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The economic impact of universities: Evidence from across the globe

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ABSTRACT

We develop a new dataset using UNESCO source materials on the location of nearly 15,000 universities in about 1,500 regions across 78 countries, some dating back to the 11th Century. We estimate fixed effects models at the sub-national level between 1950 and 2010 and find that increases in the number of universities are positively associated with future growth of GDP per capita (and this relationship is robust to controlling for a host of observables, as well as unobserved regional trends). Our estimates imply that a 10% increase in a region's number of universities per capita is associated with 0.4% higher future GDP per capita in that region. Furthermore, there appear to be positive spillover effects from universities to geographically close neighbouring regions. We show that the relationship between GDP per capita and universities is not simply driven by the direct expenditures of the university, its staff and students. Part of the effect of universities on growth is mediated through an increased supply of human capital and greater innovation. Furthermore, we find that within countries, higher historical university presence is associated with stronger pro-democratic attitudes.

A striking feature of the last hundred years has been the enormous expansion in university education. In 1900, only about one in a hundred young people in the world were enrolled at universities, but over the course of the Twentieth Century this rose to about one in five (Schofer & Meyer, 2005). The term "university" was coined by the University of Bologna, founded in 1088, the first of the medieval universities. These were communities with administrative autonomy, courses of study, publicly recognised degrees and research objectives and were distinct from the religion-based institutions that came before (De Ridder-Symoens & Rüegg, 1992). Since then, universities have spread worldwide in broadly the same form, and it has been argued that they were an important force in the Commercial Revolution through the development of legal institutions (Cantoni & Yuchtman, 2014) and the industrial revolution through their role in the building of knowledge and its dissemination (Mokyr, 2002).

While there is an extensive literature on human capital and growth, there is relatively little research on the economic impact of universities themselves. In this paper, we develop a new dataset using the World Higher Education Database (WHED) that contains the location of universities in 1,500 regions across 78 countries in the period since World War II (when consistent sub-national economic data are available). We focus on how university formation is correlated with future economic growth. Over this period university expansion accelerated in most countries; a trend partially driven by the view that higher education is essential for economic and social progress. This was in contrast to the pre-War fears of "over-education" that were prevalent in many countries, should enrolments much extend beyond the national elites (Goldin & Katz, 2008; Schofer & Meyer, 2005).

There are a number of channels through which universities may affect growth including (i) a greater supply of human capital; (ii) more innovation; (iii) support for democratic values; and (iv) demand effects. Firstly, and most obviously, universities are producers of human capital and skilled workers are more productive than unskilled workers. Geographical distance seems to matter as areas with better university access benefit both from improving the chances that locally born young people will attend college (e.g. Card, 2001) and also because students who graduate are more likely to seek work in the area where the university is located. The empirical macro literature has generally found that at the country level, human capital (typically measured by years of schooling) is important for development and growth (e.g. Sianesi & Van Reenen, 2003). Growth accounting and development accounting relate educational attainment to economic performance and find a non-trivial contribution.[1] Explicit econometric analysis usually, although not always, confirms this positive relationship.[2]

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[1] For example, Hall and Jones (1999) and Caselli (2005), Mankiw, Romer, and Weil (1992).

[2] For example, Barro (1991), de La Fuente and Domenech (2006) and Cohen and Soto (2007).

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A problem with these empirical studies is that they are at the country level and subject to the concern that there are omitted aggregate variables (e.g. Bils & Klenow, 2000; Hanusheck & Woessman, 2009). At the sub-national level, Gennaioli, La Porta, Lopez de Silanes, and Shleifer (2013) show that *regional* years of schooling is important for *regional* GDP per capita in the cross section and Gennaioli, La Porta, Lopez de Silanes, and Shleifer (2014) confirm this relationship also holds for growth regressions. Furthermore, human capital appears to also have an indirect effect via spillovers which are analysed inter alia by Moretti (2004a) at the firm level, and Moretti (2004b) and Glaeser and Lu (2018) at the individual level. In an historical setting, Squicciarini and Voigtländer (2014) show that "upper tail" knowledge was important in the industrial revolution, and they measure this type of knowledge using city level subscriptions to the Encyclopédie in mid-18th century France.

A second channel through which universities may affect growth is innovation. This may be an indirect influence because, as in the previous point, universities increase educational supply.[3] But it could also be a direct influence as university researchers themselves produce innovations, sometimes in collaboration with local firms. A number of empirical papers have found that universities increase local innovative capacity.[4] A drawback of this literature is that it uses proxies for innovation such as patents rather than looking at economic output directly. Moreover, the work is also focused on single countries, somewhat limiting its generalisability.

A third way universities may matter is by fostering pro-growth institutions. Universities could promote strong institutions directly by providing a platform for democratic dialogue and sharing of ideas, through events, publications, or reports to policy makers. A more obvious channel would be that universities strengthen institutions via their role as human capital producers. The relationship between human capital, institutions and growth are much debated in the literature. Indeed, there remains controversy over whether institutions matter at all for growth.[5] Some papers have argued that human capital is the basic source of growth, and the driver of democracy and improved institutions (e.g. Glaeser, LaPorta, Lopez-de-Silanes, & Shleifer, 2004). But the relationship between education and democracy/institutions is contested by Acemoglu, Johnson, Robinson, and Yared (2005b) who argue that the effects found in the cross section of countries are not robust to including country fixed effects and exploiting within-country variation.

Finally, universities may affect growth through a more mechanical "demand" channel. Increased consumption from students and staff and the universities' purchase of local goods and services could have a material impact on GDP. This would occur when a new university attracts new students and staff into the region, or when university costs are financed though national governments from tax revenues raised mainly outside the region where the university is located.

We show that university growth has a strong association with later GDP per capita growth at the sub-national level. Even after including a host of controls (including country or region fixed effects to control for differential regional trends, and year dummies) we find that a 10% increase in the number of universities in a region is associated with about 0.4% higher GDP per capita. We show that reverse causality does not appear to be driving this, nor do demand effects. We also find that increases in universities in neighbouring regions is also correlated with a region's growth. Finally, we show that the association of per capita GDP and university presence works partially through increasing the supply of human capital and also through raising innovation, but both these channels are not large in magnitude. In addition, in cross sectional analysis we find that universities appear to be correlated with more pro-democratic views even when we control for human capital, consistent with a story that they may have some role in shaping institutions over longer time horizons.

If policy-makers decided to open new universities in areas with strong economic potential, any positive correlation could simply be due to expectations of growth causing university formation rather than vice versa. Our view is that in the post-war period, university expansion was largely a policy pursued by national governments rather than simply a response to local sub-national conditions. Governments were focused on social equity (Dahrendorf, 1965), improving technological capacity (in response to the Cold War, especially the 1957 Sputnik crisis, see Barr, 2014) and a general recognition of the value of human capital (Becker, 1964). This kind of "development planning" (Schofer & Meyer, 2005) stood in contrast to pre-war period views which often saw little need to extend tertiary education beyond a narrow elite.

In the Appendix we describe three country case studies of largescale university expansion which all have a substantial exogenous element to local economic conditions. Nonetheless, we attempt to address endogeneity concerns by using lagged university openings, controlling for a rich set of observables and including both unobserved regional fixed effects and regional trends in the regressions. We do not have credible external instrumental variables to rule out all possibilities of endogeneity bias. In particular, time varying unobservables at the region level cannot be controlled for in our framework. If, for example, some regional policy-makers opened new universities and also pursued other growth enhancing policies, the reported association might emerge without a causal effect of universities on growth. The strength of our analysis is in the comprehensiveness of the new data across space and time and the associations we document should be seen as suggestive rather than definitive.

To date, few papers have explicitly considered the direct link between university presence and economic performance. Cantoni and Yuchtman (2014) argue that medieval universities in 14th century Germany played a causal role in the commercial revolution (using distance from universities following the Papal Schism, an exogenous event which led to the founding of new universities in Germany). In a contemporary setting, Hausman (2012) links university innovation to economic outcomes in US counties, finding that long-run employment and pay rises in sectors closely tied with a local university's innovative strength, and that this impact increases in proximity to university. Aghion, Boustan, Hoxby, and Vandenbussche (2009) consider the impact of research university activity on US states. Using political instruments, they find that exogenous increases in investments in four year college education affect growth and patenting. Kantor and Whalley (2014) estimate local agglomeration spillovers from US research university activity, using university endowment values and stock market shocks as an instrument for university research spending. They find evidence for local spillover effects to firms, which is larger for research intensive universities or firms that are "technologically closer"

[3] This may be wider than just via technology, Feng and Valero (2018) and Bloom, Lemos, Sadun, & Van Reenen (2017) also find a role for the universities in helping diffuse productivity-enhancing managerial best practices.

[4] This literature stems from Jaffe (1989) who uses US state level data to provide evidence of spillovers from university research to patenting and R&D spending by firms. A number of papers have shown that such effects are localised (see for example, Jaffe, Trajtenberg, and Henderson (1993), Anselin, Varga, & Acs (1997), Belenzon and Schankerman (2013), Fischer and Varga (2003)). Andrews (2017) exploits quasi random allocation of universities to US counties over the period 1839-1954 to estimate their causal impact on patenting. Toivanen and Väänänen (2016) consider how universities affect innovation via their role as human capital producers: they use distance to a technical university as an instrument in estimating the effect of engineering education on patents in Finland (which they find to be positive and significant). Watzinger, Treber, and Schnitzer (2018) show how the hiring of new science professors impacts on local private sector innovation.

[5] See, for example, Acemoglu, Johnson, & Robinson (2005a), Acemoglu et al. (2014) who argue institutions matter a lot, and Gerring, Bond, Barndt, and Moreno (2005) for a summary of papers that conclude that they do not.

to universities.[6] Feng and Valero (2018) use international data to show that firms that are closer to universities have better management practices (Bloom, Sadun, & Van Reenen, 2017).

This paper is organised as follows. Section 1 describes the data and some of its key features including interesting trends and correlations which give us a macro level understanding of the global rise in universities over time. Section 2 sets out our econometric strategy, and Section 3 our results. Section 4 explores the mechanisms through which universities appear to affect regional growth and finally, Section 5 provides some concluding comments.

1. Data

Our regression analysis is based upon information on universities in some 1,500 regions in 78 countries. This represents the set of regions for which our university data can be mapped to a regional time series of key economic variables obtained from Gennaioli et al. (2014), and covers over 90 per cent of global GDP.[7] We first describe the full World Higher Education Database (WHED) across all countries, with some key global trends and correlations. Then we focus on the 78 countries for which regional economic data are available, describing how we aggregate the WHED data into regions, and present some initial descriptive evidence.

1.1. World higher education database

WHED is an online database published by the International Association of Universities in collaboration with UNESCO.[8] It contains information on higher education institutions that offer at least a three year or more professional diploma or a post-graduate degree. In 2010, there were 16,326 universities across 185 countries meeting this criterion. The database therefore excludes, for example, community colleges in the US and further education institutions in the UK and may be thought of as a sample of "higher quality" universities. Key variables of interest include university location, founding date, subjects and qualifications offered and other institutional details such as how they are funded.

Our regional analysis is based on that sample of countries for which GDP and other data are available from 1955, which covers 78 countries, comprising 14,868 (or 91%) of the institutions from the full listing. Our baseline results simply use the year-specific count of universities by region as a measure of university presence, always controlling for regional population. To calculate this, we first allocate each university to a region (for example, a US state), and then use the founding dates of universities in each region to determine the number of universities that were present at any particular date.[9] High rates of university exit would invalidate this type of approach, but we find that this does not appear to be an issue over the decades since the 1950s (see Data Appendix).

A disadvantage of the "university density" measure is that it does not correct for the size or quality of the university. Unfortunately, this type of data is not available on a consistent basis across all countries over time, but we present robustness results on a sub-sample where we do have finer grained measures of university size, and use various measures of university type as proxies for quality.

1.2. The worldwide diffusion of universities

We begin by presenting some descriptive analysis of the university data at the macro level using the full university database. Fig. 1 shows how the total number of universities has evolved over time; marking the years that the number doubled. The world's first university opened in 1088 (in Bologna) and growth took off in the 19th Century, growing most rapidly in the post-World War II period (see Panel A). In Panel B we normalise the number of worldwide universities by the global population to show that university density also rose sharply in the 1800s. It continued to rise in the 20th Century, albeit at a slower rate and has accelerated again after the 1980s when emerging countries like Brazil and India saw rapid expansions.

A number of additional descriptive charts are in the Appendix. The distribution of universities across countries is skewed, with seven countries (US, Brazil, Mexico, Philippines, Japan, Russia and India, in descending order) accounting for over half of the universities in the world in 2010 (the US accounts for 13% of the world's universities). We also examine the "extensive margin" – the cumulative number of countries that have any university over time with Bhutan being the latest country to open a university in 2003. By 2010, the vast majority of countries in the world had at least one university. We also provide an historical overview of the diffusion of universities from the 1880 s in four advanced economies: France, Germany, the UK and US, and two emerging economies: India and China at the country level. We compare the timing of historical university expansions to growth and industrialisation. Descriptively, the data looks broadly in line with the thesis of Mokyr (2002) that the building and dissemination of knowledge played an important role in the industrialisation of many countries.

For further description of the data at the national level, we examine the cross sectional correlations of universities with key economic variables. Unsurprisingly, we find that higher university density is associated with higher GDP per capita levels. It is interesting that countries with more universities in 1960 generally had higher growth rates over the next four decades. Furthermore, there are strong correlations between universities and average years of schooling, patent applications and democracy.[10] These correlations provide a basis for us to explore further whether universities matter for GDP growth within countries, and to what extent any effect operates via human capital, innovation or institutions.

1.3. Regional economic data

We obtain regional economic data from Gennaioli et al. (2014) who collated key economic variables for growth regressions at the sub-national level.[11] The outcome variable we focus on is regional GDP per capita. Since for many countries, regional GDP data and other variables such as population or years of education are not available annually we follow Barro (2012) and compute average annual growth rates in GDP per capita over five year periods.[12] We also gather patents data at the regional level as a measure of innovation. For 38 countries, we obtain region-level European Patent Office (EPO) patents from the OECD REGPAT database covering 1978 to 2010.

Table 1 has some descriptive statistics of our sample of 8,128 region-years. The average region has GDP per capita of just over $13,000, average growth of 2% per annum and nearly ten universities (this is

[6] In related work, Kantor and Whalley (2016) find evidence of agricultural productivity effects from proximity to research in US agricultural research stations. Effects appear persistent where stations focused on basic research and farmers were already at the technology frontier.

[7] Based on World Bank GDP in 2014 (US dollars, PPP).

[8] For more information, see http://www.whed.net/home.php.

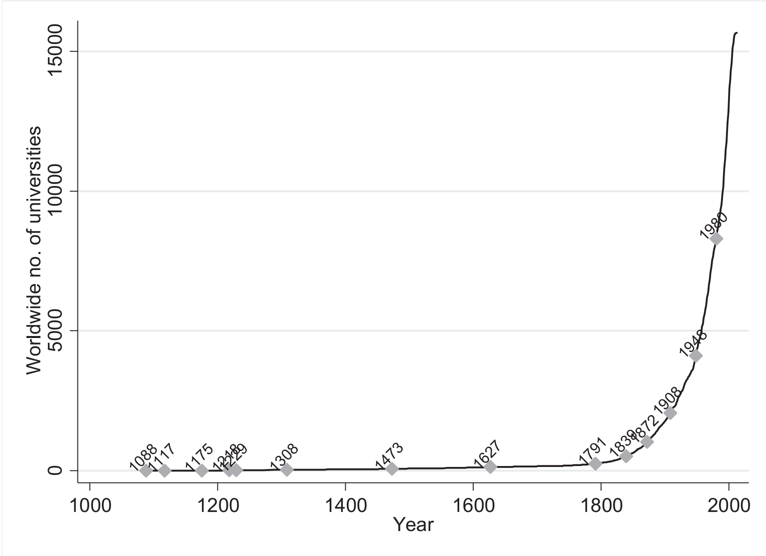
[9] Of the full sample of 16,326 universities, we were unable to obtain founding date information for 669 institutions (4% of the total). 609 of these fall into our core analysis sample (in the 78 countries for which regional economic data are available). These institutions are therefore omitted from analysis.

[10] We use Polity scores as a measure of democracy, as is common in the literature. See for example Acemoglu, Naidu, Restrepo, and Robinson (2014)

[11] The availability of regional data for different countries is outlined in Gennaioli, La Porta, Lopez de Silanes, and Shleifer (2014).

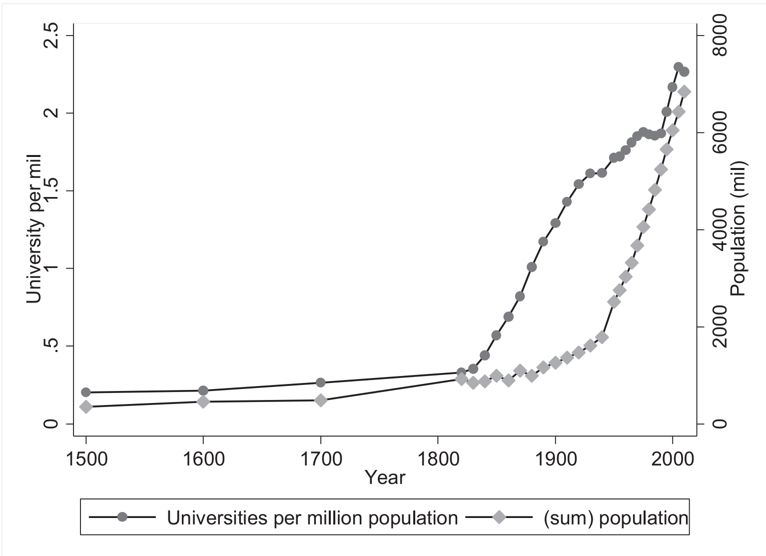
[12] We interpolate missing years, but do not extrapolate beyond the final year (or before the first year of data). Our results are robust to dropping interpolated data.

Panel A: University Count



Notes. The evolution of global universities over time; years where the total number doubled are marked. *Source: WHED.*

Panel B: University Density and Population



Notes. This chart shows the evolution of global university density (universities per million people) and population over time. *Source: WHED and Maddison population data.*

Fig. 1. Worldwide universities over time.

quite skewed with a median of 2, so in our robustness tests, we show that our results are not sensitive to dropping region-years with no universities).[13] As we set out in the next section, our core regressions will control for the level and growth of population,[14] and a number of geographic characteristics – including an indicator for whether a region contains a country's capital. Measures of regional human capital (college share and years of education) are available for sub-samples of region-years. People in the average region have an average of seven years of education with just seven percent of them having attended college.

Fig. 2 shows that the raw correlations between growth rates of universities and GDP per capita that we saw at the country level are also present within countries. Panel A simply plots the average annual growth in regional GDP per capita (on the y-axis) on the average annual growth in universities (on the y-axis), over the whole time period for which data are available (which differs by region). Average GDP per capita growth rates are plotted within 20 evenly sized bins of university growth, and country fixed effects are absorbed so that variation is within country. Panel B plots GDP per capita growth rates on lagged university growth for the 8,128 region-years (on which we conduct the core of our analysis that will follow). In both graphs it is clear that there

[13] A related fact is that the median growth rate of the number of universities is zero (5,856 observations). This implies that 28 per cent of the observations have an increase in the number of universities. We also checked that the results are not driven by regions that increased their number of universities from zero to one or more.

[14] It would be desirable to control for working age population, together with total population, since this is expected to affect production and growth. Unfortunately, demographic data at the regional level over time across a wide range of countries is not available, but we note that the region trends in our core regressions should control for demographic shifts.

Table 1
Descriptive statistics.

	Mean	S.D	Min	p50	Max	Obs
Regional GDP per capita	13,055.75	11,958.30	262.15	8,463.02	105,648.25	8,128
Growth in regional GDP per capita	0.02	0.03	−0.20	0.02	0.30	8,128
Country GDP per capita	14,094.16	11,525.30	690.66	9,157.66	64,198.29	8,128
# universities	9.60	23.71	0	2.00	461.00	8,128
Growth in # universities	0.02	0.03	0	0.0	0.28	8,128
Population (millions)	2.78	7.97	0.01	1.01	196.00	8,128
Growth in population	0.01	0.02	−0.14	0.01	0.25	8,128
Latitude	27.74	25.65	−54.33	37.75	69.95	8,128
Inverse distance to ocean	0.03	0.07	0	0.01	1.89	8,128
Malaria index	0.89	2.31	0	0.01	25.51	8,128
log(oil and gas production) 1950–2010	1.72	2.86	0	0.00	12.05	8,128
Dummy for capital in region	0.05	0.22	0	0	1.00	8,128
Distance to nearest region ('000km)	0.14	0.19	0.01	0.08	2.79	8,128
College share	0.07	0.07	0.00	0.04	0.45	5,744
Years of education	7.37	3.08	0.39	7.42	13.76	6,640

Notes. Each observation is region-year. *Source: WHED and* Gennaioli et al. *(2014) for regional economic data.*

is a positive relationship.[15]

2. Empirical framework

The underlying model we are interested in is the long-run relationship between universities and economic performance:

$$ln(Y/L_{ic,t}) = \alpha_1 \ln(Uni_{ic,t}) + \alpha_2 \ln(Pop_{ic,t}) \tag{1}$$

where $Y/L_{ic,t}$ is the level of GDP per capita ("GDPpc") for region *i*, in country *c*, and year *t*; and $Uni_{ic,t}$ is the number of universities in the region[16] and *Pop* is the population. In the empirical application we lag the university coefficient by at least five years as there is unlikely to be immediate effect. Using the fifth lag seems natural as almost all students will have graduated in a five year period and it is standard practice to calculate growth rates in 5 year blocks (for example, Barro, 2012, Gennaioli et al., 2014). In addition, using the lag means that we eliminate the effects of a contemporaneous demand shock that raises GDP per capita and also results in the opening of new universities. Since the impact of universities could take place over a longer period of time we consider this to be a conservative approach.[17] We also look at results using longer distributed lags (which means losing more of the early years of the sample). These specifications result in larger long-run implied impacts of universities, presumably because it takes longer for human capital to build up in the area.

The cross sectional relationship is likely to be confounded by unobservable region-specific effects. To tackle this we estimate the model in long (five-year) differences to sweep out the fixed effects. Our main estimating model is therefore:

$$\Delta ln(Y/L_{ic,t}) = \alpha_1 \Delta \ln(Uni_{ic,t-5}) + \alpha_2 \Delta \ln(Pop_{ic,t-5}) + X'_{ic,t-5}\alpha_3 + \eta_i + \tau_t + \varepsilon_{ic,t} \tag{2}$$

We control for a number of observables *X*, that may be related to GDP per capita growth and also the growth in universities including the lagged level of population, country and regional level GDP per capita (to allow for catch up) and an error term which we cluster at the region level. Finally, as well as time dummies (τ_t) we include region fixed effects (η_i) which in these difference equations allow for region-specific time trends, which is a demanding specification. We show the robustness of the results to including country by year dummies. We do not initially include any other measure of human capital and innovation in these specifications, so that we can capture the total effect that universities have on growth. However, we explore the effect of adding human capital and innovation when we try to pin down the mechanism through which universities impact on growth. Our data is from the match of the WHED and Gennaioli et al. (2014) databases which attempted to obtain university, education and GDP data from every sub-national region in the world. Since this is where the variation in the data lives we cluster the standard errors at this regional level in our baseline results (see Abadie, Athey, Imbens, & Wooldridge, 2017). However, to we also show more conservative approaches, for example clustering at the country level.

We also explore the extent to which GDP per capita growth in region *i* may be affected by growth of universities in *other* regions within the same country and discuss this econometric specification in Section 3.4 below.

3. Results

3.1. Basic relationships

As an initial investigation, we examine the regional cross sectional correlations between universities and regional GDP per capita, based on the year 2000. Column (1) of Table 2 shows that there is a significant and positive correlation between GDP per capita and universities: controlling for population, a 10% increase in the number of universities is associated with around 6% higher GDP per capita. Column (2) includes country fixed effects which reduces the university coefficient substantially from 0.680 to 0.214. We include a host of further geographic controls in column (3) - whether the region contains a capital city, its latitude, inverse distance to ocean, malaria ecology and the log of cumulative oil and gas production.[18] This reduces the coefficient on

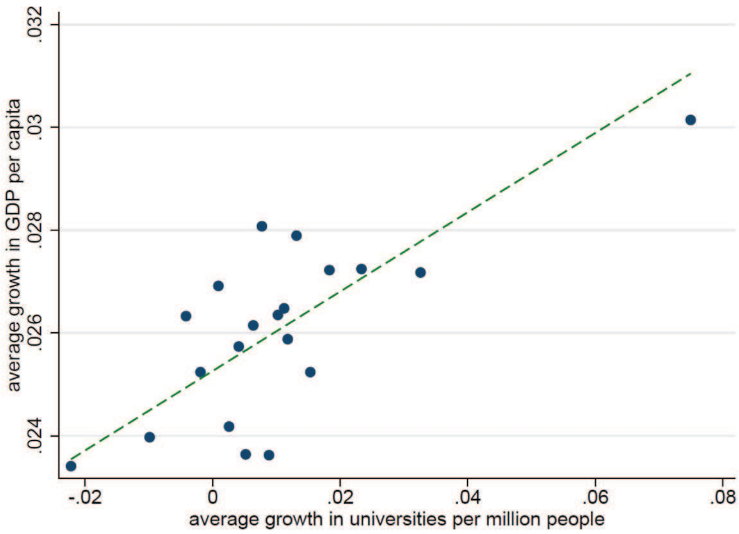
[15] In addition, these graphs show that there are observations with very high university growth in the top bin. We explore which region-years were driving this found that they are evenly spread across 60 countries and different years, so they do not appear to be data errors. Dropping the observations in the highest growth bin actually strengthens the correlation in this simple scatter plot. We keep all the data in the main regressions, but show that the results are robust to dropping these observations or winsorising the top and bottom 5% observations of lagged university growth and GDP growth.

[16] We add 1 to the number of universities before taking logs so we can include region-years where there are no universities. We show robustness to other ways of dealing with the zeros such as dropping observations with no universities.

[17] For example, using cross country panel data, Dias and Tebaldi (2012) find effects of human capital growth on GDP growth with a 10 year lag; Breton and Breton (2016) show that increased average schooling takes around 40 years to translate into GDP increases; and Marconi (2018) shows that increases in secondary schooling only show up in GDP when workers are 45-64. Of course, the impact of universities does not necessarily only come from graduate supply. It may also come through university-business linkages, executive education and effects on institutions. We discuss these further below.

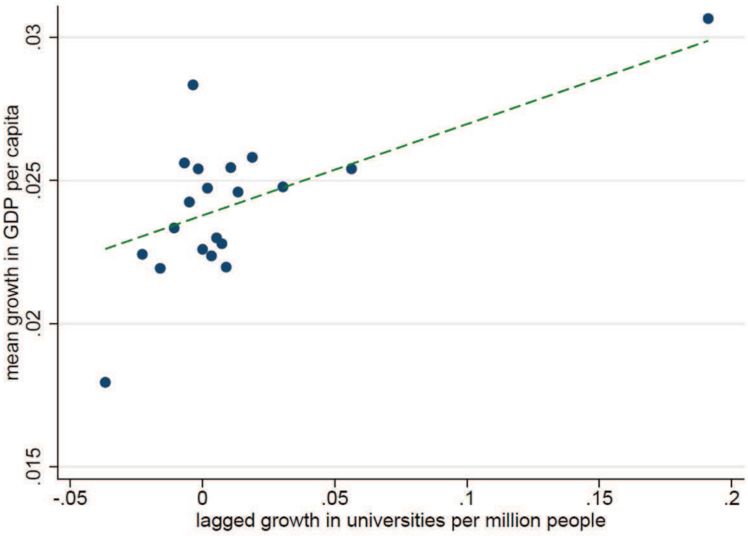
[18] Specifically, we take the natural log of 1+ this value, so that we retain zeroes in our sample.

Panel A: Average growth rates, one observation per region



Notes. 1,498 region observations are grouped equally into 20 bins, variation is within country. *Source:* WHED and Gennaioli et al. (2014) for regional GDP per capita and population.

Panel B: Average growth rates, region-year observations



Notes. 8,128 region-year observations are grouped equally into 20 bins, variation is within country. *Source:* WHED and Gennaioli et al. (2014) for regional GDP per capita and population.

Fig. 2. Growth in regional GDP per capita and university density.

universities still further to 0.160. In column (4) we add years of education. This reduces the coefficient on universities by around two-thirds.[19] In column (5) we repeat the column (2) specification but restrict to the sample for which patents data are available, and add years of education in column (6). Again, this reduces the coefficient on universities, by about half. In column (7), we see that adding a measure of patent "stock" reduces our coefficient on universities to 0.056, but it remains significant.

3.2. Main results

Table 3 presents our main results on our core sample.[20] Column (1)

[19] The coefficient on years of education is highly significant and similar in magnitude to the cross section results in Gennaioli, La Porta, Lopez de Silanes, and Shleifer (2013). In regressions of regional income per capita on years of education, controlling for geographic characteristics, Gennaioli et al. (2013) estimate a coefficient of 0.2763, see their Table IV column (2).

[20] Allowing for the lag structure, the panel covers 11 waves, from 1960 to 2010 and spans 1498 regions. The panel is unbalanced, driven by the availability of regional economic data which is better in later years. For example, in the core sample of 8,128 region years, there are only 211 observations of GDP per capita growth in 1960 (which requires regional GDP per capita in 1955 for its calculation). This sample includes advanced economies like UK, US, Germany, France and Italy, and some South American countries like Brazil and Mexico. By contrast, most regions are included in our sample in the later years (for example 1304 of the 1498 regions are observed in 2005) though economic data are not available for some countries in later years (for example data for Venezuela spans 1960-1990).

Table 2
Cross-sectional regressions.

Dependent variable: Regional GDP per capita	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(# universities)	0.680***	0.214***	0.160***	0.056***	0.164***	0.074**	0.056**
	(0.124)	(0.042)	(0.039)	(0.021)	(0.048)	(0.031)	(0.022)
ln(population)	−0.468***	−0.105**	−0.112***	−0.069***	−0.100**	−0.054*	−0.123***
	(0.100)	(0.041)	(0.033)	(0.023)	(0.041)	(0.027)	(0.032)
Years of Education				0.292***		0.283***	0.237***
				(0.028)		(0.034)	(0.040)
ln(EPO Patent "stock")							0.081***
							(0.018)
Observations	1213	1213	1182	1182	619	619	619
# clusters	65	65	62	62	34	34	34
country dummies	no	yes	yes	Yes	yes	yes	yes
region controls	no	no	yes	Yes	yes	yes	yes

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. OLS estimates based on data in 2000. Standard errors clustered at the country level. Column (1) shows the relationship between universities and the natural log of GDP per capita, controlling for population. Column (2) includes country dummies. Column (3) includes regional controls (a dummy indicating whether the region contains a capital city, together with latitude, inverse distance to ocean, malaria ecology, log(oil and gas production) 1950–2010, these are not reported here). Column (4) includes years of education. Column (5) is the same specification as column (3) but restricts the sample to the regions for which OECD REGPAT patents are available. Column (6) includes years of education, and column (7) includes the natural log of the regional patent “stock”. We add one to the number of universities and to patents before taking logs.

Table 3
Baseline results.

Dependent variable: Regional Growth of GDP per capita	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Lagged growth in #universities	0.047***	0.036***	0.040***	0.046***	0.044***	0.045***	0.047***	0.047***	0.023**
	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.016)	(0.010)
Lagged level of regional GDP per capita				−0.015***	−0.013***	−0.058***	−0.078***	−0.078***	−0.077***
				(0.001)	(0.001)	(0.003)	(0.005)	(0.007)	(0.005)
Lagged level of country GDP per capita					−0.021***		0.038***	0.038**	
					(0.004)		(0.006)	(0.018)	
Lagged level of population /100		0.178***	−0.030	−0.076*	−0.086**	−1.095***	−0.850**	−0.850	−1.724***
		(0.032)	(0.035)	(0.040)	(0.039)	(0.333)	(0.352)	(0.720)	(0.476)
Lagged growth in population				−0.099**	−0.113***	−0.209***	−0.183***	−0.183***	−0.182***
				(0.038)	(0.039)	(0.045)	(0.045)	(0.068)	(0.050)
Dummy for capital in region				0.012***	0.011***				
				(0.002)	(0.002)				
Observations	8128	8128	8128	8128	8128	8128	8128	8128	8128
# clusters	1498	1498	1498	1498	1498	1498	1498	78	1498
clustering	Region	Region	Region	Region	Region	Region	Region	Country	Region
year dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
country dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
region controls	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
region trends	No	No	No	No	No	Yes	Yes	Yes	Yes
country by year dummies	No	No	No	No	No	No	No	No	Yes

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. OLS estimates, 78 countries. Column (1) is a simple correlation between regional GDP per capita growth and the lagged growth in university numbers. Column (2) controls for the lagged log of population. Column (3) includes country and year dummies. Column (4) controls for lagged regional GDP per capita, the lagged growth in population, the lagged log population level, a dummy for whether the region contains a capital city, together with latitude, inverse distance to ocean, malaria ecology, log(oil and gas production) 1950–2010 (not reported here). Column (5) adds lagged country GDP per capita. Column (6) includes regional fixed effects, and the time varying controls of column (4). Column (7) adds lagged country GDP per capita. Standard errors are clustered at the regional level except in column (8) where they are clustered at the country level. Levels of GDP per capita and population are in natural logs.

is a simple correlation between the growth of regional GDP per capita and the lagged growth of universities with no other controls. The estimated coefficient is 0.047 and highly significant. To control for the fact that populous regions are more likely to require more universities, we add the lagged level of the population in column (2) which lowers the university coefficient slightly. Adding country and year fixed effects in column (3) has little effect. In column (4) we add the lagged level of regional GDP per capita (as in the convergence literature from Barro (2012) – see below), the growth in population, and several regional covariates (latitude, inverse distance to the coast, malaria ecology, and oil and gas production since 1950) and a dummy for the region with the capital city. In column (5) we control for lagged country-level GDP per capita which should capture time varying macro shocks. Columns (6) and (7) replicate columns (4) and (5) but include *regional fixed effects*, a very demanding specification which allows for regional trends. These do not much affect the university coefficient and in fact it is higher at 0.047 in the most general specification. Overall, these results suggest that on average, a 10% increase in the number of universities in a region is associated with around 0.4% higher GDP per person.[21] Our baseline results cluster at the regional level, but column (8) clusters the standard errors at the much more conservative level of the country and shows that the coefficient on universities remains significant. Finally column (9) includes a full set of country by year dummies which is a very demanding specification. Although the

[21] Our analysis is carried out on a sample that drops 54 observations from China pre 1970, before and during the Cultural Revolution, when universities were shut down. Our effects survive if these observations are included, with the coefficient on university growth becoming 0.0320, still significant at the 1% level. We drop them because of the unique nature of this historical episode and the fact that this small number of observations (less than 1% of the full sample) seem to have a large effect on the coefficient.

coefficient on universities falls by about half, it remains significant.

The other variables in the regressions take the expected signs. The coefficient on the regional convergence term is nearly 2% in columns (4) and (5).[22] Country GDP per capita has a negative coefficient in these specifications. This becomes a positive relationship once regional fixed effects are included. Having a capital city in a region is associated with around one percentage point higher regional GDP per capita growth. In the Appendix, we show that the geographic controls in columns (4) and (5) generally have the expected signs.

We explore different distributed lag structures, and find that in general a single five year lag is a reasonable summary of the data, although there are smaller but significant effects at the 10 year lag, and even the 25 year lag on the full sample[23] (see Appendix). We might expect the effect of universities on regional GDP to grow over time, due to the gradual accumulation of graduates entering the workforce, or the building of regional innovative capacity. However, over longer time frames, there are more factors at play which are not captured in our estimation framework, and our sample is reduced since a longer time series of economic data is not available for all countries. Interestingly, the contemporaneous (unlagged) effect of university growth is zero or negative (although not significant), suggesting that it takes some time for benefits to be felt, while presumably some costs are incurred at the regional level. There is some evidence for stronger effects at the 10 year lag and longer lags when considering only the US, UK, France and West Germany (advanced Western economies which we might associate with the Sputnik crisis).

3.3. Robustness and heterogeneity

3.3.1. Specification and sample checks

We conduct a large number of robustness checks on our baseline specifications with and without regional trends (i.e. columns (5) and (7) of Table 3), as detailed in the Appendix. Firstly, we do a block of *specification* checks: weighting by the region's population share; controlling for the current population changes (to partially address the concern that the effect of the university is simply to pull in more people to the region, who spend or produce more and hence raise GDP per capita growth – see Section 4 below); and using growth in university density instead of the count. Secondly, we check *sampling* issues: dropping regions which never have a university; dropping region-years with no universities; dropping the observation when a region opens its first university; winsorising the top and bottom 5% of university growth and/or GDP per capita growth as the dependent variable and dropping observations where we have interpolated GDP per capita. A third set of *measurement* issues includes adding a dummy for regions where more than 5% of universities in the original listing have missing founding dates (and are therefore excluded from our analysis) and exploring whether the definition of university in WHED (i.e. only institutions that offer four year courses or postgraduate degrees) may be a problem. The results are robust to all these checks (and some others described in the Appendix).

Finally, to investigate the potential concern that our results are driven by expectations of growth in the region we explore “Granger Causality” tests. We use the growth in universities as the dependent variable and regress this on the lagged growth in regional GDP per capita, and the other controls. We see that even as all controls are added, the lagged growth of regional GDP per capita has no relationship with current growth in universities and does not appear to “Granger cause” the opening up of universities.[24] As another test of reverse causality, we add lagged growth in regional GDP per capita to our core specification and find that the coefficient on universities rises to 0.053 and remains significant.[25]

3.3.2. Heterogeneity

To examine the heterogeneity in the university coefficient we first examine whether the university effect differs by groups of countries where we have reasonable numbers of observations: (i) the US, UK, France and West Germany; (ii) the rest of Europe and Canada; (iv) Latin America; (v) Asia (including Australia) and (vi) Africa. There is a positive relationship between university growth and growth in regional GDP per capita in all areas ranging from coefficients of 0.004 to 0.116 (see Appendix), although it is not significant in some groupings. We also examined whether there is heterogeneity across time periods within these groupings. It is interesting to note that in US, France, West Germany and the UK there are significant effects in the pre-1990 period and post-1990 period. Conversely, in Asian countries, we find that there is a positive significant coefficient on university growth in the post 1990 period only.

We also test whether within a country, the university effect is driven by richer or poorer regions – the latter being consistent with catch-up growth. We find that interacting the university effect with a variable that normalises a region's GDP per capita by that country's frontier region (the region with the highest GDP per capita in that year) gives a negative and significant coefficient. It does appear therefore that new universities have a stronger impact on laggard regions within a country.

3.3.3. University size and quality

A concern with our econometric strategy is that our use of university numbers is a very imperfect measure of university presence. Universities are not homogeneous, but vary in size and quality. Clearly, both of these dimensions are likely to matter in terms of economic impact (although it is not obvious why this would necessarily generate any *upwards* bias in our estimates). An alternative measure would be to use changes in enrolments over time. Even if such data were available for all countries (which it is not) one would be particularly concerned about demand side endogeneity driving enrolments. This issue notwithstanding, we can focus on the United States where state level enrolments dating from 1970 are published by the National Center for Education Statistics (NCES).[26] We find that university numbers and total enrolments are highly correlated (around 0.9 in a given year) and that there is a strong positive relationship between the growth in universities and growth in students between 1970–2010.[27] This gives us some reassurance that the number of universities is a reasonable measure of university presence at the regional/state level.

Ideally, to measure quality we would like to have global rankings for all our institutions, carried out annually throughout our sample period.[28] However, university rankings tables only tend to cover the top

[22] In the fixed effects specifications (7) and (8) this is larger, potentially reflecting the downward (Nickell-Hurwicz) bias in the coefficient of the lagged dependent variable which is particularly an issue in short panels (see Barro (2012) and Gennaioli et al. (2014)).

[23] A similar pattern is found when we include each lag separately.

[24] Interestingly, there is a negative and significant relationship between university growth and the lagged level of universities, suggesting catch-up. Similarly there is a negative relationship between lagged years of education and university growth. There is however, a positive relationship between the growth in years of education and university growth.

[25] While empirical evidence suggests that current growth is not a good predictor of future growth in the long-run (Easterly, Kremer, Pritchett, & Summers, 1993), there might be persistence in the short run. If this is the case, and lagged growth in universities is correlated with lagged growth in regional GDP per capita, then our results could be affected by reverse causality.

[26] See http://nces.ed.gov/fastfacts/display.asp?id = 98.

[27] See Fig. A4 in the Appendix.

[28] Some studies have considered the quality dimension within individual countries. For example, using data from the UK, Abramovsky and Simpson (2011) find that research quality affects the location of firm R&D; and Helmers & Rogers (2015) find that university quality affects the patenting of small firms. Valero (2018) also finds that universities of higher quality in the

few hundred institutions in the world, and tend to be available only for recent years.[29] Our data do contain some key attributes of universities which may be indicative of quality, specifically whether or not a university is a research institution (as indicated by whether or not a university can grant PhDs); whether it offers STEM (science, technology, engineering or mathematics) subjects, and whether it offers "professional service" related courses (which we define as business, economics, law, accounting or finance related courses).[30] Table 4 adds these variables to the analysis by considering the effect of the growth in the share of each type of university over and above the growth in the number of all universities.[31] Panel A shows the result for the full sample of countries. Each column includes one of these measures in turn. The effects are not significantly different from zero, suggesting that on the entire sample there seems to be a general university effect which does not vary much by type of university as defined here.

Again, we disaggregate this analysis between the more advanced economies of Western Europe and the US in Panel B of Table 4 and other countries (in Panel C). Increases in the share of PhD granting institutions, STEM and professional course institutions *are* significant in Panel B but not in Panel C. When all of these shares are included together in column (5), only the share of PhD granting institutions remains significant. This analysis is suggestive evidence that the research channel may be more important in countries nearer the technology "frontier" (as in Aghion, Meghir, & Vandenbussche, 2006).

Table 4
Differences in university quality.

Dependent variable: Regional Growth of GDP per capita	(1)	(2)	(3)	(4)	(5)
Panel A: Full sample					
Lagged growth in #universities	0.047***	0.051***	0.042***	0.050***	0.046***
	(0.011)	(0.012)	(0.013)	(0.013)	(0.014)
Lagged growth in PhD share		−0.003			−0.004
		(0.003)			(0.004)
Lagged growth in STEM share			0.002		0.005
			(0.003)		(0.003)
Lagged growth in professional share				−0.001	−0.002
				(0.003)	(0.004)
Observations	8128	8128	8128	8128	8128
Panel B: US, UK, FR, DE					
Lagged growth in #universities	0.051***	0.017	0.018	0.031*	0.014
	(0.016)	(0.016)	(0.018)	(0.017)	(0.017)
Lagged growth in PhD share		0.017***			0.015**
		(0.004)			(0.006)
Lagged growth in STEM share			0.015***		0.004
			(0.004)		(0.004)
Lagged growth in professional share				0.010**	−0.000
				(0.005)	(0.007)
Observations	1023	1023	1023	1023	1023
Panel C: All other countries					
Lagged growth in #universities	0.048***	0.054***	0.044***	0.052***	0.049***
	(0.011)	(0.013)	(0.013)	(0.014)	(0.015)
Lagged growth in PhD share		−0.004			−0.005
		(0.003)			(0.004)
Lagged growth in STEM share			0.002		0.005
			(0.003)		(0.003)
Lagged growth in professional share				−0.001	−0.002
				(0.003)	(0.004)
Observations	7105	7105	7105	7105	7105

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Panel A includes the full sample of countries, and Panel B restricts to the US, UK, France and West Germany. Within each panel, our core regression (Column (7) from Table 3) is replicated in column (1). Then in columns (2) to (4), the lagged growth of the shares of universities of different types are added as labelled.

3.3.4. Barro growth regressions

Our main specifications in Table 3 included lagged regional (and country) GDP per capita, as is standard in growth regressions to capture convergence. There are of course issues of bias when including a lagged dependent variable, particularly in fixed effects regressions with a short time dimension,[32] and in fact our baseline results are robust to dropping these regressors.[33] An alternative econometric approach is to consider Barro (1991, 2012) "conditional convergence" regressions. In the Appendix (Table A7) we replicate as closely as possible the results in Gennaioli et al. (2014). Column (1) has their basic specification and column (2) includes years of education. Columns (3) and (4) repeat these specifications but adds in the lagged level of universities.[34] Universities have a positive and significant coefficient over and above years of education. As we would expect if some of the effect of universities is via their production of human capital, the effect of universities is higher when years of education are omitted. Note that the interpretation of the university coefficient is different because in steady state we need to divide by the absolute value of the convergence coefficient (0.015). This implies a 10% increase in universities generates a 1.6% increase in long-run GDP per capita (= 0.1*0.00243/0.015). This is much *larger* than our baseline estimates of 0.4%. Due to the econometric difficulties of interpreting the coefficient on the lagged dependent variable in these kind of dynamic panel data models, we prefer our baseline estimates, but note that we might be under-estimating the strength of the growth-university relationship in our more conservative approach.[35] Finally, to understand better the difference between the growth and levels effects, we include also the lagged level of universities in our core regression (Table 3, column (7)). This actually raises the coefficient on lagged university growth to 0.059, still significant at the 1% level. The coefficient on the lagged level of universities is −0.005 (significant at the 5% level), so it does not appear that there is any substantive effect of the level of universities on growth.

(*footnote continued*)
UK have a larger impact on start-up activity and productivity in nearby firms.

[29] For example, the Shanghai Rankings have been compiled since 2003 and cover the world's top 500 universities.

[30] The way we ascertain subjects offered by each university is by extracting key relevant words from the information provided in WHED. For some universities the descriptions offered can be quite broad (e.g. it may specify "social sciences" instead of listing out individual subjects). We try to keep our STEM and professional course categories broad to account for this, but there are likely to be cases where we do not pick up the accurate subject mix at a university.

[31] We note that these characteristics apply to the universities' status in 2010. In the absence of a full time series of when universities begin to offer different courses or qualifications, we simply assume that these characteristics apply since the universities were founded.

[32] See Hurwicz (1950) and Nickell (1981), and discussion in the context of growth regressions in Barro (2012).

[33] Estimating our core regression Table 3, column (7) without lagged regional and country GDP per capita, the coefficient is 0.0434, significant at the 1% level.

[34] Column (1) follows their Table 5, column (8), omitting years of education, and column (2) includes years of education. The coefficients are very similar: the convergence term is between 1.4% and 1.8%, and the coefficient on years of education is nearly identical at around 0.004.

[35] Table A8 in the Appendix presents a similar analysis, but in long difference format. For each region the dependent variable is the average annual growth rate over a 50, 40 or 30 year time horizon to 2010. This is regressed on starting period universities and other controls. The samples differ according to availability of regional economic data over different time frames. These specifications also show positive (and significant in the case of the 50 year and 30 year differences) relationships between initial period universities and subsequent growth once country fixed effects are included.

Table 5
University spillovers from other regions.

Dependent variable: Regional Growth of GDP per capita	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged growth in #universities	0.047***	0.044***	0.044***	0.044***	0.044***	0.035***	0.037***
	(0.011)	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)
Lagged growth in #universities, nearest region		0.012	0.022**	0.049***	0.049***		
		(0.011)	(0.011)	(0.017)	(0.017)		
Lagged growth in #universities X (dist near region/median dist near region in country)				−0.033***	−0.033***		
				(0.012)	(0.012)		
Lagged growth in #universities in other regions within country						0.059***	0.061***
						(0.013)	(0.013)
Observations	8128	8128	6544	8128	8128	8128	8128
# clusters	1498	1498	1257	1498	1498	1498	1498
Nearest / other region controls	No	No	No	No	Yes	No	Yes

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Column (1) replicates our core regression (column (7) from Table 3). Column (2) adds in the lagged growth in universities in the nearest region. Column (3) replicates column (2) but conditions the sample to regions whose nearest region is less than 200 km away. Column (4) returns to the full sample, but adds an interaction term of universities with the ratio of the distance to nearest region to the median distance to nearest region in the country. Column (5) adds controls from the nearby region: namely the lagged population and population growth (not reported here). There were a small number of observations where the population in the nearest region was missing, relating to early years in the sample period. In this case, population was extrapolated back in time, using a log-linear trend, and a dummy variable included to indicate this. Column (6) includes the lagged growth in universities in all other regions of the country, and column (7) also adds the relevant controls from all other regions in the country: namely the lagged population and population growth (again with a dummy to indicate where the population in the rest of the country has been calculated with missing values for any regions that year).

3.3.5. Summary on robustness

We have shown that our results are robust to different specification and, to the extent that the data allow, consideration of the size and quality dimensions. However, this framework does not allow us to address potential endogeneity due to time-varying unobservables. Although there is no direct way to address this without an external instrumental variable, there are non-trivial time lags between (i) an unobservable local shock and a policy decision to build a university; (ii) the decision to build and opening up of the institution and (iii) the opening of the university and the economic impact. Hence, in our view such local shocks are unlikely to be the reason we observe the relationships documented in our data.

3.4. Geographical spillover effects of universities

If the effects we are finding are real we would expect to see that universities do not just affect the region in which they are located, but also neighbouring regions. To examine this we extend Eq. (2) to include the growth of universities in other regions, which may be the nearest region (*j*) or simply all other regions in the country (*-i*). Therefore, we include the growth in region *i*'s own universities ($\Delta ln\ Uni_{ic,t-5}$) as well as a potential spillover effect from universities located in neighbouring regions ($\Delta ln\ Uni_{jc,t-5}$):

$$\Delta \ln(Y/L_{ic,t}) = \theta_1 \Delta \ln(Uni_{ic,t-5}) + \theta_2 \Delta ln(Uni_{jc,t-5}) + X'_{ic,t-5}\theta_3 + X'_{jc,t-5}\theta_4 + \eta_i + \tau_t + u_{ic,t} \quad (3)$$

The lagged population level and population growth in region *j* are in the controls, $X'_{jc,t-5}$.

We allow for spatial variation by interacting university growth with the term which is the distance between region *i* and its nearest region *j* relative to the median distance to nearest region in the same country. This measure is time invariant, so the term itself in absorbed by region fixed effects. The estimating equation therefore becomes:

$$\Delta \ln(Y/L_{ic,t}) = \phi_1 \Delta \ln(Uni_{ic,t-5}) + \phi_2 \Delta \ln(Uni_{jc,t-5}) + \phi_3 dist_j{}^* \Delta \ln(Uni_{jc,t-5}) + X'_{ic,t-5}\phi_4 + X'_{jc,t-5}\phi_5 + \eta_i + \tau_t + u_{ic,t} \quad (4)$$

where the effect of the nearest region of median distance within a country (so the distance term equals 1) is $\phi_2 + \phi_3$. We expect ϕ_3 to be negative so that the effect of region *j* gets smaller for regions further away within a country.

Table 5 contains the spillover analysis with column (1) replicating our baseline result with column (2) including lagged university growth in the nearest region. This shows that universities in the nearest region have a positive but insignificant association with home region growth. However, on closer inspection it appears that some "nearest regions" are actually very geographically distant. A fifth of observations are in regions over 200 km from the next nearest region (based on distance between centroids), so column (3) we drop these observations. In this sample the nearest region university coefficient is around half the magnitude of the home region's universities. Therefore, using the full sample again in column (4), we control for the growth in universities in the nearest region interacted with the distance to that region relative to the country's median.[36] Consistent with column (3), the interaction is negative and significant. In column (5) we add the relevant controls for the neighbouring region – the lagged population and population growth (which should also control for a demand shock in the neighbouring region in the previous period). These have little effect on our coefficients or their significance.

Finally, we look at the effects of university growth in all other regions (including nearest region) in the country on our home region. Column (6) adds the lagged growth in universities in all regions of a country, excluding the home region. Column (7) also adds the relevant controls (lagged population and population growth for the other regions). These effects are now larger than our main effect and again highly significant.[37] The implication is that a 10% increase in universities in the rest of the country (which in most cases will represent a greater absolute increase than a 10% increase in home region universities) is associated with an increase in home region's GDP per capita of around 0.6 per cent.

Overall, this analysis suggests that universities not only affect the region in which they are built, but also their neighbours and that there does appear to be a spatial dimension to this, in the sense that geographically closer regions have stronger effects.

3.5. Magnitudes

Using the coefficients in Table 5 we can estimate a country-wide effect of a university expansion on the typical region in our dataset. The

[36] We take this measure relative to median to reduce the effects of outliers (for example Hawaii and Alaska in the US). However, the results are similar when we normalise by country mean.

[37] Standard errors in this analysis are clustered at the region level. Conservatively clustering at the country level does not affect significance in the nearest region analysis. The coefficients on growth in all other regions (columns (6) and (7)) remain significant at the 10% level.

average region has nearly 10 universities (see Table 1), and the average country has 20 regions (and therefore 200 universities). Increasing the universities in one region by 10% (from 10 to 11) is associated with a 0.4% uplift to its GDP per capita according to our main result. For each other region, this represents a 0.5% increase in universities in the rest of the country (a rise from 190 universities to 191). Multiplied by 6% (the coefficient on other regions in column (7) of Table 5), this implies an uplift to all other regions' GDP per capita of 0.03%. Assuming the regions in this hypothetical country are identical, the uplift to country-wide GDP per capita is simply the average of these effects: 0.05%.

As a sense check for this result, we collapse our regional dataset to the country level and run macro regressions of GDP per capita growth on lagged university growth. The coefficient on universities is 0.047 (but insignificant). According to these results, a 10% increase in universities at the country level would be associated with a 0.47% increase in GDP per capita. Therefore a 0.5% increase in universities at the country level (equivalent to our hypothetical expansion) would imply a 0.03% uplift – this is smaller (but in the same ballpark) as the 0.05% we calculate using the results from our better identified regional analysis.

While this seems like a significant amount of benefit, we also need to consider the costs of university expansion.[38] Given that the costs of building and maintaining universities will vary widely by country, we choose to focus on a particular institutional setting for this calculation. In the UK in 2010, there were 171 universities across its 10 regions. As an experiment we add one university to each region, a total increase of 10 universities (6%) at the country level. Using similar steps as in our hypothetical country above (but taking into account the actual numbers of universities in each UK region in 2010), we calculate that the overall increase to GDP per capita (or GDP, assuming population is held constant) is around 0.7%.[39] Applied to UK GDP in 2010 (£1,614 billion according to the ONS[40]) this comes to just over £11 billion per year. A crude approximation of the annual costs associated with a university can be made based on university finance data: in 2009–2010 the average expenditure per institution in the UK was around £160 million.[41] Multiplying this by the 10 universities in our experiment, the implied annual cost for the additional universities is £1.6bn, or 0.1% of GDP. So, in this example the potential benefits of university expansion appear far larger than the costs (0.7% vs. 0.1%).

While this calculation is highly simplified, it shows that there is a large margin between the potential benefits of university expansion implied by our regression results and likely costs. We note that the costs of setting up universities, and methods of university finance vary by country so we cannot generalise this result to other countries, nor make statements about the optimal number of universities in particular regions. Similar calculations for other countries could be made by delving into particular institutional settings.

4. Mechanisms

Having established a robust association of GDP per capita with universities we now turn to trying to understand the mechanisms through which universities may affect growth.

4.1. Human capital

We add measures of growth in human capital to our baseline regressions to see how this influences the university coefficient. In Table 6 we consider the relationship between universities and college share. Column (1) replicates the core result from Table 3 column (7), and column (2) shows the same specification on the reduced sample where college share is non-missing, for which the university coefficient is a bit larger at 0.08. Column (3) adds the lagged growth in college share which in itself is highly significant, and reduces the university coefficient slightly from 0.084 to 0.080. Column (4) uses contemporaneous growth in college share and column (5) adds in the lagged college share which reduces the coefficient to 0.078. This represents a reduction in the university coefficient of 8% compared with column (2). In column (6) we include also the level with both lags, with little change in the university coefficient. In column (7) we look at the raw correlation between contemporaneous growth and the lagged growth in universities (with only country fixed effects as controls), and find it to be relatively small but highly significant. Adding all the other controls dampens this relationship further and this small effect of university growth on college share is what explains the fact that adding in growth in human capital causes only a small reduction in the coefficient on universities. This analysis suggests that a 1% rise in the number of universities gives rise to around a 0.4 percentage point rise in the college share.[42]

4.2. Innovation

The best measure of innovation output available consistently at the regional level over time is patents, although unfortunately patents with locational information are not available for our entire sample of countries and years. We consider the effects of adding the growth in cumulative patent stocks[43] to our regressions, using patents filed at the European Patent Office which are available for over 38 of our countries between 1975 and 2010 (Table 7). Column (1) runs the core regression for the this sample of countries, and over the time period that we have patents data. Column (2) then includes the contemporaneous change in patents stock (allowing five years for the university growth to have an

[38] It is unlikely that these are controlled for in our regressions: a large portion of university financing tends to be at the national level, and costs are incurred on an ongoing basis (e.g. property rental or amortisation and staff salaries are incurred every year) and so would not be fully captured by the inclusion of lagged country GDP per capita as a covariate.

[39] For each of the ten regions in the UK in turn, we calculate the log difference implied by adding one university to that region's universities, and multiply this by 0.047 (the coefficient on university growth from Table 3 column (7)). We then calculate the log difference in the count of universities in all other regions, and raise home region GDP per capita by that multiplied by 0.06 (the coefficient on university growth in "other regions" from Table 5). We abstract from the 5 year lag in this calculation. We then add up the total uplifted GDP across regions, and divide by total population (assumed unchanged).

[40] Series ABMI, Gross Domestic Product: chained volume measures: Seasonally adjusted £m, Base period 2012

[41] Data on university finance, by institution, can be found at the UK Higher Education Statistical Authority (HESA) website (https://www.hesa.ac.uk/index.php?option=com_content&view=article&id=1900&Itemid=634). Total expenditure in the year 2009/10 was nearly £26 billion across 163 institutions listed in HESA, implying around £160 million per institution. University expenditure contains staff costs, other operating expenses, depreciation, interest and other finance costs. We checked if this Fig. has been relatively stable over time, finding that by 2013-14, average expenditure was £180 million. At this higher amount, the implied costs of our expansion rise to 0.11% of GDP. Note that the number of institutions present in 2010 was 171. The majority of institutions in WHED correspond to those listed in HESA, but there are a small number of discrepancies due to differences in the classifications of some institutes or colleges between the two listings. This does not matter for our purposes, as are simply using the HESA data to calculate the average expenditure of a typical university.

[42] Table A9 in the Appendix uses another measure of human capital: years of education, which is available for a larger sample of countries and years. The qualitative results are similar. Appendix A2.2 gives some simple simulations showing that the magnitude of effect of universities on human capital is consistent with the variation we are using in the data.

[43] Patent stocks are calculated with an assumed depreciation rate of 15%. Initial patent stocks are calculated by dividing the first observed patent flow for a region by the depreciation rate plus the average growth rate in patents flow over the sample period for that region. Results are not sensitive to alternative depreciation assumptions.

Table 6
Universities and share of educated workers.

Dependent Variable	(1) Δ GDPpc	(2) Δ GDPpc	(3) Δ GDPpc	(4) Δ GDPpc	(5) Δ GDPpc	(6) Δ GDPpc	(7) Δ % college	(8) Δ % college
Lagged growth in #universities	0.047***	0.084***	0.080***	0.081***	0.078***	0.078***	0.005***	0.004***
	(0.011)	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)	(0.001)	(0.001)
Lagged growth in college share			2.237***		2.077***	2.075***		
			(0.362)		(0.323)	(0.326)		
Current growth in college share				0.847***	0.721***	0.722***		
				(0.148)	(0.130)	(0.132)		
Lagged level of college share						0.001		
						(0.023)		
Lagged level of regional GDP per capita	−0.078***	−0.093***	−0.094***	−0.093***	−0.094***	−0.094***		0.000
	(0.005)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)		(0.000)
Lagged level of country GDP per capita	0.038***	0.025***	0.027***	0.026***	0.028***	0.028***		−0.001***
	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)		(0.000)
Lagged level of population/100	−0.850**	−2.136***	−2.226***	−2.289***	−2.350***	−2.348***		0.181***
	(0.352)	(0.452)	(0.451)	(0.456)	(0.456)	(0.457)		(0.038)
Lagged growth in population	−0.183***	−0.064	−0.065	−0.066	−0.066	−0.066		0.002
	(0.045)	(0.052)	(0.054)	(0.053)	(0.055)	(0.055)		(0.003)
Observations	8128	5118	5118	5118	5118	5118	5118	5118
# clusters	1498	1089	1089	1089	1089	1089	1089	1089

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Growth in college share is simply the percentage point difference: (college share (t) – college share (t-5))/5. Column (1) replicates Column (7) from Table 3. Column (2) restricts to the sample for which the change in college share is available. Column (3) drops the lagged growth in college share. Column (4) adds the contemporaneous change in college share. Column (5) includes both lagged and contemporaneous changes. Column (6) further adds the lagged level of college share (unlogged). Column (7) regresses the change in college share on the lagged growth in universities, with country dummies, but no other controls. Column (8) adds all the other controls.

Table 7
Universities and innovation.

Dependent Variable	(1) Δ GDPpc	(2) Δ GDPpc	(3) Δ patents	(4) Δ patents
Lagged growth in #universities	0.016	0.013	0.030	0.031
	(0.014)	(0.014)	(0.055)	(0.055)
Growth in EPO patent "stock"		0.054***		
		(0.006)		
Lagged level of regional GDP per capita	−0.096***	−0.096***		
	(0.007)	(0.007)		
Lagged level of country GDP per capita	0.073***	0.069***		
	(0.008)	(0.008)		
Lagged level of population/100	2.604***	2.151***		7.709***
	(0.766)	(0.740)		(2.271)
Lagged growth in population	−0.201***	−0.177***		−0.499***
	(0.061)	(0.059)		(0.158)
Observations	3559	3559	3559	3559
# clusters	757	757	757	757

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. The sample contains the countries for which regionalised EPO patents are available in OECD REGPAT (1978–2010). Column (1) replicates our core regression (column (7) from Table 3), but restricts to the relevant sample for patents data. Column (2) adds in the contemporaneous growth in cumulative patent "stock" to the regression. Column (3) regresses the growth in patent stock on the growth in universities as a raw correlation, with no other controls. Column (4) then adds the standard time varying controls (reported) and geographic controls (not reported).

effect), which reduces the coefficient on university growth from 0.016 to 0.013 (a reduction of nearly 20 per cent). Patents themselves have a positive and significant association with GDP per capita growth: A 10% increase in the patent stock is associated with 0.5% higher per capita GDP. Column (3) considers the raw correlation between lagged university growth and current patent stock growth (including only year dummies), and shows it is positive but not significant. Column (4) then adds the standard controls with little effect.

This analysis provides tentative evidence that innovation is part of the story of why universities have an economic impact, though not the entire story. This may be because the effect of newer universities on patents takes a while to accumulate.

4.3. Institutions and democracy

The use of country fixed effects throughout our analysis should rule out the possibility that the effects of universities simply reflect different (time invariant) institutions, since these tend to differ mainly at the country level. We have shown that the results survive the inclusion of country-year fixed effects in the robustness, this would capture country specific changes in institutions or changes in government. To the extent that time invariant institutions vary within countries, say at the US state level, our regional fixed effects analysis should address this.

Institutions do vary over time, however, and it is possible that universities contribute to this. There is a positive and significant correlation between country level democratic institutions (as proxied by Polity scores[44]) and universities. This correlation also exists when we consider the 1960–2000 change in universities and polity scores (see the online Appendix for more discussion). To our knowledge, a time series of data on regional institutions over our sample period is not available, but we can explore the relationships between perceptions of democracy, as obtained from the "World Values Survey" and lagged university presence in the cross section. Our measure is a categorical variable which gives the approval of a democratic system for governing one's own country, as this is more widely available across survey waves compared with other questions on democracy.[45] We note however, that the experience in one's own country (for example, if corruption prevents democracy operating effectively) may affect this judgement. Therefore, in the robustness we test whether results hold for a another more general survey question[46] (available for fewer survey waves). World Values Survey data begins in the 1980s and we pool data into a

[44] Polity scores were sourced from the Policy IV project (http://www.systemicpeace.org/inscrdata.html), the polity2 variable is used as this is more suited for time series analysis.

[45] Specifically, the question asks respondents to say whether having a democratic political system is a (1) very good, (2) fairly good, (3) fairly bad, (4) bad way of governing their country. The scale is reversed for our estimation so that a higher score reflects higher approval.

[46] This question asks respondents if they (1) agree strongly, (2) agree, (3) disagree or (4) strongly disagree whit this statement "Democracy may have problems but is better than any other form of government". Again, the scale is reversed for our estimation so that a higher score reflects higher approval.

Table 8
Universities and approval of democracy.

Dependent variable: Approval of Democracy	(1)	(2)	(3)	(4)
15 year lagged ln(universities per capita)	0.029***	0.026***	0.023**	0.023**
	(0.009)	(0.010)	(0.009)	(0.010)
Dummy for Male		0.038***	0.034***	0.034***
		(0.005)	(0.005)	(0.005)
Age (years)		0.002***	0.002***	0.002***
		(0.000)	(0.000)	(0.000)
Dummy for married		−0.001	−0.004***	−0.004***
		(0.001)	(0.001)	(0.001)
Children		−0.007***	−0.003*	−0.003*
		(0.002)	(0.002)	(0.002)
Employed (full, part time, self-employed)		0.017***	0.024***	0.024***
		(0.006)	(0.006)	(0.006)
Income scale		0.012***	0.005	0.006*
		(0.003)	(0.003)	(0.003)
Dummy for holds university degree			0.135***	0.135***
			(0.008)	(0.008)
Dummy for student			0.085***	0.086***
			(0.012)	(0.012)
Observations	138,511	138,511	138,511	138,511
# clusters	693	693	693	693
Country and year dummies	yes	yes	yes	yes
Geographic controls	no	no	no	yes

Notes. *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. OLS estimates, 54 countries. Standard errors are clustered at the regional level. Region controls include latitude, inverse distance to ocean, malaria ecology, ln(oil and gas production) 1950–2010 and a dummy for if a region contains the country's capital city.

cross section due to insufficient observations in some region–year cells to generate reliable variation over time.

Table 8 shows the results of these regressions.[47] We start with a simple correlation between our measure of university density lagged by 15 years from the survey year, controlling for country and year fixed effects (column (1)).[48] This shows that there is a highly significant association between university presence in a region and approval of a democratic system. The relationship is robust to including a host of individual demographic characteristics (column (2)) and education (column (3)). The result that one's own education is positively related to approval of democracy is consistent with Chong and Gradstein (2009). But the result that local universities matter over and above an individual's education suggests that they may be a mechanism whereby democratic ideals spillover from those who have had direct contact with universities, or there is some kind of direct diffusion of ideas from universities into their surrounding regions.[49] Column (4) adds our standard geographic controls. While data constraints mean it is not possible to account for any potential impact of this type of mechanism on growth, this analysis suggests that institutions could be part of the story, albeit on a longer term basis.

4.4. Demand

Could our results simply be driven by a mechanical impact of universities on regional GDP? Students and staff in a university consume more goods and services. Including changes in population in our regressions (lagged, and contemporaneous) should have largely controlled for the possibility that universities simply contribute to growth through a mechanical demand channel associated with people coming into the region. Moreover, showing that our university coefficient remains significant after including changes in human capital (see Table 6) should also address the concern that the effects are simply driven by higher earners entering the region.

To the extent that university finance comes from inside the same region, there should be no mechanical demand effect as this should already be netted off. For example, in the US, states have historically provided more assistance to tertiary institutions and students: 65 per cent more on average than the federal government over the period 1987 to 2012, though now the share is more equal.[50] But if university finance comes from outside the region this could also result in higher GDP per capita as the university purchases goods and services within the region (including paying salaries to staff and support services).

We think it unlikely that the regressions are merely capturing this type of effect. The initial shock to region GDP associated with the new university is likely to occur in the year it is founded (when transfers begin, and include capital and set up costs), and the level effect should be captured by lagged regional GDP which we control for in the regressions. Ongoing transfers may rise incrementally over the years as the university increases its size and scope, but we might expect the largest effect on growth would be in the initial years rather than in the subsequent five year period. Furthermore, the evidence of university spillovers from other regions (Table 5) also suggests demand is not the main mechanism.

Notwithstanding these arguments, we carry out a simple calculation to show that even under very generous assumptions, direct effects are unlikely to explain a large portion of our results. We use the hypothetical experiment of a new university of 8,500 students and 850 staff opening in the average region of our dataset. We estimate the effects of the transfer into the region assuming that all the costs of our new university are met from sources outside the region, and that these are spent within the region. We assume that the average cost per student is $10,000, and therefore the cost for a university of 8,500 students is $85 million. With a university of constant size, building up year-group enrolments over four years, there would be no effect in the following five year period. If we assume total enrolments grow by 5% per year, we can explain around 15% of the regression coefficient on universities.[51]

4.5. Summary on mechanisms

In summary, it appears some of the effects of university growth on GDP growth work via human capital and innovation channels, though the effects of these are small in magnitude. In addition, universities may affect views on democracy but this appears to be on a longer term basis. We have shown that the university coefficient is not merely driven by demand effects.

[47] This analysis is carried out on 58 of the 78 countries in our core sample, where World Values Survey data are available. World Values Survey data are available for Nigeria which is in our core sample, but it was not possible to map the regions to the regions used in WHED due to the fact that both sources used very aggregated but different regions.

[48] We explored different lag structures, and found that it takes time for universities to affect perceptions (see column (3) in Table A10 which shows a smaller positive, but insignificant effect of five year lagged university density on democratic approval). By contrast, on the full sample of countries there appear to be no effects for longer lags. When we consider the sub-sample of OECD countries where the results are stronger we see that the effects are similar in magnitude and significance for the 30 year lag.

[49] Further supporting this, we find that the result survives dropping students and graduates from the regression entirely (see Table A10 for more robustness tests and further discussion).

[50] This difference has narrowed in recent years as state spending declined since the financial crisis, and federal investments grew sharply. Today the total expenditure is similar, though spending categories differ: state funding focuses more on general running expenditure and federal funding on research and student grants. For detail, see an analysis of federal and state funding of higher education in the US by Pew Charitable Trusts, http://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2015/06/federal-and-state-funding-of-higher-education.

[51] For further detail, see Appendix A2.2.

5. Conclusions

This paper presents a new dataset on universities in nearly 1,500 regions in 78 countries since 1950. We have found robust evidence that increases in university presence are positively associated with faster subsequent economic growth. A 10% increase in the number of universities is associated with over 0.4% higher GDP per capita in a region. This is even after controlling for regional fixed effects, regional trends and a host of other confounding influences. The benefit of universities does not appear to be confined to the region where they are built but spills over to neighbouring regions, having the strongest effects on those that are geographically closest. Using these results, we estimate that the economic benefits of university expansion are likely to exceed their costs.

Our estimates use sub-national time series variation and imply smaller effects of universities on GDP than would be suggested from cross sectional relationships. But we believe our effects underestimate the long-run effect of universities through building the stock of human and intellectual capital which are hard to fully tease out using the panel data available to us. We reiterate that the coefficients on universities are conditional correlations as we do not have compelling instrumental variables to establish causality. Nevertheless, in our view the empirical evidence here does suggest some effect of universities on growth.

Understanding the mechanisms through which the university effect works is an important area to investigate further. We find a role for innovation and human capital supply although these appear to be small in magnitude, and show that the university effects do not appear to be driven by demand or transfers into a region. Better data on the flow of business-university linkages, movements of personnel and other collaborations would help in unravelling the underlying mechanisms. In addition, focusing on the relationships between universities and local economic performance in individual countries where better causal designs and richer university data is available would be a valuable extension.

We provide suggestive evidence that universities play a role in promoting democracy, and that this operates over and above their effect as human capital producers. Exploring the extent to which this may account for part of the growth effect is another important area for future research.

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Supplementary materials

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