary step to understand whether the rise of the modern supply of higher education may have paradoxically contributed to the persistent differentials in income per capita that have prevented regional economic convergence since the end of WWII (Gennaioli et al., 2013).

This paper analyses the productivity effects of the rise of the modern supply of higher education in Italy, the country with the longest history of university education in the western world. We offer a detailed historical account of its constant expansion from the inception of elite knowledge institutions during the Middle Ages, to year 2010. To evaluate the productivity effects of the rise of higher education supply, we conduct an empirical analysis at the sub-regional level, namely, the province. This is the oldest governance level in the Italian territory, historically responsible for the provision of several local public services and goods, and equivalent to the *département* in France or the county in the US or UK (Federico et al., 2019). We perform our productivity evaluation using the predicted coefficients from a twofold empirical exercise. First, we estimate neighbourhood effects, i.e., the association between the higher education supply in nearby provinces and the local supply. Second, we estimate province-level returns of local higher education supply and of the supply in neighbourhoods in terms of real gross value added (GVA, from here on) per capita. We use estimated coefficients to predict the actual distribution of economic returns in terms of productivity, and the counterfactual distribution in the absence of neighbourhood effects. By comparing the two distributions, we are able to separate local economic returns from the productivity externalities of neighbouring provinces.

For these purposes, we constructed an original historical dataset covering the History of Italian Universities (HIU). We use HIU to build a panel dataset that follows 110 Italian provinces between 1861 and 2010. We measure higher education supply as the total number of "faculties" in a province in a given year. In the Middle Ages, the faculty was the lower-level higher education institution in charge of teaching provisions (including the design of curricula) in a given field of study (De Ridder-Symoens and Rüegg, 1992).[1] The faculty maintained the same scope in the Italian higher education system until the 2010 reform, which replaced this traditional structure with a new organisational model.

The cross-province panel structure of our data features a long time span and a fine geographical disaggregation. This makes the fixed effect (FE) estimator the natural econometric benchmark for our analysis. We adopt an instrumental variable (IV) approach to address concerns related to reverse causality and time-varying omitted variable bias at the province level. We construct instruments *à la* Bartik as the interaction of the initial cross-province distribution of faculties in Italy with the faculty growth process during Italian history. The initial distribution of faculties is key to our research design since Italian provinces inherited their higher education institutions from the ancient sovereign states. We argue that this initial supply persistently affected the creation of new faculties after the Italian unification.[2] We discuss the validity of Bartik instruments and conduct an extensive array of tests and robustness checks (Goldsmith-Pinkham et al., 2020; Adão et al., 2020). This sensitivity analysis suggests that our results are not driven by persistent omitted factors correlated with

[1] In essence, a faculty is the core teaching unit, and it is meant to govern the supply of tertiary education in a given field of study (e.g., the Faculty of Economics, the Faculty of Law, etc.). The use of the term faculty should not be confused with its alternative use to denote the body of academic personnel, which is rather common among Anglo-Saxon universities. See Clark (2006) for details on historical traditions in Anglo-Saxon universities. We provide additional details on the Italian tertiary education system, also from an historical perspective, in Sections 2.1 and 2.2.

[2] The political unification of the Italian territory into the sovereign state of Italy started in 1861 and was completed in 1870 with the capture of Roma. The newly born state was a monarchy (Kingdom of Italy) until 1946, when following an institutional referendum, a new republican constitution was adopted.

the initial distribution of faculties.

The main result of this paper is that higher education institutions have sizeable and significant effects on productivity. Our estimates predict that a province exposed to the average supply of faculties in 2001 (28 faculties, including local ones and those in the neighbouring area) presents, ten years later, a 19% higher real GVA per capita compared to a province with a zero supply. This is equivalent to an annual 1.9% increase in GVA per capita between 2001 and 2010. It can also be interpreted as an elasticity of GVA per capita to higher education supply equal to 0.19. Our productivity equation estimates local returns from supply of faculties in nearby provinces, separately from the returns of local supply. We argue that a correct computation of geographical externalities needs to consider the foregone value of displacement effects from the neighbourhood on local supply. Once we properly account for this, we find economic returns are rather localised at the province level. The 58% of total returns (equivalent to an annual 1.1% increase of GVA per capita between 2001 and 2010) are due to local faculties, while faculties nearby explain the remaining 42% (equivalent to an annual 0.8% increase between 2001 and 2010). Finally, we uncover considerable inequalities between small peripheral provinces that enjoy limited returns from higher education and large provinces where the supply of faculties explains annual increases up to 7% of local GVA per capita.

Our paper builds a bridge between two strands of the literature that investigates the economic effects of higher education institutions in developed countries. The first strand focuses on the pre-industrial era, i.e., an epoch where upper-tail education was reserved to a minority of elite interested in scientific progress (Mokyr, 2005). The second strand analyses the effect of higher education on productivity and growth in postindustrial societies (e.g. Andersson et al., 2004; Valero and Van Reenen, 2019; Aghion et al., 2009).[3] Our main contribution is to analyse productivity effects of higher education supply from an historical perspective. The 150 years covered by our analysis allow to point out the effects of higher education institutions from the onset of the industrial era to today, which corresponds to the transition from elite to mass education. Besides the effects on GVA per capita, we uncover

[3] Andersson et al. (2004) use a 14-year panel dataset for Swedish municipalities to study the economic effects of higher education decentralisation on the output per worker. Aghion et al. (2009) exploit variation in the appointment of US Congressmen in Appropriations Committees to identify the effect of education investments on economic growth for a panel of 48 US states during 26 cohorts. The authors find positive effects of education investments on growth, whose size depends on a state's distance from the technological frontier. The paper closer to ours in this strand is Valero and Van Reenen (2019). They estimate economic returns of higher education supply, using a novel dataset with regional panel information on nearly 15000 universities across 78 countries for the post-WWII period. They adopt a university-level measure of higher education supply, and focus on the second half of the 20^{th} century, an epoch where public education policies expanded and decentralised undergraduate education to make it geographically and socially more accessible.

small, yet noticeable effects of local supply also on local population and population density, which we interpret as Post-Malthusian returns of upper tail human capital. Compared to existing studies, we measure higher education supply at a much more detailed institutional level (i.e. the faculty unit), which also allows us investigating field-specific returns (STEM vs. non-STEM). We find returns (particularly of STEM faculties) are larger in provinces characterised by higher levels of early industrialisation, which carries over to a gradual transition of sectoral employment shares away from agriculture towards industry and services. This evidence advances relative to existing studies that analyse the role of upper-tail human capital as a determinant of pre-industrial economic development (e.g., in terms of population growth, urban population density, and living standards) and the emergence of industrialisation (e.g., measured in terms of factory or manufacturing employment. See Squicciarini and Voigtländer, 2015; Cantoni and Yuchtman, 2014; and Becker et al., 2011). Our results align with the complementarity hypothesis, which is central to the Unified Growth Theory. This hypothesis underscores the interplay between the development of human capital and technological progress during the shift from the Malthusian era to the era of Sustained Growth (Galor and Weil, 2000; Galor and Moav, 2004).

As a second important contribution, our fine-grained province-level data enable us to advance the measurement of geographical externalities. In particular, we find out there is a cost associated with the existence of faculties in a sufficiently close neighbourhood (e.g., in the same region, within a certain distance, etc.), which prevents opening a similar faculty in a province. Our results suggest a one standard deviation increase in higher education supply in each neighbour j (4.61 faculties) results in up to -2.95 faculties in province i over a ten years' period. We argue that this *displacement cost* emerges as long as there is some individual mobility between neighbouring provinces (e.g. due to historically good railway infrastructures, or a high geographic accessibility of provinces), and this is somewhat limited to the neighbourhood itself (e.g. low out-migration due to high commuting costs outside that area) so that each province insists on a limited portion of national demand for education. We also quantify the corresponding negative geographical externality in productivity terms. The scant empirical literature on the welfare effects of higher education institutions discusses only 'gross' positive externalities that neglect displacement forces from the neighbourhood (Andersson et al., 2004; Valero and Van Reenen, 2019). Our analysis suggests that such gross externalities may severely overestimate the effective 'net' externalities that take into account also negative displacement costs.

We also make a third contribution to the side of identification. Historical papers stress the role of cross-sectional variation coming from the regional distribution of initial conditions to identify the economic effect of upper-tail knowledge. Cantoni and Yuchtman (2014) show that the establishment of Germany's first universities in the Middle Ages had a causal impact on medieval Europe's Commercial Revolution. Becker et al. (2011) use the education level observed before the start of industrialisation (i.e., in 1816) as an instrument to identify the effect of education on industrialisation in Prussia. Andersson et al. (2004) and Valero and Van Reenen (2019) use longitudinal data and estimate fixed effects models at the sub-national level, but they lack suitable instruments, and focus on the post-WWII period. As in this literature, we use instruments whose validity depends on the exogeneity of the distribution of initial conditions. However, our Bartik instrument combines cross-sectional variation with time variation coming from faculty creation during Italian history. This allows us to incorporate IVs into an empirical specification that also includes fixed effects both at the province and region-by-year level. Additionally, this provides new insights on the causal identification of mechanisms that are well-established in the context of Unified Growth Theory (Galor, 2011).

The paper is organised as follows. In the next section, we describe the institutional and conceptual framework employed. In Section 3, we present the data. The empirical strategy is presented in Section 4, while main results of neighbourhood and productivity effects are in Section 5. Section 6 discusses the potential channels driving neighbourhood and productivity effects of higher education supply. Section 7 presents the welfare analysis. Section 8 concludes.

2 A Province-Level Supply of Higher Education

The province acts as our observation benchmark, a natural geographic level for measuring human capital accumulation and analysing industrialisation, production, and wage trends (see, e.g., Squicciarini and Voigtländer, 2015; Ciccone and Peri, 2006, 2011; and Bratti and Leombruni, 2014). In this section, we explore how the role of provinces in higher education in Italy evolved following its political unification. Using data from 1870 to 2010, we will map higher education supply across economic development phases, as outlined by Unified Growth Theory (Galor, 2011). We will also address the importance of accounting for local effects on higher education provision. Many OECD countries treat higher education as a local market influenced by market forces rather than central government intervention (Catalano and Silvestri, 1999; Agasisti and Catalano, 2007). This rationale underpins considering local effects when analysing how higher education supply contributes to economic development.

2.1 Supply of Higher Education in Pre-unitarian Provinces

At the time of its political unification, Italy had 69 provinces. 59 became part of the sovereign state of Italy in 1861. An additional 8 provinces joined in 1866 (namely Belluno, Padova, Rovigo, Treviso, Udine, Venezia, Verona, and Vicenza), followed by Mantova in 1868. The final addition was Roma in 1870, marking the completion of Italian unification. Research into the history of Italian universities demonstrates that the initial provision of higher education institutions across these provinces was highly heterogeneous (Brizzi and Romano, 2007). As we discuss in Section 4 below, this diversity constitutes the primary source of variation that we leverage for empirical identification.

Table 1 summarises information on this initial provision across several relevant dimensions. In Column [1], we enumerate the 21 provinces with at least one faculty at the time they joined Italy. In Column [2], we detail the year in which the University (or the first faculty) was founded. In general, higher education had been established during the Middle Ages, resulting in two-thirds of these provinces hosting active faculties by the 16^{th} century. Higher education supply emerged later only in Cagliari, Macerata, Pesaro-Urbino, Sassari, Milano, Palermo, and Messina.

In Column [3], we catalogue the states in which the first faculty was instituted. These are termed 'Initial States'. The overwhelming majority of Initial States were Duchies, Counties, Principalities, Houses, Republics, or Communes, and covered the geographic expanse of just one province. In most initial states, university education was structured into four faculties (Brizzi and Romano, 2007): Literary Studies (including Philosophy), Law, Medical Studies, and the Natural Sciences (encompassing Mathematics and Physics). Additionally, independent faculties of Theology existed in the states under Vatican control, known as the 'Papal States'.

In Column [4], we record the last state to which the province belonged before the unification of Italy (termed the 'Pre-unitarian State'). The comparison between the Initial State and the Pre-unitarian State sheds light on the evolving political dynamics occurring between the 11^{th} and 19^{th} centuries. Smaller Initial States would forfeit their political autonomy (for example, the House of Este in Ferrara was incorporated into the Papal States, and the Republic of Genoa was absorbed by the Kingdom of Sardinia). Some larger Initial States would gradually dissolve and cease to exist (such as the Holy Roman Empire), or undergo significant political metamorphoses due to shifts in ruling dynasties (as observed in the Kingdom of Sicily, Kingdom of Sardinia, and Papal States).[4] This transformation had far-reaching impli-

[4]The Kingdom of Sicily transitioned into the Kingdom of Naples under the Angevin dynasty and later became the Kingdom of Two Sicilies under the Bourbons. The Kingdom of Sardinia initially aligned with

cations for the configuration of higher education at the province level. As an illustration, the Spanish Empire established new educational institutions to train local administrators in the occupied provinces (for instance, Cagliari and Catania). It would export its own academic model and enforce distinct accreditation regulations, which local institutions were obliged to adhere to in order to attain academic recognition (Roberts, 1996).

Column [5] provides the total count of faculties that were already present in each province before Italian unification, at the time of their integration into Italy (referred to as 'pre-unitarian faculties'). Province-level provision varies from a minimum of two faculties (in Milano, Perugia, Pesaro-Urbino, and Siena) to a maximum of eight faculties (in Torino). These faculties encompass the four academic disciplines retained by the Italian higher education system from pre-unitarian states (Humanities, Mathematics and Natural Sciences, Law, and Medicine; refer to De Ridder-Symoens and Rüegg, 1992).

Finally, Column [6] of Table 1 provides the initial evaluation of higher education institutions based on the Casati Law (Law 3725/1859). This legislation established the criteria for accrediting existing institutions within the new Italian university system. In nine provinces, higher education supply was awarded an 'A' ranking, signifying compliance with the highest quality standards set by the Italian government for both teaching and research. In multiple provinces, pre-unitarian supply received a 'B' ranking. While not meeting the highest standards, these faculties served as valuable second-tier regional institutions. Faculties associated with the Universities of Sassari and Macerata fell below the minimum requirements and were classified as 'C'. The Casati Law also recognised private higher education provision in the provinces of Ferrara, Pesaro Urbino, and Perugia, where local authorities previously directly supported universities (Brizzi and Romano, 2007).[5]

The preceding discussion indicates that the higher education system of the Italian Kingdom emerged as a confluence of substantially diverse education systems established by various states within the Italian territory since the Middle Ages. Figure A-I in online Appendix illustrates that this pre-unitarian supply was geographically dispersed across the northern, central, and southern regions. Figure A-II showcases the pre-unitarian states present in the

the Council of Aragon, subsequently becoming part of the Spanish Empire in 1402. In 1720, it joined the Duchy of Savoy until Italian unification. The Papal States modified their territorial dominion over time, reaching their peak extent in the 18^{th} century, encompassing much of central Italy as well as the Legations of Ravenna, Ferrara, and Bologna.

[5]Initially, the Casati Law was applied to the new territories of the Kingdom of Sardinia. The subsequent Matteucci Law in 1862 extended its application to all territories that progressively became part of the Italian Kingdom (refer to Table A-I in the online Appendix). De la Croix et al. (2020) demonstrate that the Casati ranking strongly aligns with their index of university prominence, which employs a distinct metric based on estimations of human capital for the top 5 academic scholars who spent time in that university during the period 1740-1800.

Italian territory before unification.

More importantly, Figure 1 presents evidence consistent with some potential comovement between population and faculty creation, particularly in scientific disciplines starting from the mid-18th century. Panel (a) presents the evolution overtime of the pre-unitarian supply of faculties between 1200 and 1860. Until roughly 1750, it shows a balanced creation of the group comprising Mathematics, Natural Sciences, and Medicine, which conveyed the main clusters of scientific knowledge at that time (Curtis and de la Croix, 2023; we denote them by STEM faculties) and Humanities and Law (non-STEM faculties). This was due to political decisions to create academic knowledge by relevant actors e.g. at the level of the Holy Roman Empire (as in the case of faculties founded in Pavia in the 14th century), the Kingdom of Sicily (as in the case of the faculty of Law in Napoli in the 13th century), or the Spanish empire (as Catania in the the 15th century) or smaller Initial states such as House of Este in Ferrara, the Republic of Genova, the Commune of Siena starting from the 13th century. In most cases the Vatican played a crucial role, by providing official recognition and validation through a Papal bull, or a Papal brief. Starting from around 1760, there is an acceleration in the growth of total faculties, mostly driven by STEM ones. This period is notably marked by the establishment of Napoleonic states, resulting in the extension of the Napoleonic model of higher education to Italian territories. This led to the creation of faculties in novel STEM fields, aiming at training professionals, favour the development of technologies, and create better and more prepared public employees (Alvazzi del Frate, 2021; Kickert, 2007).[6] In Panel (b), we report population levels on the Italian territory, starting from 800AD, i.e. 1000 years before the start of our sample period (grey line in Panel (b)).[7] The figure shows a sharp rise in population, starting roughly from the 18^{th} century too. All in all, Figure 1 offers evidence of Malthusian forces possibly correlated with the pre-unitarian supply of STEM faculties, which we will take into consideration in the empirical analysis.

[6]New STEM faculties were established either as independent schools in applied or technical fields e.g. within the faculties of the Natural Sciences (such as Architecture or Engineering), or as technical schools functioning formally outside the realm of university education (including Pharmacy and Veterinary Studies). These schools were unequivocally equivalent to university faculties, conferring a diploma of the same status as a university degree. Possession of this diploma was essential for employment in the Italian public sector or entry into field-specific highly skilled professions. Most of these specialised schools were established in the main capital cities of each Pre-unitarian State (for further details, refer to online Appendix A1).

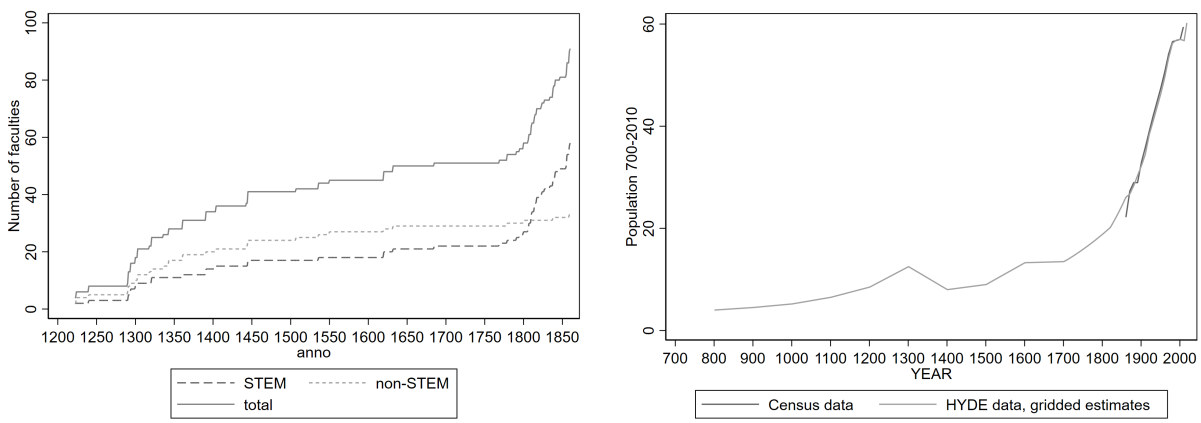
[7]This time series is based upon estimated gridded data, so it may suffer from some lack of precision. However, comparison with the actual data from population census for the sample period (black line in Panel (b)) reveals an almost complete overlap between the two series. This reassures us over the reliability of the estimated gridded data for the pre-sample period.

Table 1: Pre-unitarian higher education supply

[1] Pre-unitarian Province	[2] Foundation Year	[3] Initial State	[4] Pre-unitarian State	[5] Pre-unitarian Faculties	[6] Ranking Casati Law
Bologna	1088	Holy Roman Empire	Papal States	6	A
Cagliari	1620	Kingdom of Sardinia (Spanish Empire)	Kingdom of Sardinia	4	B
Catania	1445	Kingdom of Sicily (Spanish Empire)	Kingdom of Two Sicilies	4	B
Ferrara	1391	House of Este	Papal States	4	Private
Genova	1481	Republic of Genoa	Kingdom of Sardinia	5	B
Macerata	1540	Papal States	Papal States	3	C
Messina	1838	Kingdom of Two Sicilies	Kingdom of Two Sicilies	3	B
Milano	1791	Duchy of Milan (Habsburg Empire)	Lombardy-Venetia	2	A,A
Modena	1175	Commune of Modena	Duchy of Modena and Reggio	4	B
Napoli	1224	Kingdom of Sicily	Kingdom of Two Sicilies	6	A
Palermo	1806	Kingdom of Sicily (Spanish Empire)	Kingdom of Two Sicilies	4	A
Padova	1407	Commune of Padova	Lombardy-Venetia	4	A
Perugia	1308	Commune of Perugia	Papal States	2	Private
Pisa	1343	Republic of Pisa	Gran Duchy of Tuscany	6	A
Parma	962	County of Parma	Duchy of Parma and Piacenza	5	B
Pesaro Urbino	1671	Papal States	Papal States	2	Private
Pavia	1361	House of Visconti	Kingdom of Sardinia	5	A
Roma	1303	Papal States	Papal States	5	A
Siena	1240	Republic of Siena	Gran Duchy of Tuscany	2	B
Sassari	1765	Kingdom of Sardinia	Kingdom of Sardinia	3	C
Torino	1404	Principality of Savoy-Acaia	Kingdom of Sardinia	8	A,B

Notes: Column [1] reports the Pre-unitarian province. Column [2] reports the year of the first faculty in the province. Columns [3] and [4] report the Initial and Pre-unitarian State to which the province belonged. In Column [5] we report the number of faculties observed in the province at the moment of entry into the Italian Kingdom. Column [6] reports the quality assessment of higher education institution(s) in the province according to the Casati Law. This evaluation refers to public institutions only. In Torino, the Casati Law assigns an A score to the University of Torino and a B score to the Polytechnic. In Milano, it assigns an A score to both the Scientific Academy and the Polytechnic. In Milano, the first higher education institution was the autonomous School of Veterinary Studies, while the University of Milan was established in 1924 only. The source is HIU Data.

Figure 1: Population and university creation during 800-1861



(a) Higher education supply 1200-1861

(b) Population 800-2010

Notes: Panel (a) reports the number of pre-unitarian faculties in Italy between 1200 and 1861, distinguishing between STEM and non-STEM disciplines. The STEM (i.e., Science, Technology, Engineering and Mathematics) group includes Agricultural Studies, Architecture, Chemistry, Pharmacy and Medical Studies, Geology and Biology, Engineering and Scientific Studies. The non-STEM group includes Law and Humanities. Panel (b) reports the level of population measured using data from Italian census 1861-2010 (grey line, scale measured over the left-hand side y-axis) and the estimated population based on gridded data at NUTS3-province level from HYDE3.2 data (black line, scale measured on the right-hand side y-axis). Authors' calculations based upon HYDE3.2, Census and HIU data.

2.2 Province-Level Supply of Higher Education during Italian History

The above discussion suggests that the Italian higher education system at the end of the 19^{th} century was very polycentric and decentralised. Successive attempts to centralise it at the state level during the 20^{th} century were largely ineffective (Fioravanti et al., 2000). Both in old and recent times, the province has always been the relevant territorial jurisdiction for the supply of higher education (and local public services in general). Petracchi (1962) defines provinces as "big associations of municipalities devoted to the protection of the rights of each of them and to the management of their collective moral and material interests".

Amongst these moral and material interests, the local provision for higher education was a significant factor. Until 2010, this provision took shape through the establishment of new faculties such as Law, Economics, and Medicine. These faculties acted as operational higher education institutions, responsible for designing and delivering courses, as well as awarding degrees in their respective fields. In many instances, the emergence of a faculty preceded that of a university, exemplifying the pivotal role of the faculty itself.

For instance, the University of Milano was established in 1923. However, the Faculty of Veterinary Medicine traces its roots back to 1791, initially under the name Scuola Veterinaria Minore.[8] In the interim period, the Polytechnic of Milano was founded in 1863 as an advanced technical institution known as the Regio Istituto Tecnico Superiore. The creation of faculties often foreshadows the establishment of universities in contemporary times too. The University of Eastern-Piedmont serves as an illustration. It was founded in 1998, stemming from seven faculties that were inaugurated 5 years before, in 1993, as distinct branches of the University of Torino within the Provinces of Novara, Vercelli, and Alessandria (online Appendix A provides more details and examples).

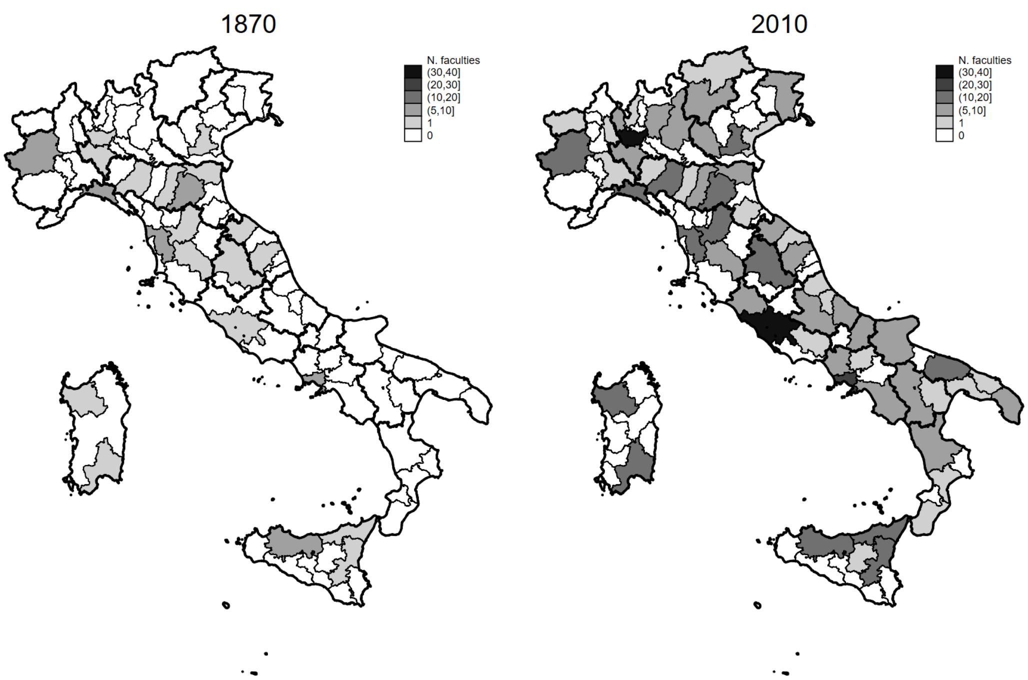
Eurydice (2000) outlines eight comprehensive reforms that shaped the Italian university system, facilitating the establishment of new faculties in numerous Italian provinces, regardless of whether they had existing higher education infrastructure.[9] The subsequent increase in Italy's total number of faculties between 1870 and 2010 reflects this transformation, which

[8] It aimed to educate a specialised group of farriers capable of performing minor surgical interventions and treating prevalent ailments in horses, cattle, and sheep.

[9] Law 2102/1923 (Gentile Law) established an organisational framework for Italian higher education prior to WWII. It introduced new faculties in social sciences and STEM fields. Law 1592/1933 (De Vecchi-Bottai Law) centralised the system by incorporating technical schools as faculties or universities. Post-WWII, Law 910/1969 liberalised access to technical school graduates contributing to the transition from elite to mass education. Law 766/1973 enlarged faculties and faculty appointments. Law 382/1980 restructured governance and academic careers. Laws 392/1989 and 245-341/1990 modified funding distribution. Law 59/1997 granted universities increased financial and teaching autonomy.

we leverage in our empirical analysis. Provinces lacked the political authority to systematically influence overarching national-level reforms, and therefore, the total supply of faculties across the country.[10] Nonetheless, they hold a pivotal institutional role in shaping the geographical distribution of higher education provision. Province-level *consortia* propose initial projects for new faculties or universities, subject to evaluation by the central government (Brizzi and Romano, 2007). Local politicians at the province level assemble academic expertise and financial resources from institutions such as banks, chambers of commerce, or local investors. The central government primarily functions as a regulator, stipulating administrative prerequisites, and adopts a relatively neutral stance regarding the spatial allocation of faculties.

Figure 2: Diffusion of faculties in Italy



Notes: Authors' calculation based on HIU data using a map of Italian provinces and regions (whose borders are in bold). The borders of 1870 refer to the 69 provinces existing in 1870, those of 2010 to the 110 provinces of 2010. For visual convenience, we use the 2010 country borders also for the 1870 figure, which include territories that in 1870 were not already part of Italy (i.e., the provinces of Trento and Bolzano).

Figure 2 provides a historical overview of the total count of faculties in 1870, marking the completion of Italian unification. This is compared to the number of faculties in 2010 (using province-level disaggregation for comparability). Even in 1870, faculty distribution

[10]The limited political significance of provinces in national politics originates from the Republican Constitutional Law, which omits specific tasks and legislative competencies for provinces (refer to Article 114; also see Fabrizzi, 2008a, 2008b, and 2008c for a historical overview). Moreover, their wide dispersion throughout the Italian territory means that each province represents only a marginal fraction of the total population.

was predominantly centred in the capitals of pre-unitarian states. By 2010, two-thirds of the provinces hosted at least one faculty. Provinces devoid of faculties are the most recent additions, established in the post-WWII era or more recently. A handful of provinces featured 15 faculties or more (including Bari, Bologna, Milano, Napoli, and Roma). Figure 2 visually illustrates that the surge in faculty numbers encompasses the entire expanse of the Italian territory.[11]

Figure 3 provides deeper insights into the evolution of higher education supply throughout the period 1870-2010. As outlined in Panel (a), the surge in higher education provision becomes notably evident post-1969, encompassing both STEM and non-STEM faculties. Panels (b) and (c) indicate that the total count of faculties increases across all NUTS1 regions and within all quartiles of province population.[12] Finally, Panel (d) demonstrates that Italy's evolution of higher education supply from the mid-19^{th} century shares a similar trajectory with that of France, Germany, and the UK. All four nations exhibit an upsurge in university numbers, particularly noticeable from the 1960s onwards. While Italy's profile is comparatively more gradual in contrast to the other three countries,[13] this pattern embodies the shift from an elite to a mass education system, mirroring developments that unfolded across Europe and the US during the same era (Eurydice, 2000; Smith, 2010).

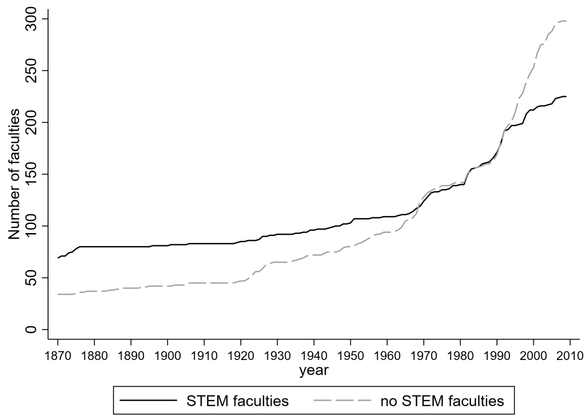
In Figure 4, we can see a picture of the total number of faculties, GVA per capita, and the overall population in Italy from 1860 to 2010. From this, three important points become clear, which match the predictions from Unified Growth Theory (Galor, 2011). Firstly, the gradual rise in GVA per capita at the beginning of the sample period indicates that Italy had already moved away from the Malthusian era of economic stagnation, on average. Secondly, a noticeable strong link emerges between GVA per capita and the number of faculties (with a correlation coefficient of 0.97, which is statistically significant at the 1% level). This suggests a robust connection between human capital formation and economic growth, through the shift from the Post-Malthusian period to the Modern Growth Regime. This shift seems to have begun after WWI and was completed after WWII. Lastly, the influence of Malthusian forces continued to matter until the second half of the 20^{th} century, when the growth of the population began to slow down.

[11]For further insights into temporal variations across different regions, consult Figure A-III in the online Appendix.

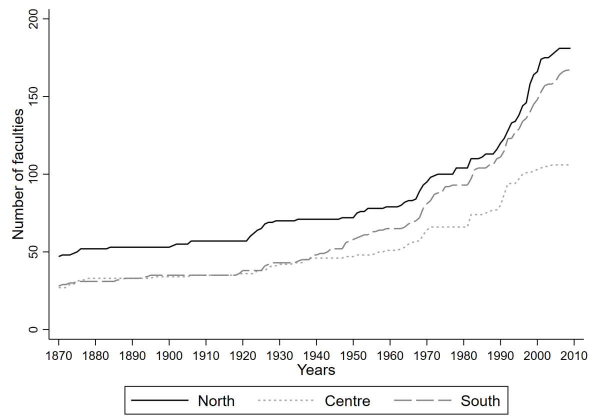
[12]Panel c highlights a more pronounced expansion of faculties in provinces belonging to the top quartile of population when contrasted with provinces in lower quartiles, a trend discernible even from the unification period. Subsequently, Figure 1 elucidates these divergent trends that surfaced during the 'Renaissance' era. Our empirical analysis thoroughly addresses and discusses the empirical concerns arising from this pre-existing trend.

[13]Various factors could underpin this disparity, such as consistently fewer high school graduates in comparison to nations like Germany, particularly within the past 40 years.

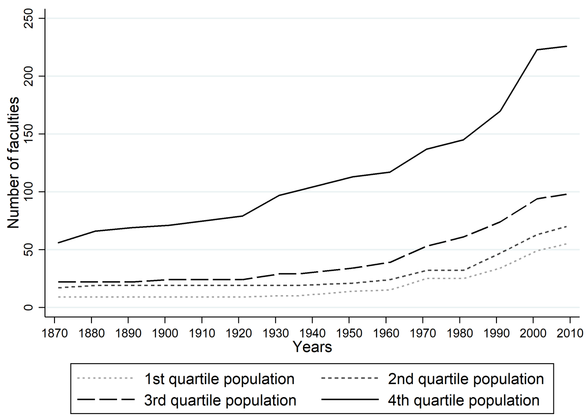
Figure 3: Evolution of the number of faculties in Italy from 1870-2010 and EU comparison



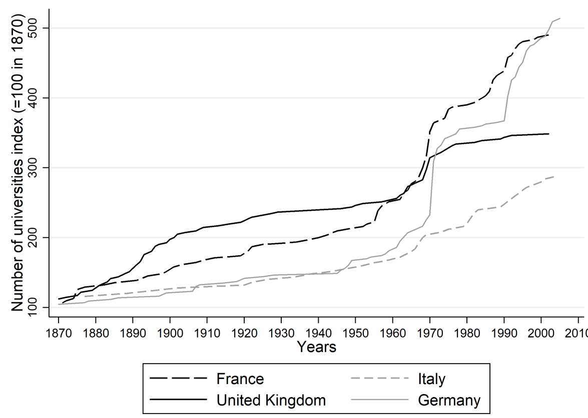
(a) by field of study in Italy



(b) by NUTS1 region



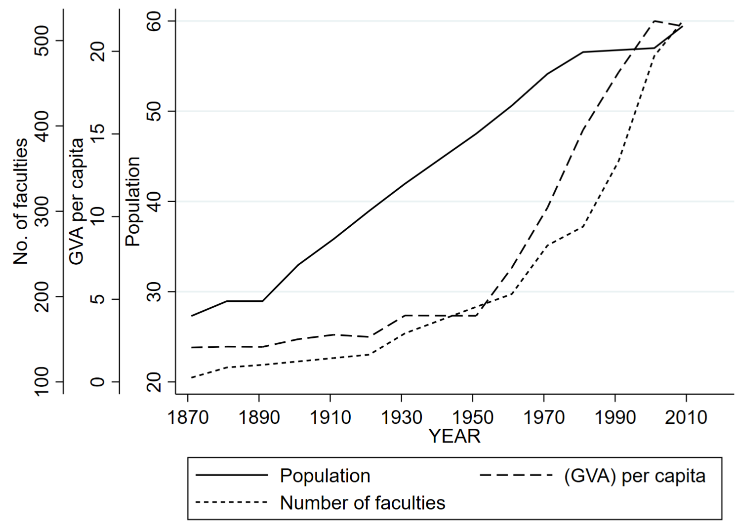
(c) by province population quartile



(d) no. of universities in EU4

Notes: Panel (a) reports the number of faculties in Italy by field of study. The STEM (i.e., Science, Technology, Engineering and Mathematics) group includes Agricultural Studies, Architecture, Chemistry, Pharmacy and Medical Studies, Geology and Biology, Engineering and Scientific Studies. The non-STEM group includes Social Sciences and Humanities. Where Social Sciences include Economics and Statistics, Law, and Sociopolitical Studies. Humanities include Education, Linguistic Studies, Literature, and Psychology. Panel (b) reports the number of faculties in Italy in the Northern, Central and Southern regions. Panel (c) shows the evolution in the total number of faculties in Italy between 1870 and 2010 in each quartile of the provincial population in 2010. Panel (d) presents the number of universities in EU4 (France, Germany, the UK and Italy). This is an index equal to 100 in the first year (1870).Authors' calculations based on HIU data and WHED data.

Figure 4: Higher education supply, GVA per capita and population 1870-2010.



Notes: Authors' calculations based on HIU and Census data.

2.3 Neighbourhood Effects on the Supply of Higher Education

The preceding discussion highlights the importance of considering the decentralised provision of education at the province level when analysing the economic effects of higher education supply. Using a framework from spatial economics might be suitable to discuss the forces triggered by this decentralised provision. In this setup, each province independently determines the local offering of higher education based on local student demand.[14] This scenario gives rise to neighbourhood effects within higher education supply, as multiple neighbouring provinces respond to the same local demand. Moreover, the Italian public higher education system lacks price-based competition due to substantially uniform and low tuition fees, which prevents provinces from enticing students by reducing local university fees.[15] Consequently, neighbourhood effects may largely be associated with the opening of new faculties: an additional faculty in a province could attract more students, thereby potentially reducing enrolment in faculties of neighbouring provinces, as admissions are generally free.[16]

[14]This approach is reminiscent of tax setting by autonomous jurisdictions (see, for example, Parchet, 2019), which is fully symmetric to traditional spatial competition models in the vein of Hotelling. In these models, it is the supplier that selects its position over space instead.

[15]Throughout our study period, universities do not face a binding budget constraint: public universities are financed by the central government through lump-sum transfers, which increase with both student admissions and past university expenditures.

[16]These neighbourhood effects arise naturally due to historical competitive forces. However, we cannot dismiss the possibility of other complementary mechanisms. For instance, there might be yardstick competition among provinces aiming to expand their higher education supply to increase public transfers from

This conceptual framework is based on two important assumptions. The first assumption concerns student mobility. Neighbourhood effects become noticeable when there is a certain degree of individual mobility, albeit confined primarily within the local neighbourhood due to high commuting costs outside that area. This *local mobility assumption* suggests that each province can cater to a limited portion of the national demand. As a result, province-level supply aligns with this local demand and contributes to the local supply of skills rather than the national one. Figure 5 below indicates that a significant portion of Italian high school graduates opt for higher education institutions within a distance of 150 km.[17] In Section 6 below, we validate that neighbourhood effects are concentrated within a comparable spatial reach (e.g. in terms of travel distance). We also show that these effects emerge in provinces located in geographically smooth areas with historically low out-migration rates, where the development of human capital becomes a critical aspect of the local labor supply. We interpret this as empirical evidence that supports the local mobility assumption (refer to Section 6 below).

The second assumption is that there exists a certain degree of differentiation, such as in teaching content, among faculties in neighbouring provinces. If student preferences exhibit heterogeneity and are influenced by both faculty proximity and study content, selecting the nearest faculty might not be the optimal choice. Provinces may take advantage of this dimension of heterogeneity and differentiate their supply accordingly. Our mechanism analysis in Section 6 indeed indicates that neighbourhood effects are particularly strong within the same field of study.

When these two assumptions are met, the establishment of a new faculty can lead to welfare benefits for provinces. A province will introduce a new faculty if it maximises local welfare. When doing so it will have to factor in the strategic responses of neighbouring provinces, which might foresee potential welfare reductions due to displacement of their own supply. In the empirical analysis, we extensively investigate the economic benefits from higher education supply, distinguishing between local returns and economic spillovers. In the welfare assessment detailed in Section 7, we will quantify the economic returns of higher education supply, net of neighbourhood effects at the province level.

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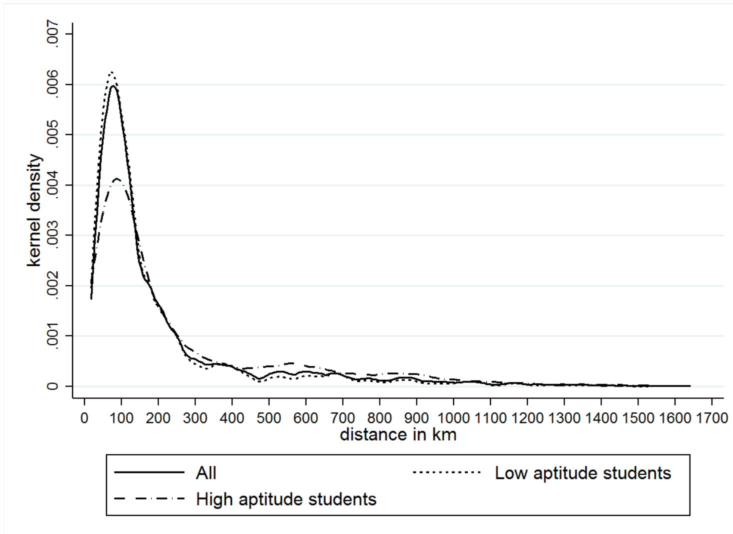
the central government. Political coordination could also play a role, such as if two provinces with similar demand agree on the choice of location.

[17] Mobility is less common among students with lower study aptitudes, a trend observed in the US as well (refer to Hoxby, 2016).

Figure 5: Students' mobility in faculty choice



Notes: Authors' calculations based on data from the Italian survey of high school graduates, 2007 (ISTAT). We define students' aptitude using their final grades at lower secondary schools, which are set on a four-point scale. High aptitude students are those with the highest grades (4), while low aptitude students are those with the lowest grades (1 or 2).

3 Data and Descriptive Statistics

Our main data archive is the History of Italian Universities (HIU). This is an own compiled original register that contains detailed information on higher education institutions in Italy, disaggregated at the faculty level. The dataset covers all years between 1861 and 2010.

Our primary source used to compile the HIU archive is Brizzi and Romano (2007), which we complemented using several sources on the history of specific universities (see, e.g., Fois, 1991 on the University of Sassari) and faculties (e.g., Silvestri, 2006 on engineering). We also heavily relied on *Gazzetta Ufficiale della Repubblica Italiana*, a weekly publication that collects every public act taken by the government since 1861. We double-checked all information against that provided by open-source archives, i.e., Wikipedia, universities' and faculties' websites.[18] We directly contacted the administrative representatives of faculties for which we could not find information from external sources. Finally, we validated the data against the current university list provided by the Italian Ministry for University, Education and Research (MIUR). In this way, we also verified that over the decades, there are very

[18]Since faculties no longer exist after 2010, their websites are not readily available on the web today. We retrieved them using the Wayback Machine (*https://web.archive.org/*), a digital archive of the Worldwide Web created by the internet archive.

few faculty closures: almost all faculties that were created in Italian history are still present in 2010.[19] The final HIU register includes the name of each faculty and its current address and 15 field identifiers, which we aggregated into 2 macro-areas of science: STEM and non-STEM.[20] Data include the year when the faculty appears as a legally recognised provider of higher education, the type of governance (private or public), and quality assessments according to the Casati ranking and its following updates (see online Appendix B for details).

In this paper, our focus is solely on higher education institutions that provide standard BSc education. Specifically, we consider 523 faculties located within 66 universities that were registered within the Italian territory from 1861 to 2010.[21] Using this sample, we construct a panel dataset at the province level, tracking the count of faculties present in each province for each year. We exclude the years 1861-1869, as this period coincides with the Italian unification process. Consequently, we create the fundamental province-level panel dataset for higher education institutions (referred to as the "HIU dataset"), which encompasses yearly observations for 110 provinces spanning from 1870 to 2010. As the number of provinces increases over time, this panel data is unbalanced. The primary variable of interest is the faculty count in province i, presented both as a total and categorised by macro-area of science. Additionally, we include details about the total count of universities, private universities, and universities categorised as A-, B-, or C-level in province i during time t. This province-level panel data forms the foundation for constructing the two primary samples used in our estimation processes.

We create our first sample by merging the province-level panel data with information on productivity indicators like Gross Value Added (GVA) per capita, and GVA per worker. These measures are adjusted for inflation and expressed in constant 2010 prices. We also incorporate indicators related to participation and employment shares within sectors such as industry, agriculture, and services. These data points are sourced from Italian censuses

[19] The only two exceptions are one scientific faculty (Chemical Studies) at Ca' Foscari University of Venezia, which was closed in 1990, and two scientific faculties (Environmental Sciences and Mathematical Sciences) at University of Urbino, which were closed in 2000. Moreover, four faculties of Engineering from the Polytechnic of Milano were closed and reopened with a different denomination and location in 2000.

[20] The former group includes Agricultural Studies, Architecture, Chemistry and Pharmacy, Medical Studies, Geology and Biology, Engineering, and Scientific Studies. The latter includes both Humanities (Education, Linguistic Studies, Literature, and Psychology) and Social Sciences (i.e. Economics and Statistics, Law, and Sociopolitical Studies).

[21] For practical reasons, we exclude universities that solely offer postgraduate education, single courses, or cater exclusively to foreign students. This group includes institutions like Universita' di Scienze Gastronomiche, Universita' Europea di Roma, Universita' Normale di Pisa, Scuola IMT Alti Studi di Lucca, Scuola superiore di studi universitari e perfezionamento "S. Anna" di Pisa, Universita' degli studi di Roma Foro Italico, Istituto universitario di studi superiori di Pavia, Scuola internazionale superiore di studi avanzati di Trieste, Universita' per Stranieri di Siena, and Università per Stranieri di Perugia.

conducted at ten-years intervals, encompassing the period from 1870 to 2010.[22] After successfully merging the HIU data with census data, our resulting dataset comprises a total of 1275 observations covering 110 provinces. These observations are recorded every ten years, spanning the timeline from 1870 to 2010.

For our second sample, we match each province i with the higher education supply of all its neighbouring provinces j. To establish these neighbouring relationships, we employ a matrix that documents contiguity connections among the 110 provinces. We also compute alternate matrices grounded in linear distance, travel distance, and travel time. Comprehensive details are available in the subsequent sections and the online Appendix B. Allowing pairwise relationships between provinces i and j increases the sample size by approximately four times (as each province i has roughly four neighbours, on average). Moreover, to align with the matched HIU-census sample, we adhere to the same ten-year structure for this paired dataset. As a result, our second working sample encompasses 5536 province pairs denoted as "ij", maintaining the contiguity relationship over the period spanning 1870 to 2010.

Table 2 presents summary statistics for the main variables in both samples. Panel A describes the local higher education supply from the matched HIU-census dataset at the province level. On average, each province has a supply of over 2.6 faculties, mostly in STEM. Each province has approximately 0.5 universities, of which 7% are private, and around 40% are classified as of level A.

Panel B turns to pairwise relationships, and reports the higher education supply of each individual neighbour j of province i. Our main objective is to model the local neighbourhood effects between the 110 provinces in our sample with the utmost precision. To accomplish this, we carefully consider the changes in provincial borders that occurred during Italian history, particularly due to the gradual creation of 41 new provinces. This approach allows us to capture evolving neighbourhood relationships (i.e., the sample of js for each i) over the 1870-2010 period.[23] It is important to notice that new provinces on the Italian territory are born without an own supply of higher education.[24] All in all, a representative neighbour,

[22] An exception is the 9^{th} wave of the Italian census, which, due to WWII, was carried out in 1936 instead of 1941. This interval deviates from the typical ten-year pattern, occurring five years after the prior wave and fifteen years before the subsequent one. Refer to Section B4 in the online Appendix for further information.

[23] For instance, let us consider the province of Treviso as an illustrative example. In 1866, when it became part of the Kingdom of Italy, we identify the contiguous provinces of Udine, Belluno, Padova, Venezia, and Vicenza as neighbours of Treviso. However, starting from 1968, the new province of Pordenone is established on the former territory of the province of Udine, situated at the border with Treviso. As a result, from 1968 onwards, Pordenone replaces Udine in the set of neighbours associated with Treviso

[24] The only exception is the province of Monza-Brianza, that is established in 2004 with one faculty of Medicine that used to belong to the province of Milano before.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Panel A: Higher education supply in province i					
no. of faculties in i	2.619	4.319	0	38	1275
no. of STEM faculties in i	1.387	2.16	0	12	1275
no. of non-STEM faculties in i	1.232	2.375	0	26	1275
no. of universities in i	0.472	0.789	0	7	1275
no. of private universities in i	0.069	0.336	0	4	1275
no. of A-level universities in i	0.366	0.602	0	3	1275
no. of faculties in $-i$ (neighbourhood of i)	12.718	10.475	0	68	1275
no. of universities in $-i$	2.213	1.687	0	11	1275
Panel B: Higher education supply of neighbouring province, j					
no. of faculties in j	2.952	4.61	0	38	5536
no. of STEM faculties in j	1.567	2.268	0	12	5536
no. of non-STEM faculties in j	1.385	2.576	0	26	5536
no. of universities in j	0.513	0.837	0	7	5536
no. of private universities in j	0.082	0.386	0	4	5536
no. of A-level universities in j	0.397	0.617	0	3	5536
Panel C: Economic and demographic characteristics of province i					
Gross Value Added per capita, real terms (in 000s)	9.095	8.525	1.402	91.100	1275
Gross Value Added per worker, real terms(in 000s)	21.589	19.795	2.918	206.397	1275
Population (in 000 000)	0.517	0.469	0.057	4.018	1275
Population density (100 inhabitants per km^2)	2.171	2.882	0.244	25.949	1275
Participation rate	44.491	7.586	25.478	98.571	1275
% of employed in industry	28.686	11.271	6.562	72.864	1275
% of employed in agriculture	38.752	25.926	0.646	85.686	1275
% of employed in services	32.562	19.74	6.643	84.243	1275
Industry-to-agriculture employment ratio	2.89	5.595	0.077	57.81	1275
Service-to-industry employment ratio	1.182	0.769	0.241	6.05	1275
Service-to-agriculture employment ratio	4.363	9.618	0.078	121.492	1275

Notes: Authors' calculation based on HIU data, ISTAT (Italian National Institute of Statistics), and Istituto Tagliacarne. Panels A and C consist of province-level data extracted from 15 waves of Italian Censuses conducted between 1870 and 2010. Panel B includes province pair information for the same time span. The Italian Census is typically conducted once every ten years, except for the 1936 census, which took place 5 years after the previous one held in 1931 and 15 years before the subsequent one in 1951. Gross Value Added (per capita or per worker) in real terms is expressed in euros at 2010 constant prices.

on average, has approximately 2.95 faculties; other figures are similar to those displayed in Panel A.

Finally, Panel C reports province-level historical information on local economy and demography. On average, in our sample, each province presents a yearly real GVA per capita equal to 9000 euros (constant 2010 prices) and a population of 517 thousand individuals. Approximately 45% of the population is active in the labor market, with 28% working in the industry sector, 38% in the agricultural sector, and 32% in the service sector.[25]

[25]It should be noted that in historical census data, the definition of active population is very blurred as unemployed individuals were not counted until 1961.

4 Empirical Strategy

In this section, we outline our empirical approach. We first describe the model used to estimate neighbourhood effects on local higher education supply. Then, we calculate province-level returns for both local and neighbouring higher education supply in terms of real GVA per capita. These coefficients form the basis for the welfare analysis outlined in Section 7.

Neighbourhood Effects of Higher Education Supply. We estimate neighbourhood effects by specifying the higher education supply F in the i-th Italian province at time t as a function of the corresponding supply in their neighbouring provinces js. Our baseline specification is a linear spatial competition model based on geographical contiguity, where neighbours are all provinces j that share a border with i. We also use alternative models based on linear distance, travel distance, and travel time.[26] All models feature heterogeneous neighbourhood relationships, which are immune to Manski (1993)'s reflection issues.[27]

We estimate a "pairwise" model, which is well suited to account for the omitted determinants of province i's supply (e.g., related to geographical factors) that are spatially correlated with those of its j neighbours (see Parchet, 2019):

$$F_{ijt} = a + bF_{jt-10} + c_{ij} + d_{r(i)jt} + X_{ijt-10}f + e_{ijt}. \tag{1}$$

F_{ijt} and F_{jt} are the higher education supply of province i, and each of its neighbouring provinces j, respectively.

Equation (1) can be estimated for all contiguous ij pairs in our dataset. Each pair of provinces is included twice in the equation, once on the left side and once on the right side. As noted earlier, we account for shifts in provincial borders that occurred throughout Italian history. This approach acknowledges that neighbourhood relationships (i.e., the set of js for each i) evolve over the period from 1870 to 2010.[28] In the equation, c_{ij} represents the fixed effect of the pair, capturing time-invariant omitted factors for each ij couple. $d_{r(i)jt}$ denotes region-by-year fixed effects (where $r(i)$ refers to the region to which province i belongs). X_{ijt} is a vector of time-varying covariates from province i and its neighbour j. In the

[26]This is done in Table 5, and in Table A-X in the online Appendix D.

[27]The reflection problem arises when interactions occur in a fixed "reference group". Neighbourhood relationships (e.g., based on distance, contiguity, and travel time) imply that each Italian province interacts in a different way with all other provinces, so reference groups differ for different provinces. By definition, these groups only partially overlap because the sets of neighbours of two provinces do not perfectly coincide. See De Giorgi et al. (2010) for a detailed discussion in the context of social interactions.

[28]In the online Appendix C, we explore alternative definitions of province borders that keep neighbourhood relationships constant over the time span (see Table A-V).

baseline specification, this includes the total number of universities in each province and for each neighbour. In this way we isolate the neighbourhood relationships that pertain to the faculty-level provision (e.g. teaching units, curricula etc) from any 'higher scale' aggregate interactions that concerns the opening of bigger institutions such as universities. These are less likely to react and quickly adjust to changes in the local environment. The inclusion of the number of universities in vector X_{ijt} makes sure that estimated effects are only induced by changes in the number of faculties, keeping constant that of universities. Otherwise, one would wonder whether the estimated neighbouring effect attributed to the change in faculties is a convolution of two different forces: the faculty effect and the effect of opening new universities.[29]

In sensitivity analyses, we also consider additional potentially relevant covariates such as population growth, the share of the active population in agriculture, controls for higher education quality in the province, and geographical accessibility.[30]

The heterogeneity that is left in equation (1) after the inclusion of the province pair fixed effects and region-by-year fixed effects is the variability over time across province pairs within the same region. Our main coefficient of interest is b, which captures the average effect of each neighbour j supply on the local supply of province i. Identification of this coefficient is achieved through a comparison of different time-varying patterns in the number of faculties across provinces. As discussed in Section 2 above, several actors are involved in the decision to open a new faculty, which implies a delay in the effect of neighbours on local supply. For this reason equation (1) models a ten-year lagged effect.

Productivity Effects of Higher Education Supply. We estimate the following model:

$$Y_{it} = \phi_1 F_{it-10} + \phi_2 F_{-it-10} + X_{it-10}\phi_3 + \varphi_i + \xi_{r(i),t} + \mu_{it}. \tag{2}$$

where Y_{it} is GVA per capita in province i at time t, in real terms.[31] F_{it-10} is the total

[29]Notice that a separate empirical identification of the effect of universities from the effect of faculties requires that each university does not consist of a relatively constant number of faculties overtime. This is exactly the case of Italy, where the variability over time in the number of faculties within universities is substantial.

[30]This information is presented in Table C-3 in Appendix C. To evaluate higher education quality, we include variables like the count of private and A-level universities, along with interactions involving the notability index developed by De la Croix et al. (2020) with university counts in both i and j. However, we avoid including all these province-level controls in the baseline estimates due to the potential problem of "bad controls" over the extensive 150-year period. Including bad controls can introduce bias to the estimates of the parameters of interest, even when the related regressors are fully exogenous (Angrist and Pischke, 2009).

[31]This definition is broadly equivalent to the Gross Domestic Product which is indeed the sum of the GVA

number of faculties in province i at time $t-10$. $F_{-it-10} = \sum_j F_{ijt-10}$ is the total number of faculties in the neighbourhood of province i at time $t-10$. X_{it-10} is the same vector of province-level controls as in equation (1) above, including the total number of universities in province i and its $-i$ neighbourhood. This is different from Valero and Van Reenen (2019), whose analysis is at the university level. Our aim is to show that a non negligible part of productivity effects of higher education happens at a more disaggregated level (the supply of faculties), conditional on the supply of universities.[32] Accordingly, we include province FEs, φ_i, and region-by-year FEs, $\xi_{r(i),t}$. Finally, μ_{it} is the error term.

For both equation (1) and (2) we exploit time variation consistent with the 10 years' timeline imposed by census data collection. This implies that over the 150-year sample period, we exploit an unbalanced panel with $T = 15$ covering the period of 1870-2010. Our main parameters of interest are b from equation (1), and ϕ_1 and ϕ_2 from equation (2). These measure the average effect of each neighbour j's supply on the local supply of province i, and the marginal product of higher education supply in province i and its neighbourhood, respectively. The estimated values of these coefficients will serve to quantify the total contribution of higher education supply to the economic welfare of the local province, distinguishing between effects of local supply, and net externalities coming from the neighbourhood. We will return to this calculation in Section 7 below.

Estimation Issues and Identification. The two models just discussed present endogeneity concerns. The most important one is omitted variables. In equation (1), unobservable time-varying determinants of one province's number of faculties (e.g., local economic conditions, shocks and demand for higher education) are likely spatially correlated such that $cov(e_{ijt}, F_{ijt}|c_{ij}, d_{r(i)jt}, X_{ijt}) \neq 0$. Even if these factors were region specific, they would not be captured by region-by-year fixed effects as long as not all neighbours belong to the same region as province i. Similarly, omitted factors in equation (2) may motivate both an increase in GVA per capita, and the opening of faculty such that $cov(\mu_{it}, F_{it-10}|\varphi_i, \xi_{r(i)t}, X_{it}) \neq 0$ and $cov(\mu_{it}, F_{-it-10}|\varphi_i, \xi_{r(i)t}, X_{it}) \neq 0$. Despite these are mitigated by the use of ten years' lagged effects, there are also concerns of reverse causality. In equation (1), the number of faculties of a neighbouring set of provinces itself depends on the number of faculties of province i. In equation (2) richer and/or more productive provinces may express higher (or lower) demand

created through the production of goods and services in the individual sectors of the economy. Conceptually, the main differences between GVA and GDP based definition of output regards financial intermediation services and product taxes, which are not counted into GVA (while they are in GDP).

[32] We perform the same set of robustness checks as for equation (1) and control for population growth, the share of the active population in agriculture, controls for higher education quality in the province, and geographical accessibility (see Table C-3 in Appendix C).

for higher education. Thus, the opening of a faculty may result from this demand.

To address endogeneity concerns, we implement a Bartik instrumental variables approach that exploits cross-provincial variation in the distribution of faculties observed at some initial time t_0, which denotes some precise moment before the Italian unification (see more below on the choice of t_0). These faculties provide the initial conditions of the Italian higher education supply. Call IC_{it_0} the total number of faculties operating in province i at time t_0, such that we can compute the province i's share of the total supply in the Kingdom of Italy at that time, i.e.:

$$sh_{it_0} = \frac{IC_{it_0}}{\sum_i IC_{it_0}}. \tag{3}$$

We construct respective Bartik indicators B_{it} and B_{jt} as the counterfactual number of faculties in provinces i and j at time t, as we allocate to each province the number of faculties observed in Italy at time t, according to its respective initial share at time t_0. We also construct a synthetic Bartik indicator B_{-it} for the neighbourhood of i:

$$\begin{aligned} B_{it} &= sh_{it_0} * F_t, \quad \textit{where} \quad F_t = \sum_i F_{it}; \\ B_{jt} &= sh_{jt_0} * F_{-it}, \quad \textit{where} \quad F_{-it} = \sum_{j \neq i} F_{jt}; \\ B_{-it} &= \sum_j B_{jt} = \sum_{j \neq i} sh_{jt_0} F_{-it}. \end{aligned} \tag{4}$$

By looking at (4), our IV approach consists of using ten years lagged values of B_{jt} as an instrument for F_{jt-10} in equation (1); ten years lagged values of B_{it} as an instrument for F_{it-10} in equation (2); ten years lagged values of B_{-it} as an instrument for F_{-it-10} in equation (2). This approach features a research design whereby initial conditions measure the exposure of pre-unitarian provinces to the faculty growth process during Italian history (cfr. Figure 3). This is an exogenous 'shift' to the higher education supply of each individual province. As discussed in Section 2.2 above, the faculty creation process over Italian history is driven by general higher education reforms, which are independent of previous provincial conditions and likely uncorrelated with past shocks. Following Goldsmith-Pinkham et al. (2020), we argue that the identification of Bartik instruments (4) comes from the cross-province variation of IC_{it_0} and IC_{jt_0}, through respective initial shares. Higher education institutions inherited from the past had a persistent impact on the process of faculty creation at the province level. Throughout the analysis, we measure initial conditions at $t_0 = 1860$, and $t_0 = 1700$. The former timing captures the annexion of pre-unitarian provinces to the Kingdom of Italy,[33] while the latter predates the Age of Enlightment and the industrial revolution in Italy, being predetermined to the sharp acceleration in the supply of faculties in the second half of the 18th century (cfr. Panel (a) of Figure 1). In the robustness section, we also consider earlier timings, back to 1400, i.e. the end of a century of declining population (cfr. Panel (b) of Figure 1).

As our IV approach builds upon the exogeneity of initial conditions, in Table 3, we present correlations between the initial distribution of the number of faculties and observable characteristics of province i before the start of our sample period. In Columns [1]-[8], we check whether initial conditions correlate with time invariant characteristics at the onset of Italian unification. We consider linear distances (in km) from Bologna (i.e., the city with the oldest active university), Roma (the capital of the Italian Kingdom during our sample period), the respective capital of each pre-unitarian state (cfr. Figure A-II in online Appendix A), GVA per capita, the share of workers in the agriculture and industry sectors, urbanisation rate, and total population density. In Columns [9] and [10], we consider population growth between 800AD and 1500, and between 1500 and time t_0, when we measure initial conditions. These correlations are meant to capture any long-term historical pre-trends during different epochs. We subject these correlations to an alternative clustering of standard errors. We report standard errors clustered at the NUTS2 level between (...). Standard errors are clustered at the NUTS1 level between [...] and at the level of the pre-unitarian state the province belonged to between {...}.

With very few statistically significant correlations, evidence in Table 3 does not suggest historical factors that pose a systematic threat to our identifying assumptions. Panel A presents the battery of correlations of the respective IC_js, with the aforementioned set of preexisting characteristics of province i as we set $t_0 = 1860$. This first battery of tests suggests that IC_js are uncorrelated with linear distances and time invariant economic characteristics of province i (cfr. Columns [1]-[8]). A negative correlation emerges with the initial level of population density, which however becomes statistically not significant as we cluster standard errors at the pre-unitarian state level. Tests of pre-trends in Columns [9] and [10] evidence a negative spillover from population growth during the 1500-1860 period. Panel B presents the same battery of correlations for the IC_is instead. The first set of tests on time invariant characteristics now suggests a positive significant correlation of initial conditions with the share of industry, and local population density (cfr. Columns [6] and [8]). Further to that, an inspection of changes into the pre-sample period reveals a statistically significant pre-trend relating to population growth between 1500-1860 (cfr. Column [11]), which

[33] We adopt the notation $t_0 = 1860$ for simplicity but this is not precise. Belluno, Padova, Rovigo, Treviso, Udine, Verona, Vicenza, Venezia, Mantova, and Roma became part of Italy between 1866 and 1870.

Table 3: Balancing and Pre-trend analysis for IC_j and IC_i.

	Initial Levels (in 1861)								**Pre-trends**	
	[1] dist. of i, Bologna	[2] dist. of i, Roma	[3] dist. of i Capital	[4] per capita GVA of i	[5] share of agric. in i	[6] share of industry in i	[7] urban. in i (> 6000 inh.)	[8] total pop. density	[9] $\Delta_{800-1500}$ pop. in i	[10] Δ_{1500-t_0} pop. in i
Initial conditions: $t_0 = 1860$										
A) IC_j	–0.0010	–0.0007	–0.0001	0.3784	–0.0048	–0.0142	–0.6109	–0.0012	3.1237	–1.8473
	(0.0010)	(0.0014)	(0.0013)	(0.6836)	(0.0079)	(0.0167)	(0.9122)	(0.0003)***	(3.3786)	(0.4875) ***
	[0.0006]	[0.0017]	[0.0013]	[0.7926]	[0.0076]	[0.0191]	[0.6184]	[0.0005]*	[5.1109]	[0.8250]*
	{0.0012}	{0.0010}	{0.0014}	{0.9197}	{0.0062}	{0.0151}	{0.7251}	{0.0006}	{3.4460}	{0.5053}**
Observations	286	286	286	286	286	286	239	286	286	286
B) IC_i	–0.0007	–0.0008	–0.0006	1.6973	–0.0429	0.0395	0.7859	0.0037	–10.5807	2.7827
	(0.0009)	(0.0016)	(0.0019)	(1.1806)	(0.0233)*	(0.0347)***	(1.2903)***	(0.0006)	(5.4222)	(1.7422)
	[0.0008]	[0.0018]	[0.0011]	[1.2095]	[0.0265]	[0.0322]	[0.5615]	[0.0007]***	[7.0213]	[0.8633]**
	{0.0011}	{0.0013}	{0.0022}	{1.2111}	{0.0211}	{0.0099}**	{1.1000}	{0.0007}***	{5.7625}	{1.1661}*
Observations	69	69	69	69	69	69	59	69	69	69
Initial conditions: $t_0 = 1860$, without provinces in the top population decile										
C) IC_j	–0.0008	–0.0004	–0.0005	0.7907	–0.0118	–0.0054	–0.0311	–0.0016	4.2986	–1.5042
	(0.0009)	(0.0018)	(0.0015)	(0.7362)	(0.0073)	(0.0174)	(0.7529)	(0.0030)	(3.5391)	(0.4955)***
	[0.0005]	[0.0022]	[0.0014]	[0.8962]	[0.0104]	[0.0226]	[0.6943]	[0.0050]	[5.3433]	[1.0378]
	{0.0011}	{0.0015}	{0.0014}	{0.9632}	{0.0120}	{0.0165}	{0.3273}	{0.0044}	{3.8794}	{0.5163}**
Observations	254	254	254	254	254	254	212	254	254	254
D) IC_i	–0.0007	0.0002	0.0019	0.3845	–0.0268	0.0304	0.3791	0.0074	–13.2706	1.4551
	(0.0011)	(0.0013)	(0.0016)	(1.1736)	(0.0187)	(0.0331)	(0.5802)	(0.0056)	(5.3017)**	(1.6602)
	[0.0007]	[0.0016]	[0.0017]	[1.4404]	[0.0199]	[0.0257]	[0.4790]	[0.0055]	[6.9956]	[1.4389]
	{0.0014}	{0.0017}	{0.0017}	{1.4853}	{0.0141}	{0.0206}	{0.7787}	{0.0046}	{6.4548}	{1.7582}
Observations	61	61	61	61	61	61	52	61	61	61
Initial conditions: $t_0 = 1700$										
E) IC_j	–0.0009	–0.0007	0.0006	0.3125	–0.0030	–0.0085	–0.4819	–0.0007	–0.3846	9.0179
	(0.0006)	(0.0008)	(0.0007)	(0.4263)	(0.0042)	(0.0081)	(0.5275)	(0.0002)***	(2.3629)	(13.7687)
	[0.0003]**	[0.0009]	[0.0009]	[0.5627]	[0.0038]	[0.0083]	[0.3585]	[0.0003]**	[3.0012]	[9.6263]
	{0.0008}	{0.0008}	{0.0007}	{0.5982}	{0.0043}	{0.0072}	{0.4958}	{0.0004}*	{1.7126}	{18.1201}
Observations	286	286	286	286	286	286	239	286	286	286
F) IC_i	–0.0007	–0.0008	0.0008	0.5583	–0.0130	–0.0002	0.1904	0.0009	–5.8161	11.5749
	(0.0006)	(0.0009)	(0.0012)	(0.7174)	(0.0106)	(0.0174)	(0.5142)	(0.0005)	(3.6941)	(24.4610)
	[0.0005]	[0.0010]	[0.0010]	[0.8530]	[0.0105]	[0.0138]	[0.2952]	[0.0005]	[4.9745]	[16.3630]
	{0.0007}	{0.0011}	{0.0011}	{0.9075}	{0.0091}	{0.0090}	{0.4456}	{0.0005}	{4.5848}	{27.9605}
Observations	69	69	69	69	69	69	59	69	69	69

Notes: In Columns [1]-[8], we report correlations of initial conditions with time invariant characteristics of province i. The urbanisation rate is measured in 1861 for provinces that already belonged to the Italian Kingdom by then. All other variables are measured in 1870 for Belluno, Mantova, Padova, Roma, Rovigo, Treviso, Udine, Vicenza, and Verona and in 1861 for all other provinces. For column [3] refer to Figure A-II in the online Appendix A1 for identifying the capital cities of pre-unitarian regions.In Columns [9] and [10], we report correlations of initial conditions with growth rates of province i's population as reported in each column. Standard errors are clustered at the NUTS2 regional level between (). Standard errors are clustered at the NUTS1 regional level between []. Standard errors are clustered at the level of the pre-unitarian country between {}. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

becomes less evident when we split the sample by geographic area (see Table A-III in the online Appendix). This last correlation suggests some potential co-growth between population, demand for human capital, and faculty creation starting after the end of Middle-Ages in line with predictions by the Unified Growth Theory (Galor, 2011). In Panels C and D, we replicate the battery of tests after excluding provinces in the top decile of the population distribution back in 1500. All correlations become non-significant, with the only exception of the negative spillover between population growth during 1500-1860 to initial conditions of neighbours (Cfr. Panel C, Column [10]). Finally, in Panels E and F, we perform the same battery of correlation tests as we set $t_0 = 1700$. These tests still showcase some correlation of IC_js with the level of population density in Column [9]; however (and more importantly), we no longer observe any significant population pre-trend in Columns [9] and [10]. This is reassuring against endogeneity concerns - e.g., reverse causality, going from economic development to demand for technical skills, and thus the distribution of faculties (particularly in STEM fields) measured in 1700.

In the empirical section, we also verify that our main results hold when we anticipate further initial conditions to 1600, 1500, and 1400, thus even before the start of the Renaissance. We present an extensive sensitivity analysis that ensures that our empirical results are not driven by other omitted factors that could have affected the initial distribution of faculties among pre-unitarian provinces and might be correlated with local observable characteristics. First, we present the outcomes of a comprehensive set of robustness checks designed to address various forms of spatial auto-correlation, which could potentially introduce bias into our estimates. Second, we examine the results of additional robustness and placebo tests that serve to further validate our identifying assumptions. This thorough battery of robustness checks consistently yields similar qualitative and quantitative outcomes (see Section 5.1 and online Appendix C for detailed information). This reinforces our confidence that our estimates of b, ϕ_1, and ϕ_2 are not being determined by unaccounted factors or outliers. This is a prerequisite for conducting the welfare analysis in Section 7.

While evidence presented in this section seems reassuring, it is worth noting that any underlying omitted factors deeply correlated with the cross-provincial distribution of initial conditions, such as cultural aspects, would not invalidate our analysis. Rather, it would prompt an interpretation of F_i and F_{-i} as "proximate" determinants of local welfare, albeit not exact ones.[34]

[34] We acknowledge Nico Voigtländer for highlighting this insightful point.

5 Empirical Results

Table 4 showcases the main empirical findings. Panel A presents the outcomes of neighbourhood effects derived from equation (1), while Panel B displays the estimates of productivity effects from equation (2). In Columns [1]-[4], we presents results for all provinces in our sample (110 in the baseline), while Columns [5]-[8] concentrate solely on pre-unitarian provinces (69 in the baseline). We present OLS FE estimates (Columns [1], [5]), and three different IV FE estimates. In the first IV estimation (Columns [2], and [6]), we use Bartik instrument which considers $t_0 = 1860$. In the second one (Columns [3], [7]), we still use $t_0 = 1860$, and drop provinces in the top decile of the population distribution. In the third (Columns [4], [8]), we assume $t_0 = 1700$ instead. In all estimations, we cluster standard errors at the level of the local province.[35]

First stage results are satisfactory in both panels. The first stage coefficients of each Bartik instrument are strongly correlated with their corresponding indicator for the total number of faculties. F-statistics signal that instruments have strong predictive power.[36] In Panel A, the coefficient of the total number of faculties in a neighbouring province is always negative and significant at the 1% or 5% level for both OLS FE and IV FE estimates, irrespective of the specification. IV FE coefficients are up to five times larger than the corresponding OLS FE coefficient. This observation suggests that unobservable and time-varying factors contribute to increasing the number of faculties in both province i and its neighbours. These factors diminish the OLS estimates of neighbourhood effects. As discussed above, a plausible explanation for this trend lies in technical advancements under the Post-Malthusian regime, which generate a local demand for human capital. This may induce an expansion of higher education supply in both province i and province j, consequently moderating the neighbourhood effects estimated by equation (1) using the OLS FE model.[37]

Taken at face value, IV FE estimates of Panel A suggest that having one faculty more

[35] Appendix C showcases results obtained through clustering standard errors at the regional or kingdom level, along with outcomes of equation (1) featuring two-way clustered standard errors at the ij level (refer to Table C-2). These methodologies enable us to address potential concerns regarding correlation and heteroskedasticity within the data, thereby reinforcing the robustness of our findings.

[36] It should be acknowledged that in dyadic regressions such as those presented in Panel A having multiple similar entries may result in inflated t-stat and F-stat values compared to having only one entry for each province-time combination. We thank an anonymous referee for this remark. In online Appendix D we provide a detailed discussion and argue that a reasonable estimate of the correct F-stat is lower than the F-stat computed in Table 4 Panel A, but still safely above the standard threshold level of 10. See Table A-XIII.

[37] Other potential factors that could counteract these effects include administrative agreements, political arrangements, or the establishment of forty-one new provinces throughout Italian history, which might mitigate competition among existing ij pairs. We explore some of these hypotheses in the sensitivity analysis.

Table 4: Neighbourhood and productivity effects in the higher education supply.

	All provinces				Pre-unitarian provinces			
	[1] OLS FE	[2] IV FE (t_0=1860)	[3] IV FE (t_0=1860; drop top pop decile)	[4] IV FE (t_0=1700)	[5] OLS FE	[6] IV FE (t_0=1860)	[7] IV FE (t_0=1860; drop top pop decile)	[8] IV FE (t_0=1700)
Panel A: Neighbourhood effects								
Total no. faculties in j	-0.088**	-0.217***	-0.129***	-0.260***	-0.042*	-0.162**	-0.155**	-0.205**
	(0.042)	(0.074)	(0.048)	(0.094)	(0.023)	(0.066)	(0.065)	(0.094)
Total no. of universities in i	3.339***	3.288***	2.633***	3.271***	3.651***	3.595***	2.453***	3.575***
	(0.683)	(0.626)	(0.318)	(0.627)	(0.639)	(0.593)	(0.467)	(0.595)
Total no. of universities in j	0.023	0.018	0.011	0.017	0.015	0.005	0.003	0.001
	(0.022)	(0.024)	(0.013)	(0.026)	(0.025)	(0.025)	(0.015)	(0.028)
K-P rk Wald F-stat		54.996	46.711	40.894		50.558	39.140	29.650
K-P rk LM-stat		38.154	33.518	30.230		28.527	23.574	20.672
p-value KP		0.000	0.000	0.000		0.000	0.000	0.000
		F_jt	F_jt	F_jt		F_jt	F_jt	F_jt
B_{jt}		0.311***	0.280***	0.236***		0.305***	0.280***	0.203***
		(0.042)	(0.045)	(0.037)		(0.040)	(0.045)	(0.037)
Observations	5209	5209	4703	5209	3868	3868	3496	3868
Panel B: Productivity								
Total no. faculties in i	0.287***	0.326***	0.327**	0.349***	0.241**	0.283**	0.333**	0.311**
	(0.071)	(0.102)	(0.134)	(0.109)	(0.115)	(0.136)	(0.150)	(0.150)
Total no. faculties in $-i$	0.060*	0.108**	0.095*	0.127**	0.071*	0.116**	0.092*	0.130**
	(0.035)	(0.053)	(0.053)	(0.050)	(0.039)	(0.056)	(0.056)	(0.052)
Total no. of universities in i	-0.093	-0.245	-0.406	-0.329	0.123	-0.044	-0.190	-0.142
	(0.702)	(0.632)	(0.501)	(0.609)	(0.932)	(0.791)	(0.518)	(0.762)
Total no. of universities in $-i$	-0.101	-0.256	-0.458*	-0.319	-0.161	-0.307	-0.445*	-0.349
	(0.223)	(0.256)	(0.240)	(0.241)	(0.257)	(0.278)	(0.255)	(0.256)
K-P rk Wald F-stat		10.751	18.083	12.602		22.819	12.514	34.063
K-P rk LM-stat		18.551	22.132	14.900		22.315	20.085	14.136
p-value KP		0.000	0.000	0.000		0.000	0.000	0.000

	[1]	[2] F_{it}	[2] F_{-it}	[3] F_{it}	[3] F_{-it}	[4] F_{it}	[4] F_{-it}	[5]	[6] F_{it}	[6] F_{-it}	[7] F_{it}	[7] F_{-it}	[8] F_{it}	[8] F_{-it}
B_{it}		0.301***	0.045	0.268***	0.085	0.261***	0.052		0.247***	0.093	0.261***	0.085	0.208***	0.095
		(0.060)	(0.091)	(0.040)	(0.087)	(0.050)	(0.079)		(0.037)	(0.080)	(0.041)	(0.092)	(0.025)	(0.067)
B_{-it}		-0.002	0.336***	-0.005	0.329***	-0.012	0.293***		0.012	0.325***	-0.003	0.333**	-0.002	0.289****
		(0.022)	(0.053)	(0.017)	(0.053)	(0.019)	(0.046)		(0.020)	(0.054)	(0.018)	(0.057)	(0.018)	(0.047)
Observations	1231	1231		1112		1231		1025	1025		906		1025	

Notes:. Regressions in Column [1] are based upon the entire set of provinces, including those established during 1870-2010 (these are 110 provinces). Regressions in Column [2] exploit the sample of pre-unitarian provinces only for the entire period (these are 69 provinces). In each column, we present three sets of IV FE estimates (which are performed using 2SLS estimation) with Bartik instruments. The first set computed the instruments using initial conditions at time $t_0 = 1860$; the second set uses initial conditions at time $t_0 = 1700$. The third set considers $t_0 = 1860$, but excludes provinces that belonged to the top decile of the Italian total population in 1500 (Bari, Caserta, Como, Lecce, Milano, Napoli, Roma, Torino). This implies the last set of IV estimates is based on a sample of Regressions of 102 provinces in Column [1], and 61 provinces in Column [2]. In all regressions we take 10 years lags of regressor and controls. Specifications in Panel A include province pair fixed effects. Specifications in Panel B include province fixed effects. All specifications include region-by-year fixed effects. They also include the total number of universities in province i, and its neighbours (at the level of j province in Panel A, and in the neighbourhood $-i$ in Panel B) as provincial controls. In IV estimates, the total number of faculties in province i, j, $-i$ is instrumented by the respective Bartik instrument B_{it}, B_{jt}, B_{-it}, as they are defined in equation (4) above. Standard errors clustered at the level of the local province are reported in parentheses. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

in province j is associated with a decrease by $0.16 - 0.26$ local faculties in province i, on average. We can better gauge the magnitude of this effect considering that each Italian province has four neighbours, on average. IV FE estimates in Column [6] suggest that a one standard deviation increase in higher education supply in each neighbour j (4.61 faculties) results in up to $-2.95 (= -0.16 * 4.61 * 4)$ faculties in province i over a ten years' period. This is a decrease in local supply as large as the sample mean, and two thirds of the standard deviation of local supply of province i (cfr. Table 2).

Turning to productivity effects, in Panel B, the estimated coefficients of the total number of faculties in province i and its neighbourhood are positive and statistically significant. Compared to Panel A, the higher similarity in the size of coefficients between OLS FE and IV FE suggests that province and region-by-year fixed effects already account for many time-varying unobserved factors that influence both productivity and higher education supply at the provincial level. From these coefficients, we quantify GVA returns of higher education supply, thus the opportunity cost of neighbourhood effects in productivity terms. IV FE estimates suggest that, on average, one more faculty in the local province is worth about 280€-350€per capita after ten years, while one more faculty in the neighbourhood is worth 90€-130€per capita to the local province (after ten years). More precisely, IV FE estimates in, e.g., Column [6] imply that one standard deviation increase in local supply (4.3 faculties) and neighbours' supply (11.9 faculties) create in ten years per capita value to the local province up to 2597€$= (283 * 4.3 + 116 * 11.9)$. This is equivalent to about one third of a standard deviation of GVA per capita. Notice that these are effects determined by a large scale intervention that increases the relevant supply of higher education by 16.2 faculties in total (summing up local and neighbours' supply). Such an intervention cannot be plausibly put in place in one specific year. The decennial structure of our productivity data indeed suggests that our effects should be interpreted over a time horizon of ten years.

In what follows, we select as our preferred specification the one in Table 4 Column [6]. By doing so, we focus on the 69 pre-unitarian provinces only. This is meaningful from an identification perspective, as initial conditions cannot be defined for the 41 post-unitarian ones. Also the choice to measure initial conditions at $t_0 = 1860$ can be made without loss of generality. While Table 3 evidenced some co-movement of initial conditions measured at $t_0 = 1860$ with population growth, estimates in Table 4 show that this co-movement does not drive our main results. Estimates in Column [6] are fully confirmed both in Column [7], as we drop provinces in the top population decile, and in Column [8] as we choose $t_0 = 1700$.[38]

[38]Importantly, also results in the sensitivity and mechanisms analyses presented in Sections 5.1 and 6 for $t_0 = 1860$ are confirmed in terms of both significance and direction as we use $t_0 = 1700$ or we drop the top decile of population. These estimates are available upon request from the authors.

In Appendix A we use the IV FE estimated coefficients in Column [6] to evaluate the productivity effect in terms of GVA per capita elasticity. We show that a balanced 10% increase in the supply of faculties in province i and its neighbourhood evaluated at sample averages produces an annual increase of 0.24% in per capita GVA over a time horizon of ten years. We also discuss to what extent this elasticity based on faculties openings is comparable with elasticity estimates obtained from university openings (notably by Valero and Van Reenen, 2019). In the welfare analysis we find a slightly smaller elasticity (0.19 instead of 0.24), when we evaluate effects at 2001 supply (see Section 7 for details). Finally, in Appendix B we compare our estimates to the long-run effect of higher education supply that emerge from conditional convergence models (Barro, 1991, 2012; Gennaioli et al., 2013).

5.1 Sensitivity Analysis

In this section we discuss robustness checks presented in Appendix C.

In Table C-1 we carry out a first set of robustness checks to verify how our results change for alternative timing of initial conditions. We consider $t_0 = 1800, 1600, 1500, 1400$. By doing so, we compute instruments (see equation (4)) using initial conditions that go back to Middle Ages, at the end of a century of declining population (cfr. Panel (b) of Figure 1). While the point estimate for the local productivity effect of faculties is not precisely estimated when $t_0 = 1500, 1400$, our results are confirmed. Notice that going back in time reduces by up 50% the number of faculties considered to compute the initial conditions.

In Table C-2 we carry out a first set of robustness checks to account for spatial auto-correlation, which may potentially bias our estimates. In Columns [1] to [2] we implement Conley's and Driscoll and Kraay (1998)'s corrections. In Column [3], we correct standard errors by two-way clustering, i.e. both at the local and neighbouring province. In Column [4] we cluster at the level of the pair ij, i.e. we allow for serial correlation within the same pair of observation. In Column [5] we explicitly account for the dyadic structure of the data used to estimate equation (1), and apply the correction proposed by Fafchamps and Gubert (2007), Aronow et al. (2015) and more recently by Carlson et al. (2023) to account for errors being correlated between all pairs that have in common either province i or j (or both).[39] Results from this first set of robustness shows that, if anything, standard errors are lower than in baseline estimates, so that the coefficients of interest are estimated more precisely. In Columns [6] and [7], the clustering of standard errors at the NUTS2 region,

[39]Robustness of Columns [3] to [5] can be implemented only for estimates of equation (1) as the unit of observation is the province pair ij. We cannot cluster two-ways standard errors computed when estimating equation (2), as the unit of observation for these estimate is the local province i.

and the pre-unitarian state level (respectively) confirms our findings.

Next, in Table C-3 we account for potentially omitted factors, both for the local province and the neighbours, which may affect both faculty creation and GVA per capita. In Columns [1] and [2] we consider population shocks, or shocks on the overall level of development. We show that our results go through as we control for population growth of the province and its neighbourhood, and the share of employment in the agricultural sector in province and its neighbourhood, respectively.[40]

After that, we consider unobserved quality of higher education supply at the province level. Thus, in Column [3] we control for the number of private universities and elite universities according to the Casati ranking (cfr. Table 1, Column [6]), while in Column [4] we include the interaction between the number of universities and the academic notability of university supply in the pre-unitarian province by De la Croix et al. (2020).[41] In Column [5], we consider altitude as a measure of ruggedness. So we include province-level interactions of a dummy equal to one if the local province has an average altitude above 350 metres (above sea level) and time fixed effects. Our results go through also in this robustness. In Column [6], we run our baseline specification without controls for the number of universities in the local province and its neighbours. Results are confirmed again, however the drop of the F-stat in Panel B confirms it is important to control for this dimension of higher education supply in baseline estimates.

In section C of the online Appendix we present a battery of additional robustness and placebo exercises that provide further validations of our identifying assumptions. In line with suggestions by Goldsmith-Pinkham et al. (2020), we replicate the entire analysis using alternative estimators that combine the moment conditions in potentially more efficient ways, and check the sensitivity of our results to the adoption of alternative empirical strategies (see Table A-IV). In these cases, the results remain qualitatively unchanged in terms of both significance and direction.

For neighbourhood effects, we confirm our results as we consider alternative and time invariant definitions of territory and borders of pre-unitarian provinces (see Table A-V); we verify that our results are not driven by specific sub-periods or regional outliers (see Table A-VI); we apply the Adão et al. (2020) (AKM) correction to account for arbitrary correlation

[40]In the next section we show that sectoral employment shares are to be viewed as alternative productivity outcomes in the Post-Malthusian transition during the time span of our analysis. As such, these variables may be viewed as 'bad controls' in our setting. This is why we do not include them in the main analysis.

[41]The quality assessments provided by the Casati ranking is time-varying, due to updates made during Italian history (see online Appendix B for details). Conversely, the time variation in the academic notability index stops at the end of the pre-unitarian period. So we take its last value (which refers to the 1740-1800 period) for the interaction term.

in the error term across provinces with similar initial conditions (see Table A-VII).

In Figure A-V we display coefficients from a complementary exercise, where we replicate estimates of equation (1) 100 times, using random draws of 30 provinces out of the 41 in our sample with a initial supply of faculties equal to zero, in order to have a more balanced number of provinces with and without initial faculties. Size and statistical significance of the estimated coefficients from these replications are very similar to the baseline estimates. This suggests that our main results are not driven by unobserved province-level factors, possibly correlated with an initial zero supply of faculties.

Finally, in Table A-IX we check the sensitivity of productivity effects to an alternative definition of initial shares. In each column, the placebo Bartik instrument is constructed multiplying the total number of faculties in any given year in province i (or in provinces $-i$) with initial shares (see equation(3)) computed upon initial characteristics of pre-unitarian provinces, other than is initial number of faculties.[42] The power of first stages drop tremendously, to worryingly low levels, which makes second stage estimates of equation(2) meaningless. Indeed, the pattern in the estimated coefficients does not seem anyway close to the effects estimated in Panel B of Table 4, and are in general not significant. This suggests that, indeed, only the interaction with shares of initial faculties is what matters for our results.

6 Mechanism Analysis

The aim of this section is twofold: firstly, to validate empirically the conceptual framework discussed in Section 2.3 for the emergence of neighbourhood effects; and secondly, to discover evidence that aligns with the insights from Unified Growth Theory regarding the role of human capital formation in driving economic development (Galor, 2011).

6.1 Neighbourhood Effects: a Spatial Competition Channel?

An unanswered question is whether neighbourhood effects can be understood within the conceptual framework described in Section 2.3, or if alternative explanations unrelated to spatial competition could be at play. To shed light on this question, Table 5 offers insights into potential mechanisms driving neighbourhood effects. We explore varying effects between STEM and non-STEM fields; analyse historical, regional, and political factors; delve into mobility costs; and investigate the spatial reach of these effects.

[42] These characteristics are total GVA, GVA per capita, GVA per worker, participation rate, population, population density, share of active population in agriculture, services and industry.

STEM vs non-STEM Faculties. We start with the field of study, and analyse separately neighbourhood effects triggered by faculties that operate in STEM and non-STEM fields of study. Panel A examines cross-field neighbourhood effects, while Panel B focuses on within-field neighbourhood effects. The results demonstrate that non-STEM faculties are influenced by both STEM and no-STEM fields (see Columns [1] and [4], respectively). In contrast, STEM faculties are only affected by neighbouring faculties within the same field. These findings align with the perspective discussed in Section 2.3, suggesting that diversifying own supply from supply of provinces nearby may protect the local province from neighbourhood effects. More precisely, STEM faculties may still experience neighbourhood effects from neighbouring STEM faculties. However they are not subject to displacement forces arising from non-STEM faculties, which have proliferated in more recent periods (see Figure 3(a)).

Historical and Regional Factors. Next, we investigate the role of historical and regional factors. In Panel C, we show that neighbourhood effects exist both before and after WWI, being twice as large in the second spell (i.e. 1921-2010). As argued above, this period sees the transition from the Post-Malthusian to the Sustained Growth Regime, and meanwhile the transition from elite to mass higher education. In Panel D we account for the fact that provinces i and j may or may not belong to the same administrative region. Thus, we analyse separately neighbourhood effects between provinces that belong to different regions (cfr. Column [7]), and between provinces that belong to the same region (cfr. Column [8]). Caution is needed in interpreting neighbourhood effects across regions in Column [7] due to the low power of the first stage; neighbourhood effects appear large and precisely estimated within the same region, instead. The negative, non significant coefficient in Column [8] suggests that displacement forces between provinces in different regions are weaker, even though these provinces share a border. This result is consistent with the theory presented in Section 2.3, as it is well known that Italian university students are much less mobile between different regions than within the same region (DeAngelis et al., 2017).[43]

History of Political Coordination. Results in Panel D may also emphasise intra-regional cooperation as a trigger of neighbourhood effects: from a public governance perspective, coordinating on the supply of higher education is easier for provinces belonging to the same region than for provinces belonging to different regions. The next heterogeneity

[43]For example, in 2007 only 10% of 1st-year BSc students enrolled in a university outside their region of residence. More than 80% of these students chose to study in their home region. Among them, 28% moved to another province within the same region, while over half of the students stayed in their province of residence. This trend was even more pronounced in the regions of the 'Mezzogiorno,' where only 5% of students ventured to a province in a different region (cfr. DeAngelis et al., 2017; Table 1).

Table 5: Mechanism for neighbourhood effects

	Panel A: across study field		***Panel B: within study field***	
	[1] non-STEM (outcome var.) on STEM	[2] STEM (outcome var.) on non-STEM	[3] STEM on STEM	[4] non-STEM on non-STEM
STEM faculties in j	-0.383**	-0.037	-0.146*	-0.153**
	(0.176)	(0.029)	(0.081)	(0.075)
Observations	3868	3868	3868	3868
K-P rk Wald F-stat	48.836	52.744	48.836	52.744
	Panel C: pre-WWI vs. post-WWI period		***Panel D: Intra vs. Inter-regional effects***	
	[5] pre-WWI	[6] post-WWI	[7] different region	[8] same region
no. of faculties in j	-0.099**	-0.179**	-0.084	-0.185**
	(0.043)	(0.079)	(0.102)	(0.079)
Observations	1370	2498	1640	2228
K-P rk Wald F-stat	38.212	37.512	7.676	70.299
	Panel E: Political color before 1884		***Panel F: Outmigration***	
	[9] same political color	[10] different political color	[11] low outmigration	[12] high outmigration
no. of faculties in j	-0.390***	-0.201**	-0.223**	-0.047
	(0.136)	(0.101)	(0.092)	(0.068)
Observations	1118	1469	1959	1909
K-P rk Wald F-stat	19.739	25.016	56.786	19.429
	Panel G: Spatial reach (linear distance)			
	[17] within 90Km	[18] btw 90Km and 180Km	[19] btw 180Km and 270Km	[20] btw 270 and 360Km
no. of faculties in j	-0.154***	-0.024	-0.017	-0.019
	(0.052)	(0.031)	(0.019)	(0.026)
Observations	4801	9504	10646	8378
K-P rk Wald F-stat	83.300	127.332	177.355	110.945

Notes: In Panels A and B, we use the STEM and non-STEM classification described in Figure 3. In Panel C, the pre-WWI period includes years 1870-1911 while post-WWI period starts in 1921. In Panel D, intra-regional effects are estimated between provinces in the same NUTS2 region, while inter-regional effects are between provinces belonging to different NUTS2 regions. In Panel E, we define the political colour of a province based upon the party (historical left or historical right) of the 50%+1 of the deputies from this province elected in the parliament of the Italian Kingdom between legislatures VIII (1861-65) and XIII (1876-80). In Panel F we split the sample between provinces characterised by an out-migration rate in 1881 below or above the median (2.07%). The out-migration rate considers only international emigration to a European country, or transatlantic emigration. In Panel G, we use linear distances between province centroids extracted by the Google Maps. Details on sources and construction of these indicators are in online Appendix B. Standard errors are clustered at the province level. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

exercise provides more insight into the political cooperation versus spatial competition interpretation of neighbourhood effects. In Panel E, we allow for heterogeneous effects between provinces that historically shared the same political colour (Column [9]), and provinces historically characterised by a different political orientation (Column [10]).[44] A concentration of neighbourhood effects within historically politically-aligned pairs of provinces would suggest strong evidence for pure political coordination channel (i.e. provinces with the same history of political representation may coordinate more easily). Estimates in Panel E do not seem to support a pure political coordination explanation, as neighbourhood effects are sizeable and significant in both columns. Nonetheless, the coefficient in Column [9] is larger than coefficient in Column [10], indicating the potential presence of political channels that complement spatial competition mechanisms rather than offering an alternative explanation.

Mobility Costs. In Section 2.3 we discussed mobility costs as the main trigger to spatial competition mechanisms. We argued neighbourhood effects arise as long as there is some mobility between ij province couples, and this is somewhat limited to the neighbourhood itself (e.g. due to high costs faced by individuals to migrate to a non-neighbouring province, another distant region or abroad). In Panel F, we consider costs of migrating outside the neighbourhood. We proxy them by historical province level emigration rates abroad (to another European country or the US) between 1861 and 1884 (Gray et al., 2019). We distinguish provinces characterised by an out-migration rate below and above the median (equal to a yearly out-migration between 1861 and 1884 of about 2 x 1000 inhabitants). Neighbourhood effects are concentrated in low emigration provinces (cfr. Column [15]), while there is no evidence in high emigration provinces (cfr. Column [16]). This provides further support to the local mobility assumption, indicating that neighbourhood effects emerge in areas with a stable incumbent population that consistently demands education to foster local skills and human capital.

In Table C-4, we consider two additional heterogeneity exercises. First we use altitude as a measure of geographic isolation, and we estimate neighbourhood effects separately for relatively isolated provinces (with an average altitude above the median, 350 meters above sea level) and more accessible provinces (with an altitude below the median). Then, we use

[44] We define the historical political orientation of the province based on the party (either historical left or historical right) of the majority of local Deputies elected in the Lower House of the Italian Parliament at national elections taking place during 1861-1880. We focus on Deputies, as they were elected through majority rule, while Senators and other key province-level political roles were not directly elected but appointed. To ensure sufficient data, we consider multiple national elections. However, we stop data collection after the 13th legislature (1876-1880) because, from the 1880 elections onwards, salience of deputies' political party affiliations declines due to the phenomenon commonly known as "Transformism." See online Appendix B3 for details over the construction of this variable.

the presence of transportation infrastructure in the pre-sample period as a historical proxy for highly accessible provinces. We examine the effects separately for provinces that lacked any railway endowment and provinces that already had some railway endowment (i.e. at least one railway connection) by 1861. The estimates indicate that neighbourhood effects are concentrated among smoother, more geographically accessible provinces, characterised by an initial endowment of railways. This evidence is consistent with the hypothesis that accessibility increases the salience of neighbourhood effects, arguably through a high local mobility.

Spatial Reach of Neighbourhood Effects The higher education supply of province i may be influenced by supply in province j if the two provinces are positioned close enough regardless of whether they share a border or not. In Panel I, we propose a complementary definition of a neighbourhood based on the linear distance d_{ij} between province capitals, regardless of their contiguity. In practice, we compute i-to-j distances from Google Maps applications and assume province j is a neighbour of province i as long as $d_{ij} < D$, where D is a supposed distance bandwidth for neighbourhood effects (see Parchet, 2019). In Columns [17]-[20], we consider i-to-j linear distances $D = 90, 180, 270, 360$ km. The results reveal that, on average, neighbourhood effects occur within a 90-kilometer linear distance. In Table A-X, in the online Appendix D, we replicate the analysis based on travel-based bandwidths measured as of today. We show that, on average, neighbourhood effects operate within a bandwidth of 120 kilometres of travel, and a bandwidth of 80 minutes of travel time. This is the average "spatial reach"of neighbourhood effects, measured in linear distance, travel distance, or travel time terms.[45] Beyond these spatial reaches, estimated coefficients are much smaller and non significant. This does not exclude that neighbourhood effects may be at work, e.g. at a small scale and within specific sets of ij couples, even though they are very distant.[46]

[45]Table A-XI presents results with complementary neighbourhood definitions, incorporating factors such as distance and contiguity, as well as spatial restrictions imposed by Italian geography. A more detailed discussion and additional results can be found in the online Appendix.

[46]For example, Table A-VIII reports the distribution of negative and statistically significant coefficients as we re-estimate neighbourhood effects considering for each province in the sample, 100 random draws of five fictitious neighbours across provinces that are located over 500 km away. If we repeat the exercise 100 times, (100 repetitions of 100 extractions each), we observe that on average about the 7% of extractions involves some evidence of neighbourhood effects.

6.2 Productivity Effects: Industrialisation and Human Capital Formation

In this section, we interpret our results through the lens of the Unified Growth Theory. We point out effects on the multiple components of GVA per capita; we scrutinise the impact of STEM supply, and its interaction with early industrialisation, and explore sectoral composition changes. This will help us to highlight the role of higher education through the Post-Malthusian era, and the transition to Sustained Economic Growth in Italy.

Break Down of the Productivity Effect. In Table 6, we present the results of equation (2) on a set of outcomes that allow to disaggregate the effect of higher education supply on GVA per capita. For comparability purposes in Column [1] we report baseline estimates (cfr. Table 4, Panel B, Column [2]). In Columns [2] and [3], we show a positive effect of local higher education supply on both population and population density, respectively. This describes a yearly elasticity of population to higher education supply equal to 0.04, which is equivalent to the 6% of the spike in population growth Western European countries experienced between 1870 and 1913, on average (equal to 0.7; cfr. Figure 2.9 (b) from Galor, 2011).[47] Figure C-1 in the Appendix, shows these returns start to decline in the immediate aftermath of WWI, then disappear after WWII. This timing seems consistent with the demographic transition in Italy (cfr. e.g. Galor, 2011 Figure 2.17). It is also in line with the transition of the Italian higher education from elite knowledge to modern tertiary education. Overall, we can interpret estimates in Table 6 (Columns [2], [3]), and Figure C-1 as small yet noticeable Post-Malthusian returns of upper tail human capital. In Table A-XII in the online Appendix we use the pre-1500 value of the index of historical potential crop yield by Galor and Özak (2016) to investigate the trajectory of provinces potentially at different stages of development. These estimates suggest a larger, more precise effect of higher education supply on productivity measures (GVA per capita and per worker) as we include in the sample provinces in the top quartile of the distribution of the caloric suitability index. Conversely, higher education supply displays a larger and more precisely estimated effect on population and population density, as we include in the sample provinces in the bottom quartile of the index distribution (thus more likely to be on a Malthusian stage).

Neighbourhood faculties show a negative coefficient on local population in Column [2], suggesting they may counterbalance population concentration within the province; however,

[47] We compute a population elasticity of 0.44(=0.087*2.619/0.517) over a decennial time horizon, or a 0.04 on a yearly basis, on average. This positive effect confirms population would be a bad control in baseline productivity estimates. The same holds true for sectoral employment shares (see below).

Table 6: Compositional effects of higher education supply on productivity

	[1] GVA per capita	[2] Population	[3] Pop. density	[4] Participation rate	[5] GVA per worker
Total no. faculties in i	0.283**	0.087***	0.425**	0.487*	0.446*
	(0.136)	(0.028)	(0.184)	(0.250)	(0.271)
Total no. faculties in $-i$	0.116**	-0.018**	-0.041	0.161	0.249***
	(0.056)	(0.009)	(0.039)	(0.133)	(0.091)
Observations	1025	1025	1025	1025	1025
K-P rk Wald F-stat	22.819	22.819	22.819	22.819	22.819

Note: Column [1] reports IV FE results of the baseline specification (see Table 4, Panel B, Column [2]) for comparison purposes. In Columns [2]-[5] we report results using related measures of province-level productivity. In Column [2] we use total population. In Column [3], we use population density measured as total population per Km^2. In Column [4] we use participation rate in the labor market (total active population/total population). In Column [5] we consider GVA per worker (total GVA of the province/total active population). All specification include the usual set of controls (i.e. the total number of universities in province i, and its neighbourhood $-i$), province and region-by-year fixed effects. Standard errors are clustered at the province level. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

this impact is not statistically significant in terms of population density in Column [3]. In Columns [4] and [5], we consider participation rate of workers in the labor market and GVA per worker, respectively the extensive and intensive margins of productivity. Our findings indicate that local supply of higher education contributes significantly to both margins of productivity, while supply of neighbours creates positive externalities only on the intensive margin.

(STEM) Faculties, Industrialisation, and Economic Transition. So far we implicitly assumed that all faculties provide an equal boost to local productivity. However, it is realistic assuming heterogeneous effects among institutions operating in different fields: for example the presence of an engineering faculty (in the province and/or in the neighbourhood) may have more sizeable productivity effects than a humanities faculty. In Figure 6, we present separate regression plots for the estimated coefficients of STEM and non-STEM faculties on productivity measures reported in Table 6. The figure shows STEM faculties have approximately double the economic impact compared to non-STEM faculties across all observed dimensions. Conversely the productivity externality does not seem to differ significantly between STEM and non-STEM faculties. This evidence suggests that productivity effects of STEM education are more localised compared to non-STEM faculties.

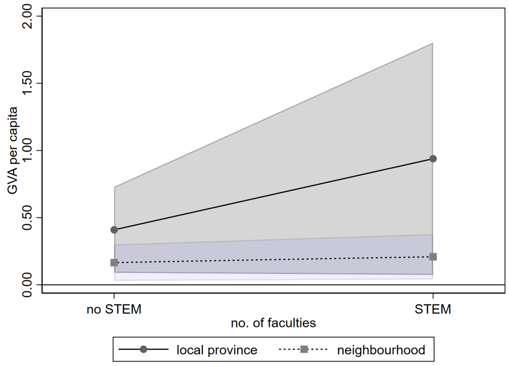
One possible explanation for evidence in Figure 6 is a stronger interaction of STEM faculties with the local economy, particularly during early phases of industrialisation. STEM human capital could provide a crucial local endowment to reach further stages of local development. To explore this hypothesis, we investigate whether the productivity effect of higher education supply varies based on the early stage of industrialisation in the province. Thus, we categorise provinces depending on whether they display a "low" early level of industrialisation (below the sample median of the index by Ciccarelli and Fenoltea, 2013), or a "high" level of early industrialisation (above the sample median).[48] In Figure 7, we show the estimated coefficients for all faculties and STEM faculties; Panels (a)-(c) report coefficients for faculties in the local province; Panels (b)-(d) report coefficients for faculties in the neighbourhood. Results suggest a complementarity between early industrialisation and higher education supply, particularly of STEM faculties. Productivity effects are concentrated in provinces with high early industrialisation. Furthermore, productivity returns are magnified as we dive into the supply of STEM faculties.

If our estimates are capturing the contribution of higher education supply to the structural transformation of the Italian production system through the transition from the Post-Malthusian to the Modern Growth Regime, we should observe meaningful effects of higher education supply on sectoral employment shares in industry, services relative to agriculture. Figure 8 plots the sectoral composition effects of total supply, and STEM supply respectively. Panel (a) reports estimated coefficients on the industry-to-agriculture employment ratio; Panel (b) shows results on the services-to-industry employment ratio; Panel (c) focuses on the services-to-agriculture employment ratio. Results are in line with expectations. Local supply of faculties is associated with increasing employment ratios, featuring a gradual province-level transition from agriculture to industry and services. Gradients of these sectoral transition are larger as we focus on STEM faculties: one more STEM faculty in the local province explains the 38% of a standard deviation of the industry-to-agriculture ratio, the 22% of a standard deviation of the service-to-industry ratio, and the 75% of a standard deviation of the service-to-agriculture ratio over the sample period.[49] Interestingly, we find no positive externalities on sectoral ratios; we even observe a negative externality on the local province's industry-to-agriculture intensity ratio. This result seems in line with the negative externality on local population in Table 6 above: higher education supply in neighbouring provinces not only avoids the concentration of population in province i, but also prevents concentration of industrial activities.

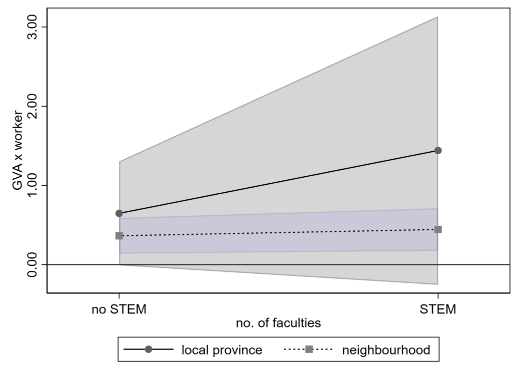
[48]The relative index of early industrialisation by Ciccarelli and Fenoltea, 2013 measures the province's average share of the national industrial value added, relative to the share of the male population at the beginning of our sample period (1881-1911).

[49]By dividing each estimated coefficient by the standard deviation of the respective variable we obtain $38\%(= 2.2/5.647*100)$ for the industry-to-agriculture ratio, $22\%(= 1.17/0.77*100)$ for the service to industry ratio and $75\%(= 7.3/9.73 * 100)$.

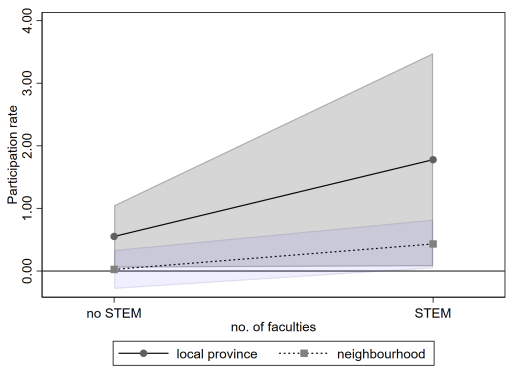
Figure 6: Productivity effects of higher education supply by higher education sector (STEM vs. non-STEM)



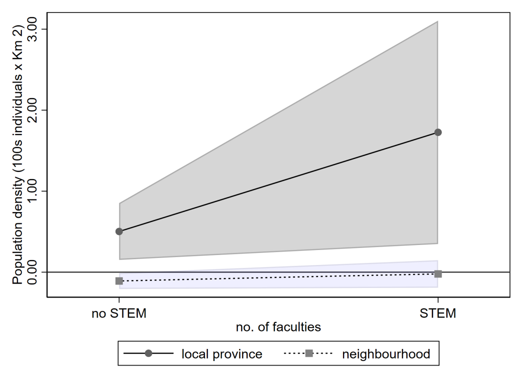
(a) GVA per capita



(b) GVA per worker



(c) Participation rate



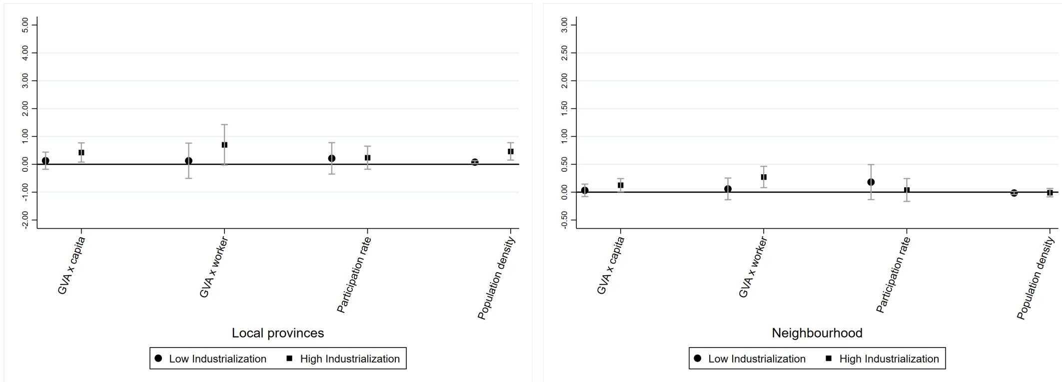
(d) Population density

Notes: authors' calculations on HIU and Italian Census data. The graphs plot coefficients of IV estimates of equation (2) for the number of faculties in the STEM and non-STEM fields in the local province and its neighbourhood (using respective STEM and no-STEM version of Bartik instruments shown in equation (4)) on the dependent variables reported in Panels (a)-(d)). All the regressions include the usual set of controls (i.e. the total number of universities in province i, and its neighbourhood $-i$), region-by-year and province fixed effect. Details of all regressions are available to the authors upon request. Standard errors are clustered at the province level. The shadowed area represent the 90% interval of confidence.

7 Welfare Analysis

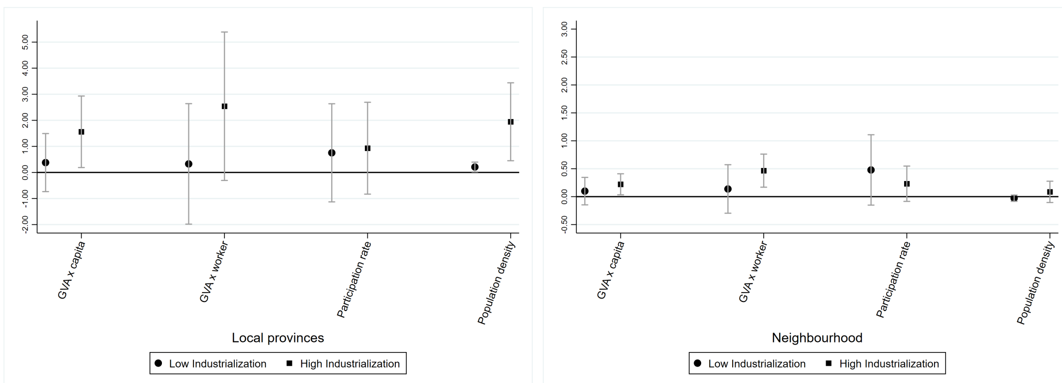
We are now ready to quantify the total contribution of higher education supply to the welfare of the local province, measured in per capita GVA terms. To do this, we have to take into full consideration how productivity effects of faculties in the neighbourhood complement the productivity effect of local faculties. Our analysis thus far has highlighted two opposite externalities. The first is measured by ϕ_2 in equation (2). This reflects a positive effect of the higher education supply of neighbouring provinces on local GVA per capita, which is

Figure 7: Productivity effects of higher education supply by initial level of industrialisation



(a) all faculties, local province

(b) all faculties, neighbourhood



(c) STEM faculties, local province

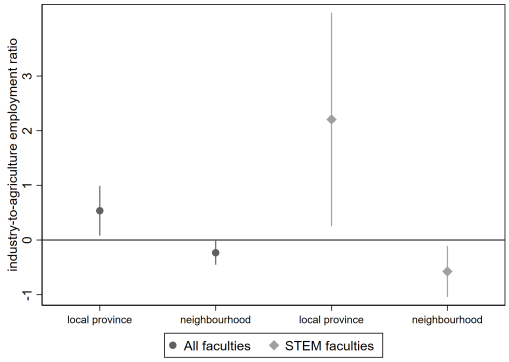
(d) STEM faculties, neighbourhood

Notes: authors' calculations on HIU and Italian Census data. The graphs plot coefficients of IV estimates of equation (2) for all faculties (Panel (a) for local faculties, and (b) for faculties in the neighbourhood), and STEM faculties (Panels (c) for local faculties, and (d) for faculties in the neighbourhood), using respective versions of Bartik instruments shown in equation (4), on the dependent variables reported on the x axis. All the regressions include the usual set of controls (i.e. the total number of universities in province i, and its neighbourhood $-i$), region-by-year and province fixed effect. Details of all regressions are available to the authors upon request. Standard errors are clustered at the province level.

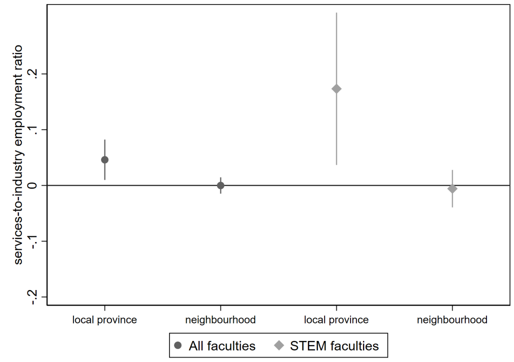
well known in the literature. The second is shown by $b < 0$ in equation (1). This features a negative *displacement externality*, which the literature has never pointed out.

To measure the 'net' externality, we perform a simulation exercise using the value of coefficients from equation (1) and (2). In practice, we compare the *actual returns* from higher education supply with the *counterfactual returns* in the absence of neighbourhood effects. For simplicity, we take as a reference the last year of our sample, i.e., $t = 2010$ (from now on we omit subscript t). The actual returns in province i relate to the number of faculties in province i and its neighbourhood, i.e.:

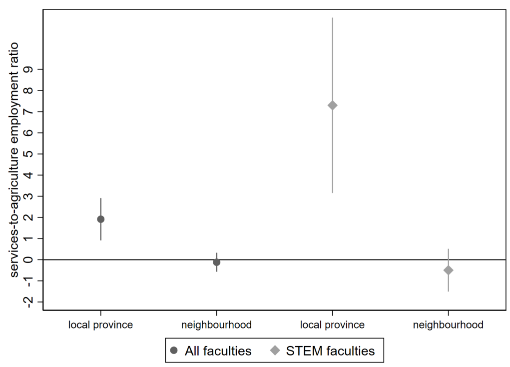
Figure 8: Higher education supply and sectoral employment ratios



(a) industry-to-agriculture ratio



(b) services-to-industry ratio



(c) services-to-agriculture ratio

Notes: authors' calculations on HIU and Italian Census data. The graphs plot coefficients of IV estimates of equation (2) for all faculties, and STEM faculties, using respective versions of Bartik instruments shown in equation (4), on the dependent variables reported in Panels (a)-(c). All the regressions include the usual set of controls (i.e. the total number of universities in province i, and its neighbourhood $-i$), region-by-year and province fixed effect. Details of all regressions are available to the authors upon request. Standard errors are clustered at the province level.

$$\widetilde{Y}_i = \widehat{\phi}_1 F_i + \widehat{\phi}_2 F_{-i}, \tag{5}$$

where F_i, F_{-i} is the observed number of faculties in province i and its neighbourhood in 2001 (given the time structure of our data), and $\widehat{\phi}_1$ and $\widehat{\phi}_2$ are the estimated productivity returns. If there were no faculties in the neighbourhood, province i would neither benefit from positive GVA externalities nor suffer from negative displacement effects from those faculties. Counterfactual returns in this scenario are as follows:

$$\widetilde{\widetilde{Y}}_i = \widehat{\phi}_1 \widehat{F}_i = \widehat{\phi}_1 (F_i - \widehat{b} \sum_{j \neq i} F_{ij}) = \widehat{\phi}_1 (F_i - \widehat{b} F_{-i}), \quad (6)$$

where $\widehat{b} < 0$ is the neighbourhood effect predicted from equation (1), and $\widehat{F}_i$ measures the counterfactual number of faculties in province i in the absence of neighbourhood effects. This is higher than observed supply, as relaxing neighbourhood pressures from contiguous provinces acts as an incentive for local provision. Net externality Ext_i is the difference between (5) and (6):

$$Ext_i = \widetilde{Y}_i - \widetilde{\widetilde{Y}}_i = (\widehat{\phi}_2 + \widehat{\phi}_1 \widehat{b}) F_{-i}. \quad (7)$$

This is the sum between the positive value of direct welfare externalities $\widehat{\phi}_2 F_{-i}$ and the negative value of displacement externality $\widehat{\phi}_1 \widehat{b} F_{-i}$.

Table 7 reports summary statistics of returns predicted by eqs. (5) - (7) using $\widehat{b}$ and $\widehat{\phi}$s from our preferred specifications.[50] Based on the predicted values $\widehat{\phi}_1 F_i = 1.276$ and $\widehat{\phi}_2 F_{-i} = 2.679$ in Table 7, the local supply of faculties seems to contribute roughly half as much as the neighbouring supply of faculties. More importantly, once we take into account the opportunity cost of cross-provincial displacement forces $\widehat{\phi}_1 \widehat{b} F_{-i}$, the net productivity contribution of local faculties ($\widetilde{\widetilde{Y}} = 2.293$) is approximately one and half times larger than the corresponding contribution of faculties in the neighbourhood, on average ($Ext = 1.662$).

Thus, after we account for displacement forces, average local supply in 2001 (equal to 5 faculties) accounts for about 58% of total productivity returns in the average province in 2010. These gains (compared to a benchmark situation with zero local faculties in 2001) are equivalent to the 11% of average (province level) GVA per capita in 2010. Net externalities (from an average supply of 23 faculties in the neighbourhood in 2001) explain the remaining 42% of total returns in 2010. This is equivalent to 8% of average GVA per capita in 2010 (relative to having zero faculties in the neighbourhood in 2001).[51] As these productivity gains accrue over a ten years period, their annual counterparts (reported in the lower rows of Table 7) are one tenth of the total effect, and are equal to respectively the 1.1% and 0.8% of average GVA per capita in 2010. This is a smaller total effect than the one we computed in Appendix A (0.19 vs. 0.24 in elasticity terms), where we evaluated $\widehat{\phi}_1$ and $\widehat{\phi}_2$ at sample averages.

[50] These are IV FE estimates in Table 4, Panel A, Column [2] for equation (1) and Table 4, Panel B, Column [2] for equation (2).

[51] Shares of local supply and supply in the neighbourhood over total returns are computed as $(\widetilde{\widetilde{Y}} * 100/\widetilde{Y}) = (2.293 * 100/3.955) = 58\%$ and $(Ext * 100/\widetilde{Y}) = (1.662 * 100/3.955) = 42\%$. Productivity gains are quantified as follows: $(\widetilde{\widetilde{Y}}_i * 100/\overline{Y}) \approx 11\%$, and $(Ext_i * 100/\overline{Y}) \approx 8\%$.

Table 7: Simulation exercise: summary of welfare and productivity effects

Variable	Mean	Std. Dev.	Min.	Max.	N
$\widehat{\phi}_1 F_i$	1.276	1.823	0	10.765	107
$\widehat{\phi}_2 F_{-i}$	2.679	1.64	0	7.684	107
$\widehat{\phi}_1 \widehat{b} F_{-i}$	-0.989	0.662	-3.029	0	107
$\widetilde{Y}_i = \widehat{\phi}_1 F_i + \widehat{\phi}_2 F_{-i}$	3.955	2.28	0	12.512	107
$\widetilde{\widetilde{Y}}_i = \widehat{\phi}_1 (F_i - \widehat{b} F_{-i})$	2.293	1.858	0	11.454	107
$Ext_i = (\widehat{\phi_2} + \widehat{\phi_1 b}) F_{-i}$	1.662	1.052	0	4.654	107
Annual effects (in % of $\overline{Y}$)					
$\widetilde{Y}_i / \overline{Y}$	1.882	1.096	0	6.417	107
$\widetilde{\widetilde{Y}}_i / \overline{Y}$	1.086	0.858	0	5.357	107
$Ext_i / \overline{Y}$	0.796	0.517	0	2.348	107
$\overline{Y}$ (mean in 2010)	21.518	5.198	12.413	32.571	107

Notes: Predicted effects from equations (5)-(7) in the text. Values are computed using 2010 data. The yearly effects are obtained dividing each ratio by 10 (since the effects computed in the upper panel refer to a decade) and multiplying by 100 (to express them in % terms).

In the Introduction we had stated that quantifying benefits and costs is necessary to understand the role of higher education supply for the persistent differentials in income per capita that have prevented regional economic convergence since the end of WWII (Gennaioli et al., 2013). In Figure 9 we move a first step in this direction. In Panel (a) we draw the cross-province distribution of the predicted total annual returns in % of local GVA per capita in 2010. The figure shows that economic returns tend to be negligible (less than 1% of local GVA per capita; transparent grey provinces) or small (between 1% and 2%, light grey areas) in peripheral provinces without own supply, that only benefit from faculties of a few small neighbours. Small provinces with own local faculties, or benefitting from externalities from major metropolitan areas enjoy returns of up to annual 3% of GVA per capita (grey provinces). Annual returns in large provinces such as Milano and Roma that benefit from local university hubs are between 3% and 4% of local GVA per capita (dark grey provinces). In the case of Napoli, annual returns explain up to 6.4% of local GVA per capita (darkest grey province). Panel (b) shows the geographical distribution of the net annual externalities, also in % terms of GVA per capita. Everywhere in the Italian territory, externalities are non-negative, suggesting that economic returns are larger than displacement costs in all provinces. In most border provinces (particularly in the northeast), net annual externalities account for less than 1% of local GVA per capita (transparent grey provinces). Around most urban areas, they explain between 1% and 2% of local GVA per capita (light grey areas). In the neighbourhood of large university centres such as Roma and Napoli, net externalities predict up to $2\% - 3\%$ of the local GVA per capita every year (grey provinces).

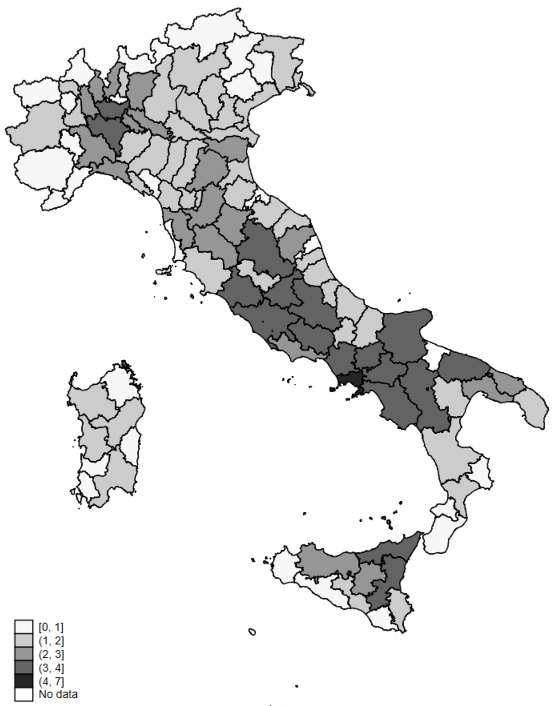
This evidence already suggests that annual total returns in cities that benefit from a local supply, are likely larger than the corresponding positive externalities on neigbouring provinces. We can have a more precise picture, by looking at the complete distribution of annual returns in Table C-5. Consider a province characterised by a small local supply (4 faculties) such as Bergamo. Based upon our estimates, this supply produces local annual returns equivalent to 1.06% of local GVA per capita. This is larger than the net externalities accruing to the neighbouring province of Sondrio (equal to 0.5% of local GVA per capita), which does not have a local supply. In practice, faculties in Bergamo contribute to creating a differential between Bergamo and Sondrio, two provinces whose levels of GVA per capita in 2010 are quite similar (21.5 for Bergamo and 28.2 in Sondrio). Evidence is more striking when we consider a larger university centre such as Roma. Based on our estimates, its large local supply (38 faculties) generates local annual returns equal to 3.86% of local GVA per capita. This is larger than annual total net externalities enjoyed by neighbouring provinces such as Latina (1.79% of local GVA per capita), or Rieti (2.35% of local GVA per capita), that do not have an own supply. In practice, these 38 faculties tend to widen the productivity gap observed in 2010 between Roma (GVA per capita equal to 29.6) and its neighbours (19.8 in Rieti, and 20.1 in Latina). Overall, these results suggest that, if any, higher education supply contributes to widen differentials in GVA per capita between Italian provinces.

8 Conclusions

In this study, we utilised a unique, self-constructed historical dataset for Italy, providing detailed province-level information. The aim was to assess the productivity-related economic benefits of higher education supply. Our investigation spanned a time-frame of 150 years (1870-2010), shedding light on the evolution of higher education institutions from elitist to widespread education. This analysis revealed the economic impacts of higher education institutions from the industrial era's inception to the contemporary period, considering the transition from the Post-Malthusian phase to the Sustained Growth epoch.

We leveraged variations linked to the initial conditions of university faculties to identify the productivity effects of higher education supply in a province, accounting for the influence of displacement forces stemming from neighbouring provinces. Our findings indicated that a balanced 10% increase in faculty supply in both the local province and its surrounding area led to an annual rise of 0.24% in per capita GVA, over a decade. In practical terms, these estimates suggest that if a province, initially without any faculties, were to be exposed to the

Figure 9: Geographical distribution of predicted returns (annual effects, in %)



(a) total returns, $\widetilde{Y}_i/Y_i$

(b) net externalities, Ext_i/Y_i

Notes: Values are expressed in % of local real GVA of province i (gross terms). The Yearly effects are obtained dividing each ratio by 10 (to obtain yearly effects from effects that refer to a decade) and multiplying by 100 (to express them as percentages). All values are computed using 2010 levels. Information on GVA is not available for the provinces of Barletta, Fermo, Monza-Brianza. Detailed values by province are shown in Table C-5.

average faculty supply of 28 (combining local faculties and those in the neighbouring areas) in 2001, it would experience an annual rise of 1.9% in per capita GVA between 2001 and 2010. Furthermore, when adequately accounting for the forgone impact of displacement forces from the neighbourhood, we discovered that 58% of total returns in 2010 were attributable to the local average supply (approximately 5 faculties), with the remaining 42% of these returns explained by the supply in the neighbouring regions (around 23 faculties, on average). One potential limitation of our analysis is that we consider a regulated higher education system akin to that of Italy, where factors such as public university tuition fees are centrally determined, and local institutions compete to attract enrollments from adjacent areas due to fee considerations. Considering countries where spatial competition coexists with other channels, like decentralised fees in public universities (as in the UK) or a significant private education sector (as in France), could be an important avenue for future research.

In the paper's concluding section, we argued that disparities in higher education supply between provinces may contribute to persistent differentials in GVA per capita across Italian provinces. Further research is needed to ascertain the broader applicability of these findings, especially in terms of regional disparities in higher education supply and their implications for cross-regional differences in human capital and productivity across OECD countries. Extending this evidence at the cross-country level would bolster the argument that expanding higher education supply might be a factor preventing regional economic convergence since WWII (see Gennaioli et al., 2013 for a discussion). Methodologically, our analysis underscored that considering the economic cost associated with displacement forces from neighbouring areas is crucial for accurately quantifying externalities. From a policy perspective, our results provide an economic rationale for aligning local higher education provision with local development needs. Hence, having a higher education supply more evenly distributed across space could be desirable to mitigate cross-regional inequalities.

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Appendix A Evaluating the productivity effect of faculties

Let us define the elasticities $f_{i,i}$ and $f_{i,-i}$ of GVA per capita in province i to the supply of faculties in the same province i, and its neighbourhood $-i$, and evaluated at sample means. Recall that equation (2) considers a lag of ten years to measure the returns of faculty supply. By utilizing the coefficients reported in Table 4 (IV FE estimates in Panel B, Column [2]), and evaluating the elasticities at the sample means reported in Table 2, we obtain the following results:

$$\begin{aligned} f_{i,i} =& \frac{dY_{i,t}}{dF_{i,t-10}} * \frac{\overline{F_i}}{\overline{Y}_i} = 0.283 * 2.6/9.09 = 0.08, \\ f_{i,-i} =& \frac{dY_{i,t}}{dF_{-i,t-10}} * \frac{\overline{F}_{-i}}{\overline{Y}_i} = 0.116 * 12.7/9.09 = 0.16. \end{aligned} \tag{A-1}$$

These elasticities imply that a balanced 10% increase in the supply of faculties in province i and its neighbourhood produce a $0.8 + 1.6 = 2.4\%$ increase in local GVA per capita that develops over a time horizon of 10 years. This is equivalent to a yearly increase of 0.24%, on average. In Section 7 we find a smaller total elasticity (equal to 0.19 instead of 0.24), as we evaluate marginal effects at 2001 supply instead of the sample averages.

It is useful to understand under what conditions $f_{i,i}$, $f_{i,-i}$ are comparable to corresponding elasticities of GVA per capita to supply of universities $u_{i,i}$ (and $u_{i,-i}$):

$$u_{i,i} = \frac{dY_{i,t}}{dU_{i,t-1}} * \frac{\overline{U_i}}{\overline{Y}_i} \tag{A-2}$$

We can decompose the first term in (A-2) as

$$\frac{dY_{i,t}}{dU_{i,t-1}} = \frac{dY_{i,t}}{dF_{i,t-1}} * \frac{dF_{i,t-1}}{dU_{i,t-1}} \tag{A-3}$$

which implies that the productivity effect of a marginal increase in the number of universities is equivalent to the productivity effect of opening up one faculty multiplied by the marginal increase in the number of faculties associated with opening up a university. A similar condition exists for $\frac{dY_{i,t}}{dU_{-i,t-1}}$. Let us assume that the second term is constant, and equal to the ratio between faculties and universities at their sample means i.e.

$$\frac{dF_{i,t-1}}{dU_{i,t-1}} = \frac{\overline{F}_i}{\overline{U}_i} \qquad and \qquad \frac{dF_{-i,t-1}}{dU_{-i,t-1}} = \frac{\overline{F}_{-i}}{\overline{U}_{-i}} \tag{A-4}$$

Plug in (A-4) into (A-2) and obtain:

$$u_{i,i} = \left(\frac{dY_{i,t}}{dF_{i,t-1}} * \frac{\overline{F}_i}{\overline{U}_i} \right) * \frac{\overline{U}_i}{\overline{Y}_i} = f_{i,i} \tag{A-5}$$

Similary it holds $u_{i,-i} = f_{i,-i}$. Thus, from equation (A-4), GVA elasticities to faculty supply or university supply are equivalent as long as as opening up a new university does not have a differential productivity effect through the number of faculties opened.

Appendix B Conditional convergence model

In this section we estimate a conditional convergence regression model as Barro (1991, 2012). This approach has the advantage of improve comparability of our results to closely related studies such as Gennaioli et al. (2013) and Valero and Van Reenen (2019). The model underlying a conditional convergence regression is equivalent to ours in the sense that it estimates levels-on-levels relationships that operate in the long run.

In Table B-1, we present results from our Barro growth regression estimates. We use as a dependent variable the change in GVA per capita (in logarithmic terms), and we include the lagged levels of GVA per capita at the province and regional level as controls. While in Columns [1]-[8] we use the number of faculties as a measure of higher education supply, in Columns [9] and [10] we adopt the number of universities as a regressor (see in Valero and Van Reenen, 2019). Moreover, while in Columns [1]-[5] we consider the entire time period, in Columns [6]-[10] we focus on the post-WWII period only. Throughout the analysis, we add progressively controls for population, population density, and a vector of distances (see Gennaioli et al., 2013), both at the local province and neighbourhood level. Besides, all specifications also include region and year fixed effects.

Results from Table B-1 offer additional insight into the long-run productivity returns of higher education supply. Higher education supply in the local province and the neighbourhood take the expected positive sign. Coefficients are statistically significant at conventional levels, even in the more demanding specification in Column [7], where we include the shares of tertiary educated individuals in the province and the neighbourhood as additional controls.[52]

The specification more closely comparable to our baseline is the one reported in Column [4]. As it is standard in Barro conditional regression models, we obtain the long-run elasticity of GVA per capita to local and neighbours' supply by dividing the respective coefficients of the higher education supply variables by the coefficient of the lagged dependent variable at the province level. Using these coefficients from Column [4] of Table B-1, we obtain $0.046 (= 0.019/0.415)$ and $0.031 (= 0.013/0.415)$. This implies an approximate long-run elasticity of GVA per capita to higher education supply equal to $0.77 (= 0.046 + 0.031)$. This is larger than elasticities $0.19 - 0.24$ estimated by our model.

Column [9] of Table B-1 presents results from a specification equivalent to Column [3] of Table A-7 of Valero and Van Reenen (2019), which refers to the 1951-2010 period only. This is the closer we can get to their analysis. Taken at face values, our estimated coefficients suggest that long-run GDP per capita increases by 1.5% in response to a 10% increase in the supply of universities, in the local province and its neighbourhood,[53] which is very close the 1.6% increase in long-run GDP per capita they find. This is also larger than baseline estimates provided by Valero and Van Reenen (2019) (cfr. their equation (1)), which suggest an elasticity equal to 0.4.

[52]This is inspired by Column (4) of Table A-7 in Valero and Van Reenen (2019)'s study, where a comparative analysis, resembling a horse-race, is conducted between the inputs (higher education supply) and outputs (average years of education) of the human capital formation process.

[53]Using coefficients in Column [9] we obtain $0.10 = 0.069/0.692$, and $0.057 = 0.040/0.692$. This implies that long-run GDP per capita increases by 1% in response to a 10% increase in local universities, and by 0.5%, in response to a 10% increase in universities in the neighbouring provinces.

Table B-1: Long-term returns of higher education supply: Barro conditional convergence model

	Dependent variable Δ (ln) GVA per capita in i									
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
lagged HE supply in i	0.021***	0.021***	0.015***	0.019***	0.020***	0.036***	0.039***	0.009*	0.069***	0.071***
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.009)	(0.009)	(0.004)	(0.019)	(0.020)
lagged HE supply in $-i$				0.013*	0.013*	0.027***	0.031***	0.013**	0.040**	0.045**
				(0.007)	(0.008)	(0.010)	(0.011)	(0.006)	(0.017)	(0.018)
lagged (ln) GVA per capita in i	-0.397***	-0.397***	-0.411***	-0.415***	-0.415***	-0.704***	-0.705***	-0.481***	-0.692***	-0.693***
	(0.053)	(0.053)	(0.050)	(0.049)	(0.049)	(0.131)	(0.128)	(0.026)	(0.137)	(0.133)
lagged (ln) GVA per capita in region		0.657***	0.591***	0.783***	0.758***	1.358***	1.321***	0.797***	1.227***	1.246***
		(0.100)	(0.080)	(0.130)	(0.134)	(0.307)	(0.309)	(0.093)	(0.298)	(0.313)
Observations	1227	1227	1227	1227	1227	663	663	571	663	663
Measure of HE supply	#Faculties	#Faculties	#Faculties	#Faculties	#Faculties	#Faculties	#Faculties	#Faculties	#Universities	#Universities
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	No	No	No	No	No	No	No	No	No	No
Population density controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distances controls	No	No	No	No	Yes	No	Yes	No	No	Yes
Share tertiary educated population controls	No	No	No	No	No	No	No	Yes	No	No
Time span	1861-2010	1861-2010	1861-2010	1861-2010	1861-2010	1950-2010	1950-2010	1950-2010	1950-2010	1950-2010

Notes: The dependent variable is change in GVA per capita (in logarithmic terms), lagged levels of GVA per capita at the province and regional level are included as controls. In Columns [1]-[8] we use the number of faculties as a measure of higher education supply, in Columns [9] and [10] we adopt the number of universities as a regressor (see Valero and Van Reenen (2019)). In Columns [1]-[5] we consider the entire time period, in Columns [6]-[10] we focus on the post-WWII period only. The vector of population density controls include population density of the local province and the neighbourhood. The vector of distance controls is the same as Valero and Van Reenen (2019) (Table A-7), and includes the distance of the local province from the Capital, the administrative capital of the region, and the corresponding average measures for the neighbourhood. Similarly, population % with tertiary education are for both local and neighbours' population. We include region and year fixed effects. Standard errors are clustered at the province level. Significance levels: $*: 10\%$ $**: 5\%$ $***$:1%.

Appendix C Additional Figures and Tables

Table C-1: Sensitivity Analysis (1): alternative t_0s

	$t_0 = 1800$	$t_0 = 1600$	$t_0 = 1500$	$t_0 = 1400$
	Panel A: Neighbourhood effects			
Total no. faculties in j	-0.193**	-0.198**	-0.188**	-0.193*
	(0.079)	(0.092)	(0.096)	(0.100)
Observations	3868	3868	3868	3868
K-P rk Wald F-stat	53.197	31.220	31.772	25.095
K-P rk LM-stat	29.768	21.041	20.360	16.814
p-value KP	0.000	0.000	0.000	0.000
	Panel B: Productivity			
Total no. faculties in i	0.309**	0.272*	0.258	0.299
	(0.142)	(0.152)	(0.166)	(0.205)
Total no. faculties in $-i$	0.117**	0.119**	0.128**	0.122**
	(0.050)	(0.050)	(0.054)	(0.057)
Observations	1025	1025	1025	1025
K-P rk Wald F-stat	34.319	31.981	28.660	23.011
K-P rk LM-stat	16.781	13.953	11.883	9.484
p-value KP	0.000	0.000	0.001	0.002

Notes: We take as preferred specifications IV FE one used to produce results reported in Table 4, Column [6] (Panel A for Neighbourhood effects; Panel B for productivity effects). In Columns [1] to [4] we report IV FE results as we compute initial conditions at t_0s reported in each column. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

Table C-2: Sensitivity Analysis (2): spatial correlation and clustering

	[1] Conley correction	[2] DKRAAY correction	[3] Two-way clustering	[4] Pair-level clustering	[5] Dyadic clustering	[6] Region-level clustering	[7] Kingdom clustering
	Panel A: Neighbourhood effects						
Total no. faculties in j	-0.162***	-0.162***	-0.162***	-0.162***	-0.162***	-0.162**	-0.162***
	(0.027)	(0.016)	(0.042)	(0.037)	(0.046)	(0.066)	(0.054)
Observations	3868	3868	3868	3868	3868	3868	3868
K-P rk Wald F-stat	73.961	46.244	28.719	64.115	–	30.396	30.724
	Panel B: Productivity effects						
Total no. faculties in i	0.283**	0.283**	–	–	–	0.283**	0.283***
	(0.115)	(0.124)				(0.143)	(0.091)
Total no. faculties in $-i$	0.116*	0.116***	–	–	–	0.116*	0.116***
	(0.069)	(0.045)				(0.061)	(0.034)
Observations	1025	1025	–	–	–	1025	1025
K-P rk Wald F-stat	30.127	20.751	–	–	–	15.453	10.640

Notes: We take as preferred specifications IV FE one used to produce results reported in Table 4, Column [2] (Panel A for Neighbourhood effects; Panel B for productivity effects). In Columns [1] and [2] we implement Conley and Driscoll and Kray Driscoll and Kraay (1998)'s corrections, respectively to account for spatial auto-correlation. In Column [3] we compute two-way clustering following the methodology by Gu (2019). In Column [4] we cluster the standard errors at the level of the pair. In Column [5] we report DCRSE (dyadic clustered robust standard errors), using the procedure proposed by Aronow et al. (2015). For Columns from [3] to [5] the clustering procedure is applicable only to the pairwise model. For Column [5], the dcr routine in Stata does not provide K-P statistics on instruments validity. In Column [6] we cluster standard errors at the regional level. In Column [7] we cluster standard errors at the level of the pre-unitarian state. Significance levels: $*: 10\%$ $**: 5\%$ $***: 1\%$.

Table C-3: Sensitivity Analysis (3): varying the set of control variables

	[1] Pop Growth controls	[2] control for %s in agriculture	[3] Elite & Private Uni. Controls	[4] (Notability)* (no. Univ.) Controls	[5] (Ruggedness)* (Year FE)	[6] Drop all controls
Panel A: Neighbourhood effects						
Total no. faculties in j	-0.164**	-0.188***	-0.163***	-0.161**	-0.181***	-0.186**
	(0.065)	(0.070)	(0.063)	(0.070)	(0.066)	(0.084)
Observations	3868	3868	3868	3859	3868	3868
K-P rk Wald F-stat	50.402	51.695	50.746	55.069	49.608	51.266
Panel B: Productivity effects						
Total no. faculties in i	0.275**	0.396**	0.259*	0.408**	0.298**	0.323***
	(0.135)	(0.198)	(0.138)	(0.190)	(0.141)	(0.118)
Total no. faculties in $-i$	0.110*	0.127**	0.097*	0.115**	0.148***	0.123*
	(0.058)	(0.064)	(0.054)	(0.056)	(0.056)	(0.066)
Observations	1025	1025	1025	1025	1025	1025
K-P rk Wald F-stat	22.703	23.105	20.114	22.506	22.079	5.605

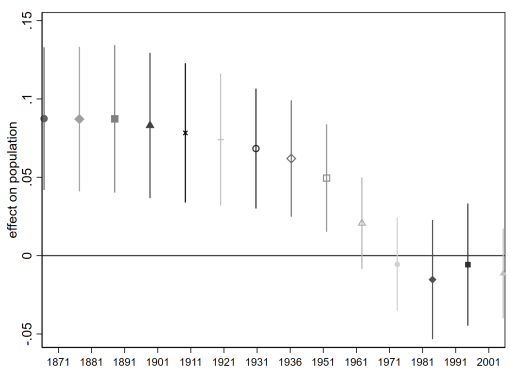
Notes: We take as preferred specifications IV FE one used to produce results reported in Table 4, Column [2] (Panel A for Neighbourhood effects; Panel B for productivity effects). In Column [1] we control for the rate of growth of population in province i, and its neighbourhood. In Column [2] we include in the set of controls the shares of active people in the agricultural sector. In Column [3], we include in the set of controls indicators for the number of elite universities and the number of private universities, both for the local province and its neighbourhood. In Column [4], we include in the set of controls the interaction between the number of universities in each province and the corresponding indicator of academic notability (noto7) by De la Croix et al. (2020). In Column [5], we include interactions between time dummies and a dummy for local province having an altitude higher than 350 metres, on average. In Column [6], we drop controls for the total number of universities (in the province and the neighbourhood). Coefficients of all additional control variables used in this table are available to the authors upon request. In Columns [1]-[6], standard errors clustered at the level of the local province are reported in parentheses. Significance levels: $*$: 10% $**$: 5% $***$: 1%.

Table C-4: Mechanism analysis: altitude and transportation

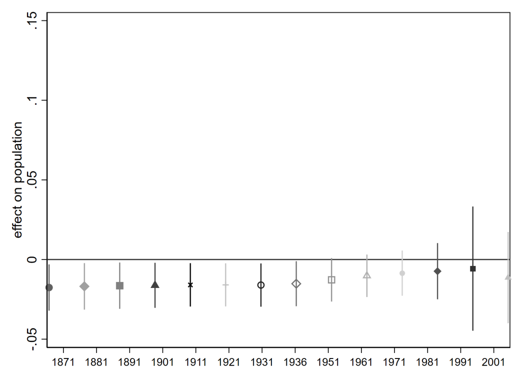
	Panel A: Railway connections in 1860		***Panel B: Low vs. high altitude (sea level)***	
	[1] no connection	[2] some connection	[3] altitude below 350m	[4] altitude above 350m
no. of faculties in j	-0.105	-0.208**	-0.261**	-0.051
	(0.069)	(0.093)	(0.107)	(0.060)
Observations	1871	1997	2046	1822
K-P rk Wald F-stat	32.616	25.228	21.404	21.945

Notes: In Panel F we split the sample between provinces characterized by a standard deviation in the altitude above and below the sample median (350 metres above sea level). In Panel G, we split the sample between provinces with or without railway connections in 1860.

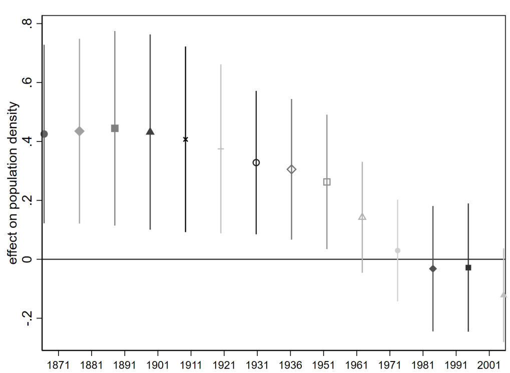
Figure C-1: Productivity effects of higher education supply by initial level of industrialisation



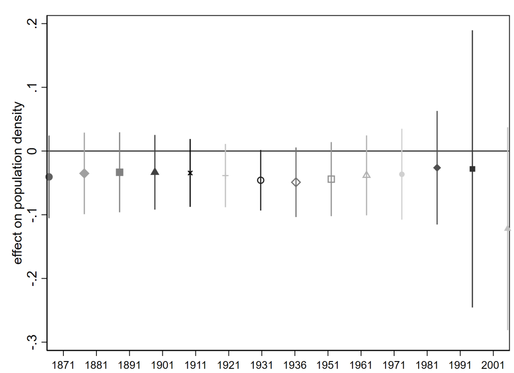
(a) all faculties, local province



(b) all faculties, neighbourhood



(c) all faculties, local province



(d) all faculties, neighbourhood

Notes: authors' calculations on HIU and Italian Census data. The graphs plot the coefficients and 90% confidence intervals of the total no of faculties in the local province and its neighbourhood on dependent variables reported on the y axis for the sub-sample starting on the year reported on the x-axis (i.e. dropping from the sample all previous years). All the regressions include the usual set of controls (i.e. the total number of universities in province i, and its neighbourhood $-i$), region-by-year and province fixed effect. Details of all regressions are available to the authors upon request. Standard errors are clustered at the province level.

Table C-5: Welfare analysis of higher education supply.

Province	F_{-i}	F_i	$\widehat{F}_i$	Yearly effects (in %) $\widetilde{Y}_i/Y_i$	$\widetilde{\widetilde{Y}}_i/Y_i$	Ext_i/Y_i	Y_i
Agrigento	11	0	1.78	0.93	0.37	0.56	13.76
Alessandria	37	3	8.99	2.13	1.05	1.08	24.24
Ancona	29	5	9.69	1.89	1.08	0.81	25.36
Aosta	15	2	4.43	0.88	0.48	0.4	26.32
Ascoli Piceno	25	1	5.05	1.56	0.7	0.86	20.46
Aquila	55	6	14.9	4.4	2.29	2.11	18.43
Arezzo	45	1	8.28	2.27	0.96	1.3	24.34
Asti	17	0	2.75	0.85	0.33	0.51	23.39
Avellino	44	0	7.12	3.38	1.33	2.05	15.17
Bari	10	16	16.81	3.71	3.1	0.61	15.36
Bergamo	41	4	10.64	2.07	1.06	1.01	28.53
Biella	17	0	2.75	0.82	0.32	0.5	24.14
Belluno	18	0	2.91	0.79	0.31	0.48	26.40
Benevento	40	3	9.47	3.79	1.85	1.94	14.54
Bologna	26	15	19.21	2.44	1.83	0.62	29.79
Brindisi	25	0	4.05	2.07	0.82	1.26	14.04
Brescia	18	6	8.91	1.42	0.94	0.47	26.79
Bolzano	6	2	2.97	0.41	0.28	0.14	30.60
Cagliari	0	10	10	1.45	1.45	0	19.50
Campobasso	22	3	6.56	1.87	1.02	0.85	18.27
Caserta	34	9	14.5	4.85	3.06	1.79	13.41
Chieti	13	4	6.1	1.45	0.94	0.5	18.31
Carbonia Iglesias	10	0	1.62	0.9	0.35	0.55	12.94
Caltanisetta	22	0	3.56	1.78	0.7	1.08	14.35
Cuneo	14	0	2.27	0.6	0.24	0.37	27.04
Como	40	2	2.97	2.16	0.35	1.81	24.23
Cremona	57	1	10.23	2.78	1.16	1.61	24.93
Cosenza	7	6	7.13	1.64	1.32	0.32	15.31
Catania	12	11	12.94	3.06	2.48	0.57	14.77
Catanzaro	9	3	4.46	1.12	0.74	0.37	16.95
Enna	33	0	5.34	2.79	1.1	1.69	13.79
Forli Cesena	13	5	7.1	1.06	0.73	0.33	27.76
Ferrara	22	8	11.56	2.08	1.41	0.67	23.26
Foggia	26	5	6.62	3.21	1.35	1.85	13.85
Firenze	40	11	17.47	2.81	1.79	1.02	27.62
Frosinone	54	4	12.74	3.49	1.7	1.79	21.26
Genova	16	11	13.59	2	1.55	0.45	24.86

				Yearly effects (in %)			
Province	F_{-i}	F_i	$\widehat{F}_i$	$\widetilde{Y}_i/Y_i$	$\widetilde{\widetilde{Y}}_i/Y_i$	Ext_i/Y_i	Y_i
Gorizia	22	0	3.56	1.11	0.44	0.67	23.04
Grosseto	24	0	3.88	1.19	0.47	0.72	23.42
Imperia	0	0	0	0	0	0	22.92
Isernia	26	1	5.21	1.94	0.87	1.08	17.05
Crotone	9	0	1.46	0.84	0.33	0.51	12.41
Lecco	40	0	0.97	1.84	0.11	1.73	25.35
Lecce	1	8	8.16	1.62	1.57	0.05	14.72
Livorno	11	0	1.78	0.55	0.22	0.33	23.42
Lodi	46	0	7.44	2.29	0.9	1.39	23.36
Latina	51	0	8.25	2.96	1.16	1.79	20.09
Lucca	32	0	5.18	1.43	0.56	0.87	26.03
Macerata	17	9	11.75	2.05	1.51	0.54	22.05
Messina	22	11	14.56	3.69	2.68	1.01	15.38
Milano	24	34	37.56	3.82	3.27	0.55	32.57
Mantova	42	0	6.8	1.73	0.68	1.05	28.20
Modena	26	7	11.21	1.74	1.1	0.64	28.74
Massa Carrara	13	0	2.1	0.73	0.29	0.44	20.80
Matera	27	0	4.37	1.89	0.75	1.15	16.62
Napoli	21	23	26.4	6.42	5.36	1.06	13.96
Novara	49	3	10.93	2.63	1.24	1.39	24.95
Nuoro	21	0	3.4	1.42	0.56	0.86	17.18
Ogliastra	10	0	1.62	0.74	0.29	0.45	15.80
Oristano	21	0	3.4	1.57	0.62	0.95	15.54
Otranto	11	0	1.78	0.64	0.25	0.39	20.04
Palermo	11	11	12.78	2.86	2.36	0.51	15.36
Piacenza	33	3	8.34	1.75	0.88	0.87	26.85
Padova	12	13	14.94	1.96	1.63	0.33	25.96
Pescara	15	3	5.43	1.39	0.82	0.57	18.66
Perugia	33	11	16.34	3.25	2.16	1.09	21.43
Pisa	19	11	14.08	2.14	1.6	0.54	24.85
Pordenone	15	0	2.43	0.71	0.28	0.43	24.58
Prato	26	0	4.21	1.21	0.48	0.73	24.98
Parma	18	10	12.91	1.79	1.33	0.46	27.53
Pistoia	33	0	5.34	1.69	0.67	1.03	22.68
Pesaro-Urbino	18	9	11.91	1.97	1.43	0.54	23.60
Pavia	44	8	15.12	3.12	1.81	1.31	23.66

Province	F_{-i}	F_i	$\widehat{F}_i$	Yearly effects (in %) $\widetilde{Y}_i/Y_i$	$\widetilde{\widetilde{Y}}_i/Y_i$	Ext_i/Y_i	Y_i
Potenza	36	4	9.83	3.12	1.63	1.49	17.05
Ravenna	39	0	6.31	1.79	0.7	1.08	25.04
Reggio Calabria	3	3	3.49	0.83	0.69	0.15	14.38
Reggio Emilia	17	3	5.75	1.1	0.63	0.47	25.79
Ragusa	12	0	1.94	0.93	0.37	0.57	14.97
Rieti	66	0	10.68	3.88	1.53	2.35	19.82
Roma	15	38	40.43	4.22	3.86	0.36	29.64
Rimini	15	1	3.43	0.75	0.36	0.39	27.11
Rovigo	33	0	5.34	1.52	0.6	0.92	25.26
Salerno	27	9	13.37	3.54	2.36	1.19	16.07
Siena	39	8	14.31	2.68	1.6	1.08	25.40
Sondrio	20	0	3.24	0.82	0.32	0.5	28.23
La Spezia	21	0	3.4	1.07	0.42	0.65	22.86
Siracusa	11	1	2.78	1	0.51	0.5	15.59
Sassari	0	11	11	1.87	1.87	0	16.63
Savona	14	0	2.27	0.69	0.27	0.42	23.77
Taranto	24	1	4.88	2.06	0.92	1.13	14.97
Teramo	10	5	6.62	1.43	1.04	0.39	18.08
Trento	15	6	8.43	1.26	0.88	0.39	27.26
Torino	6	14	14.97	1.91	1.74	0.17	24.40
Trapani	11	0	1.78	0.91	0.36	0.55	14.02
Terni	24	0	3.88	1.38	0.54	0.84	20.26
Trieste	0	12	12	1.19	1.19	0	28.48
Treviso	18	0	2.91	0.84	0.33	0.51	25.07
Udine	5	10	10.81	1.35	1.21	0.14	25.31
Varese	39	6	12.31	2.4	1.34	1.06	25.97
Verbania	10	0	1.62	0.58	0.23	0.35	20.03
Vercelli	30	1	5.86	1.49	0.65	0.83	25.39
Venezia	23	5	8.72	1.54	0.93	0.61	26.54
Vicenza	26	0	4.21	1.12	0.44	0.68	27.01
Verona	25	7	11.05	1.84	1.17	0.66	26.65
Medio Campidano	10	0	1.62	0.9	0.35	0.55	12.93
Viterbo	46	5	12.44	3.28	1.71	1.57	20.64
Vibo Valentia	6	0	0.97	0.51	0.2	0.31	13.59
Total	23.01	4.5	8.09	1.88	1.09	0.8	21.52

Notes: All values refer to 2010 levels. Information on Y_i is not available for provinces of Barletta, Fermo and Monza-Brianza. The Yearly effects are obtained dividing each ratio by 10 (since the effects computed in the upper panel refer to a decade) and multiplying by 100 (to express them as percentages).