College Openings and Local Economic Development

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October 26, 2017

Abstract

We study the effect of universities and colleges on the local economy using administrative data from Germany. Our empirical approach proceeds in two steps: first, we exploit college openings in order to identify the short- and medium-run effects on regional development. Second, we combine a matching procedure with a time-varying difference-in-differences approach to find suitable control regions for regions with a college opening. The results indicate that a college opening increases the share of high-skilled workers without reducing high-skilled wages which is consistent with shifts on the demand side. We will next investigate the potential sources of these demand shifts: changes in the output mix, technology, innovation or local multipliers.

Keywords: Human capital, Local labor markets, Spillover effects

JEL codes: J24, J31, J61, I23, I25

Acknowledgments: We thank Henrik Overman, Sascha Becker, Pat Kline and participants at the CESifo Summer Institute, Verein für Socialpolitik, EALE and the ZEW for very helpful comments and suggestions. We are responsible for all remaining errors.

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1 Introduction

Income and unemployment rates differ substantially across cities and regions in most countries. In the United States, for example, wages in the highest and lowest paying metropolitan areas differ by a factor of three (Moretti, 2011). Similar discrepancies in income per capita are observed between regions in the European Union (OECD, 2009). The variation in unemployment rates is even larger. In Germany, for example, local unemployment rates across metropolitan areas vary by a factor of five or even six (BMWi, 2013).

In response to these large disparities, many governments promote policies aimed at reducing regional inequalities. These place-based policies could be direct subsidies to firms located in or planning to move into a disadvantaged area. Alternatively, they can take the form of investments in infrastructure by local, state or federal governments in order to increase the economic attractiveness of a region. One such local policy is the opening of educational institutions like universities or colleges in a region. The opening of new universities and colleges could be a powerful tool for regional development for at least three reasons: first, by improving the human capital base in the region, they may attract new investments or plants to the region. Second, staff and students as well as the universities and colleges themselves may stimulate the demand for local goods and services. Finally, universities and colleges might generate positive spillover effects on local firms through research collaborations or knowledge spillovers, for instance.

Yet, do colleges really promote regional economic development in disadvantaged regions? And if so, what are the channels: is it the direct consequence of the educational institution itself? Or, does an educational institution create spillover effects by raising labor demand and by encouraging innovation in private firms in the region?

Our study sheds light on these important questions. An important challenge in this endeavor is that the location of colleges is not random. As numerous universities and colleges were originally established many decades ago, it is difficult to isolate the impact of a university from other cumulative developments in the local economy. We solve this identification problem in two steps: first, we use the establishment of new colleges in Germany during the 1980s and early 1990s to study the short- and medium-run impact on regional development. Using college openings, we can trace the evolution of skilled labor and other adjustments in the local labor market and economy more broadly. Nevertheless, regions that obtain a new college might differ from other regions without a college opening in terms of prior employment, wages and innovative capacity. In a second step, we therefore combine matching with a time-varying difference-in-differences approach. Our empirical approach allows us to compare flexibly employment and wages in regions with a college opening to employment and wages in suitable control regions that did not obtain a new college.

We have three main findings. First, the opening of a technical college results in large, persistent growth in the regional student population relative to the control regions. In line with the notion that college openings change the composition of the workforce, we find that high-skilled employment in the region increases by 12% eight to nine years after the opening. Second, we find evidence that new colleges also raise the employment of workers without a college degree suggesting complementarities in the local production function. Third, we find that wages of high-skilled workers do not decrease in the medium run, indicating a shift in local demand. The employment and wage effects remain if we exclude all employees working in the education sector indicating that a college opening has an impact on the local economy beyond creating additional jobs in teaching and research. The large increase in employment and the lack of a drop in wages instead point to sizable adjustments on the labor demand side. We find no employment effect in new establishments, suggesting that most of the adjustments happen in incumbent firms either through changes in the output mix or through changes in technology.

Our article is related to several strands of the literature. A sizable amount of literature has documented the correlation between the location of universities and patenting activity, innovation and business start-ups (Jaffe, 1989; Bania et al., 1993; Audretsch and Feldman, 1996; Cohen et al., 2002; Woodward et al., 2006; Andersson et al., 2009). Most studies focus on the importance of academic research for the development of specific local industries, such as pharmaceuticals or electronic equipment.[1] Closer to our analysis are two studies specifically on universities. Beeson and Montgomery (1993) study the link between the quality of a university and local employment growth. Kantor and Whalley (2014a) use shocks to a university's financial endowment to identify wage effects outside the education sector.[2] The analysis in this paper uses a different, plausibly exogenous variation to identify the link between universities, local

[1] Valero and Van Reenen (2016) use a global dataset to explore the link between research universities and economic growth.

[2] Kantor and Whalley (2014b) take a long-term view tracing the role of experiments in agricultural technology for the evolution of agricultural activity over more than a century.

employment and innovation: the opening of new technical colleges. A second way in which this paper differs from most of the literature is that we investigate the impact of colleges focused on applied research but concentrate on their impact on the local economy as a whole - rather than just on specific, technology-driven industries.

Furthermore, our analysis contributes to a sizable literature on the local effects of labor supply shocks. A large number of studies in labor economics analyze how inflows of immigrants into a region affect local wages (Card, 2001; Borjas, 2003; Glitz, 2012; Manacorda et al., 2012; Ottaviano and Peri, 2012). Most studies using the local area approach suggest that immigrants have a small effect on the local wages of natives (but see Dustmann et al., 2016, who show that employment effects on natives may be sizable in remote areas). Traditional open economy models instead emphasize adjustments to labor supply shocks through changes in the output mix produced by the local economy. Regions with a relative growth in low-skilled labor, for instance, experience shifts to products and sectors that make intensive use of low-skilled labor. A third adjustment mechanism is that firms adjust their production technology either through changes in the actual technology of production (Acemoglu, 1998) or by redirecting research efforts (see, e.g. Beaudry and Green, 2003, 2005; Caselli and Coleman, 2006). Evidence on technology adoptions suggests that automation machinery does indeed expand more slowly in areas with high growth rates in the relative supply of low-skilled labor (Lewis, 2011) and that skill abundance leads to a faster adoption of new technologies (Beaudry et al., 2010).

As immigrants in most countries are on average less skilled than the native population, these studies focus on adjustments to an increase in low-skilled labor (but see Ciccone and Peri, 2011, which analyzes the growth in the number of medium-skilled workers following compulsory schooling laws). Our study contributes to this literature by exploiting the opening of new colleges as a plausibly exogenous shock to the high-skilled workforce in the local labor market (see Carneiro et al., 2015). The adjustments to a low-skill supply shock are likely to differ from the response to a shock to high-skilled labor if there are human capital externalities or other types of knowledge spillovers. If high-skilled workers raise the productivity or innovative capacity of other workers in the same firm or other firms in the region, for instance, the effects on the local economy might be much larger than a growth in the low-skilled workforce (Moretti, 2004; Ciccone and Peri, 2006).

Another reason why college openings may foster economic growth in the region are local multiplier effects: an increase in local employment may raise the demand for local goods and services. The local multiplier effect could be especially strong in the case of a college opening because much of the additional employment is concentrated among high-skilled workers with more disposable income. Recent research suggests that local multiplier effects may be sizable (see, for example, Moretti, 2010, for the US; Moretti and Thulin, 2013, for Sweden; and Faggio and Overman, 2014, for the UK). Our study relies on a different, plausibly exogenous source of identification to investigate how the creation of new college-related jobs generates additional benefits in the non-tradable sector.

Finally, knowing whether an increase in high-skilled labor improves the economic conditions of other workers in that region and the regional economy overall has important policy implications. If there are indeed positive externalities from college openings on the local economy, this could be one argument for public subsidies for tertiary education.[3] In addition, our results may also be important for the design of regional policies. National and state governments often use regional policies to support areas with high unemployment and low economic growth. Prominent examples include region-specific subsidies to firms or local governments, such as the Federal Empowerment Zones in the US (Busso et al., 2013), regional subsidy programs in France (Gobillon et al., 2012), Italy (Bronzini and de Blasio, 2012), the UK (Criscuolo et al., 2012) or Germany (von Ehrlich and Seidel, 2015); or the European Structural Funds (Becker et al., 2010, 2013).[4] Our research can shed new light on the question of whether public investments like the opening a new college can improve employment prospects and local development in a region and thus contribute to a decline in regional disparities.

The paper proceeds as follows. The next section introduces the empirical setting of the college openings we analyze. Section 3 presents our data sources and discusses the empirical strategy we use to identify the effects of a college opening on the local economy. Section 4 presents the results. Finally, Section 5 discusses the implications of our findings and concludes.

[3] We focus on the pecuniary benefits of an increase in the human capital stock of a region; there might be other spillover effects, such as reduced criminal activity or increased political participation, for instance, which we do not consider here (see e.g. Valero and Van Reenen, 2016).

[4] Earlier work has focused on the relationship between city (or local industry) size or density and productivity more generally (see, for example, Ciccone and Hall, 1996, for a seminal contribution and Rosenthal and Strange, 2004, for a survey).

2 College Openings in West Germany

In 1968, the federal government of Germany decided to expand the tertiary education sector in order to improve the competitiveness of Germany's industry by increasing the human capital base.

The resulting reform focused on the nationwide establishment of technical colleges (*Fachhochschulen*) to complement tertiary education at regular universities.[5] As student capacity at existing universities and colleges was exhausted, policy-makers turned to the establishment of new institutions in the face of rising demand for post-secondary education. Technical colleges were considered particularly suitable for this purpose because of their close ties to the local economy. Unlike universities, technical colleges focus on teaching. Degree programs at technical colleges last three to four years and combine academic study with periods of practical training allowing students to gain work experience. It was only in the 1990s that technical colleges became more actively engaged in research activities. Teaching and also research are more practice-oriented than at universities and are often conducted in cooperation with local companies. In 2003, 31% of third-party funding in technical colleges came from private companies, while it is only 20% in universities (Haug and Hetmeier, 2003).

Technical colleges rank below universities in terms of pay and status. However, the teaching staff have PhDs and, in addition, unlike at universities, several years of practical work experience. Unlike universities, technical colleges also cover a more narrow set of academic subjects. In 2001, 42% of all students of technical colleges were enrolled in economics, social sciences or law, while around 30% were studying engineering (Haug and Hetmeier, 2003).[6]

While the costs for establishing and running the new colleges were divided between the federal and the respective state governments (see the law of 1969, *Hochschulbauförderungsgesetz*), the individual states were responsible for setting up the new colleges. Municipalities and local governments had only limited influence on the decision where a new college would be located. A common goal in all states was to distribute post-secondary educational institutions more evenly across space in order to reduce costs and facilitate access to tertiary education. Our data show

[5] see "Abkommen der Länder in der Bundesrepublik Deutschland zur Vereinheitlichung auf dem Gebiet des Fachhochschulwesens"(see also Wissenschaftsrat, 1991).

[6] Admission criteria for a technical college is a high school degree or a more specialized secondary school degree, which are both obtained after 12 or 13 years of schooling. Given their more practice-oriented nature, technical colleges cannot award doctoral degrees.

that new colleges were indeed predominantly opened in rural and semi-rural districts with no university or technical college (see Table 1 and Figure A1).

Local economic performance also played a role in the decision-making process. The perceived risk of structural problems was often taken as an explicit criterion for the selection of suitable regions. It was hoped that colleges would attract new businesses and prevent out-migration of potential students and other workers (Schindler et al., 1991; Landtag, 1991; Wissenschaftsrat, 1995).[7] Technical colleges were also seen as a tool to meet the demand for high-skilled workers.[8]

Yet, targeted areas also had to fulfill certain criteria that would not apply to the least developed regions. A prerequisite was that the demand for the degree programs offered was deemed adequate and that a sufficient number of students and teaching staff could be attracted in the catchment area. Local industry was required to cooperate with the college and to offer jobs to graduates. Whether or not this was plausible was assessed on the basis of measures of economic viability, infrastructure like transportation and overall attractiveness of the region (see, e.g. Landtag, 1991; Schindler et al., 1991). In some cases, technical colleges mainly served as a political bargaining tool: technical colleges were used to compensate the Bonn area when the federal government moved to Berlin, for instance (Wissenschaftsrat, 1996).

Based on the discussion above, we expect that the average economic performance of regions with a new college would not differ much from the performance of other districts, which is clearly supported by our data (see Table 1). However, technical colleges are more likely to be established outside of metropolitan areas. Hence, regions with a college opening are unlikely to be similar to the average region in West Germany in terms of wages, employment and industry structure, for instance. In Section 3.2, we use a matching procedure to select suitable control regions that have a similar industry and employment structure in the years before the opening to that of districts that eventually get a new technical college.

For our empirical analysis, we focus on college openings in the 1980s and 1990s. Earlier openings often happened to be transformations of former vocational schools or similar institutions for secondary education. We expect those adjustments to have a small and relatively

[7] In North Rhine-Westphalia, for example, policymakers hoped to speed up the structural transformation from coal and steel to other industries and services (Holuscha, 2012). In a similar fashion, policymakers in Rhineland-Palatinate hoped to counterbalance structural changes (Wissenschaftsrat, 1995).

[8] The employers' federation were typically in favor of opening new colleges (see e.g. Landtag, 1991; Wissenschaftsrat, 1994).

smooth effect on the regional supply of high-skilled workers (see Wissenschaftsrat, 1991; Kulicke and Stahlecker, 2004). Furthermore, we cannot trace openings prior to 1980 as the social security data start in 1975 and we require up to four years before the opening for our estimation approach. Our analysis is further restricted to publicly funded colleges which were created following the federal law of college expansion. Private colleges make up only a small fraction of tertiary education in Germany. These institutions are often very small and cover only a narrow range of subjects. As a result, their founding does not generate a sizable shift in local labor supply.[9]

In 1984, there were 58 public technical colleges with in total 97 campuses in West Germany. By 2004, the number of campuses had increased to 123 located in 110 West German districts. Of the 26 openings of a new campus, we analyze 23 events in 21 districts. Two college openings took place in the same district and year which we combine into a single event.[10] In two other districts, our matching procedure was unable to identify suitable control regions (see section 3.2 for further details).[11] Finally, we drop one opening of a small campus because the post-treatment period overlaps with the opening of a larger campus in the same district.[12] Table A1 provides a list of the new colleges, the district in which they were founded and the year of the opening. Our sample of colleges is relatively small as are most technical colleges. Five years after the opening, the new technical colleges have 98 employees as teaching and support staff on average. The total number of students and employees of technical colleges amounts to just about 2.8% of local employment eight to nine years after the college opening.

3 Data Sources and Empirical Strategy

3.1 Data Sources

To analyze the consequences of college openings empirically, we use German Social Security Records over more than three decades. More specifically, we draw on employment data from the German Establishment History Panel (BHP), a 50% random sample of all establishments

[9]Finally, the founding of private institutions is often financed (or co-financed) by local companies and hence, much more likely to be correlated with labor demand.

[10]These are the district of Göppingen in 1988 and the district of Rhein-Sieg in 1995.

[11]These are the district of Salzgitter and the district of Emsland, where new campuses for existing technical colleges were opened in 1993 and 1995 respectively.

[12]This is the campus in Idar-Oberstein that was opened in 1986 in the district of Birkenfeld.

with at least one employee covered by the social security system in Germany (see Schmucker et al., 2016, for more details). Civil servants, military personnel and the self-employed are not included.[13] The data have been available annually since 1975 which enables us to compare districts with a new college opening to suitable control regions without an opening several years before the opening. Another advantage of our dataset is that we observe the location of each plant. We can thus identify whether an establishment is potentially affected by a college opening in the same district. We further observe the detailed industry of an establishment which allows us to analyze whether the effects of a new college affect the local economy as a whole or specific industries. To study whether labor demand changes in new or incumbent plants, we rely on the procedure developed by Hethey and Schmieder (2010) to distinguish plant openings from a simple change in the establishment identifier as a consequence of spin-offs of existing establishments, for instance.

Furthermore, we have detailed information on the workforce in each establishment, especially the number of workers by skill, occupation and age. We distinguish three skill groups based on the highest qualification obtained. High-skilled workers are workers who have graduated from a college or university. Medium-skilled workers have completed a vocational training program or obtained the university entrance certificate after high school (*Abitur*). Low-skilled workers have lower qualifications or no qualifications at all. In the raw data, the education variable is missing for about 9% to 37% of the observations depending on the year. The BHP provides adjusted education variables based on standard imputation procedures reducing missing education to less than 1% (see Fitzenberger et al., 2006). We further distinguish three age groups (20-34, 35-49 and 50-64). Moreover, we proxy the R&D intensity of a plant as the number of employees in engineering and natural sciences.

Establishments also report for each employee the daily wage of the employment spell which contains the reference date (June 30 of each year). As is common in social security records, wages are right-censored at the highest level of earnings that are subject to social security contributions. We use imputed wages based on the imputation procedure of Card et al. (2013). All wages are deflated using the consumer price index with 1995 as the base year.

We aggregate establishment data to the district level which is our main unit of analysis.

[13] The social security data cover around 80% of the German labor force.

Overall, we observe 325 districts in West Germany with an average population of 196,000 and around 93,000 employees. Local employment refers to full-time employment on June 30 of each year; it excludes apprentices, workers in marginal employment or partial retirement. We further compute regional employment shares and levels by skill level, age and industry. We complement this data with regional information on population, total employment and gross value added which is based on the European regional Database of Cambridge Econometrics.

3.2 Matching Procedure

Regions that experience a new college opening are likely to differ from regions that did not get a new college. The anecdotal evidence discussed in Section 2 suggests that local governments had little influence on the location decision of a new college. In most cases, the location was chosen by the federal or state government which were also responsible for financing the new institution. Nevertheless, politicians at the state and national level might have chosen a location in order to foster economic development in the region. In that case, the region with a new college might have had a less favorable economic development prior to the opening.

A comparison of treatment regions (i.e. regions with a college opening) to the average district in West Germany shows that event regions differ in some important characteristics (see the first columns of Table 1). Specifically, regions with a college opening have a lower employment share in agriculture and fishing, a higher employment share in public administration and lower total employment (even if the difference is not statistically significant). They were also less likely to have a university or technical college in their district.

To find suitable controls for the event regions, we use a matching procedure. To each region with a new college, we match a region without a college opening that is similar to the event region in terms of its age structure (3 age groups 20-34, 35-49, 50-64), industry structure (17 broad industries), skill structure (high-, medium- and low-skilled) and population in the five years before the opening.[14] In addition, we match on an indicator whether a district had a university or college in the year prior to the college opening. Including this indicator ensures that event and control regions have similar numbers of students prior to the college opening.

To find a match for each event region, we use the Mahalanobis matching algorithm which

[14]We include the age and skill shares in $\tau - 1, \tau - 3$ and $\tau - 5$ where τ is the year of the college opening. Industry shares and population are measured in $\tau - 1$ and $\tau - 5$.

Table 1: Treatment Versus Control Districts in the Pre-Event Period

	Treated Districts	Other West German Districts	Control Districts	Difference Treated versus Other Districts		Difference Treated versus Control Districts	
				Coeff.	S.E.	Coeff.	S.E.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Matched Characteristics							
Age:							
Age: 25-34	0.439	0.442	0.448	-0.002	(0.008)	-0.009	(0.009)
Age: 35-49	0.347	0.346	0.342	0.000	(0.007)	0.005	(0.007)
Age: 50-64	0.193	0.193	0.188	0.000	(0.005)	0.005	(0.006)
Education:							
High-Skill Share	0.055	0.065	0.053	-0.010	(0.007)	0.002	(0.005)
Medium-Skill Share	0.792	0.790	0.800	0.003	(0.009)	-0.008	(0.014)
Low-Skill Share	0.148	0.139	0.142	0.008	(0.009)	0.006	(0.016)
Industry:							
Agriculture and Fishing	0.009	0.012	0.010	-0.004*	(0.002)	-0.002	(0.002)
Energy and Mining	0.020	0.024	0.022	-0.004	(0.009)	-0.002	(0.009)
Food	0.031	0.040	0.031	-0.009	(0.006)	-0.000	(0.005)
Consumer Goods	0.084	0.066	0.081	0.018	(0.011)	0.003	(0.019)
Producer Goods	0.086	0.104	0.102	-0.018	(0.019)	-0.016	(0.019)
Investment Goods	0.179	0.175	0.175	0.004	(0.024)	0.004	(0.035)
Construction	0.098	0.105	0.110	-0.006	(0.008)	-0.012	(0.009)
Retail Trade	0.160	0.145	0.138	0.015	(0.009)	0.021*	(0.012)
Transport and Communications	0.044	0.041	0.038	0.002	(0.005)	0.006	(0.006)
Finance and Insurance	0.028	0.032	0.027	-0.004	(0.005)	0.001	(0.004)
Hotel and Restaurant Industry	0.020	0.026	0.025	-0.006	(0.005)	-0.005	(0.004)
Educational Services	0.013	0.015	0.013	-0.002	(0.002)	-0.000	(0.002)
Health and Social Services	0.083	0.078	0.096	0.005	(0.008)	-0.013	(0.012)
Corporate Services	0.050	0.053	0.042	-0.003	(0.007)	0.007	(0.008)
Other Services	0.016	0.019	0.016	-0.003	(0.003)	-0.001	(0.002)
Non-Profit Organizations	0.007	0.009	0.006	-0.002	(0.003)	0.001	(0.002)
Public Administration	0.075	0.057	0.066	0.018***	(0.007)	0.008	(0.013)
Other:							
Population (in Thousands)	162.8	195.5	167.6	-32.7	(37.3)	-4.9	(41.7)
Technical College in Region	0.095	0.303	0.190	-0.208**	(0.101)	-0.143	(0.100)
University in Region	0.143	0.331	0.095	-0.188*	(0.103)	0.048	(0.102)
Panel B: Characteristics Not Matched							
Population Per Square km	469.2	565.1	373.2	-95.9	(156.8)	96.0	(124.5)
Employment (in Thousands)	74.70	93.38	73.4	-18.68	(22.99)	1.31	(15.25)
Employment Growth (past 3 years)	0.024	0.027	0.027	-0.004	(0.015)	-0.004	(0.015)
Average Daily Wage	84.07	86.32	82.05	-2.25	(2.08)	2.02	(1.66)
Wage Growth (past 3 years)	0.051	0.048	0.050	0.002	(0.008)	0.001	(0.011)
Gross Value Added	3241	4482	3147	-1240	(1369)	95	(742)

Note: Mahalanobis matching: all matched variables for t=-1; industry shares and population also for t=-5; age and skill shares also for t=-3 and t=-5. The main data source is the BHP. Population, total employment and GVA data come from the Cambridge Econometrics' European regional Database.

minimizes the standardized Euclidean distance of all matching variables between treatment and control regions.[15] We then use nearest-neighbor matching with replacement, i.e. we select for each event region the control region with the smallest sum of normalized squared distances. This matching method works best if the number of matching variables is not too large (see Stuart and Rubin, 2008).

Note that we do not match on outcome variables prior to the event. Instead we work with district fixed effects using a difference-in-differences approach.[16]

To rule out other confounding factors, we impose two additional restrictions. We first exclude all control districts which share a border with an event district in order to eliminate concerns that the event spills over across district boundaries to control districts. Moreover, we drop matches with the highest difference in total employment growth using a 5% trimming margin. This results in excluding two treatment districts from our analysis.

Figure A1 shows the geographic location of treatment districts and control districts in West Germany. Most college openings during our sample period occurred in Southern Germany, especially in the states of Baden-Württemberg and Bavaria. The figure also reveals that most districts with a college opening are located in more remote areas; the same is true for most of the control districts.

Overall, the matching procedure successfully eliminates differences in observable characteristics between the event and chosen control districts. The right-hand side of Table 1 reveals that the selected control districts are very similar to the treated districts along observable characteristics.

3.3 Empirical Model

Using our matched sample of regions, we then compare labor market outcomes in the event regions to those in the control regions before and after a college opening. In particular, we

[15]The distances between each treatment and each potential control region are normalized by the variance-covariance matrix of the pooled sample of event and possible control regions. Normalizing by the variance-covariance matrix in the control group only does not alter the results.

[16]The difference-in-differences method allows for time-invariant unobservable confounders but requires common trends. Matching in turn on pre-treatment outcomes does not require common trends but assumes that conditional on pre-treatment outcomes unobservable confounders are mean independent of the outcome (Lechner, 2011).

estimate variants of the following time-varying difference-in-differences model:

$$Y_{r\tau t} = \sum_{\tau=-5}^{-2} \beta_\tau I_\tau \cdot Treat_r + \sum_{\tau=0}^{9} \gamma_\tau I_\tau \cdot Treat_r + \theta_\tau + \delta_t + \alpha_r + \epsilon_{r\tau t} \quad (1)$$

where $Y_{r\tau t}$ is the labor market outcome of interest in region r in a given calendar year t for the event period τ. τ denotes the period relative to the year of the college opening, which occurs in period $\tau = 0$. We consider a period of five years before and nine years after the college opening (i.e. $-5 <= \tau <= +9$). $Treat_r$ is a binary variable equal to 1 if there is a college opening in region r and 0 for all other regions. I_τ is an indicator function equal to one in the year τ before or after the college opening and zero otherwise. Note that t and τ differ as college openings happened in different regions in different years. Below, we report estimates for two-year increments of the event time τ.

Our parameters of interest are the γ_τ which trace the evolution of the outcome of interest in the event region between τ years after the college opening and the pre-event period ($\tau = -1$) relative to the development in the control region over the same span of years. The empirical model in (1) further controls for event fixed effects (θ_τ) which are measured relative to the year before the opening (i.e. $\tau = -1$). Furthermore, we include year fixed effects (δ_t) and region fixed effects α_r. Standard errors are clustered at the district level to account for the level of aggregation in the treatment variable.

The key identifying assumption is that labor market outcomes would have evolved similarly in the event and control district in the absence of a college opening. The region fixed effect allows for differences in the levels of the outcome variables. We only require that *trends* in outcome variables are comparable between event and control districts conditional on our control variables. The evolution of outcomes in the pre-event period sheds light on the plausibility of this assumption. If the identifying assumption is valid, the parameters β_τ should be close to zero and statistically insignificant. We next discuss our empirical results.

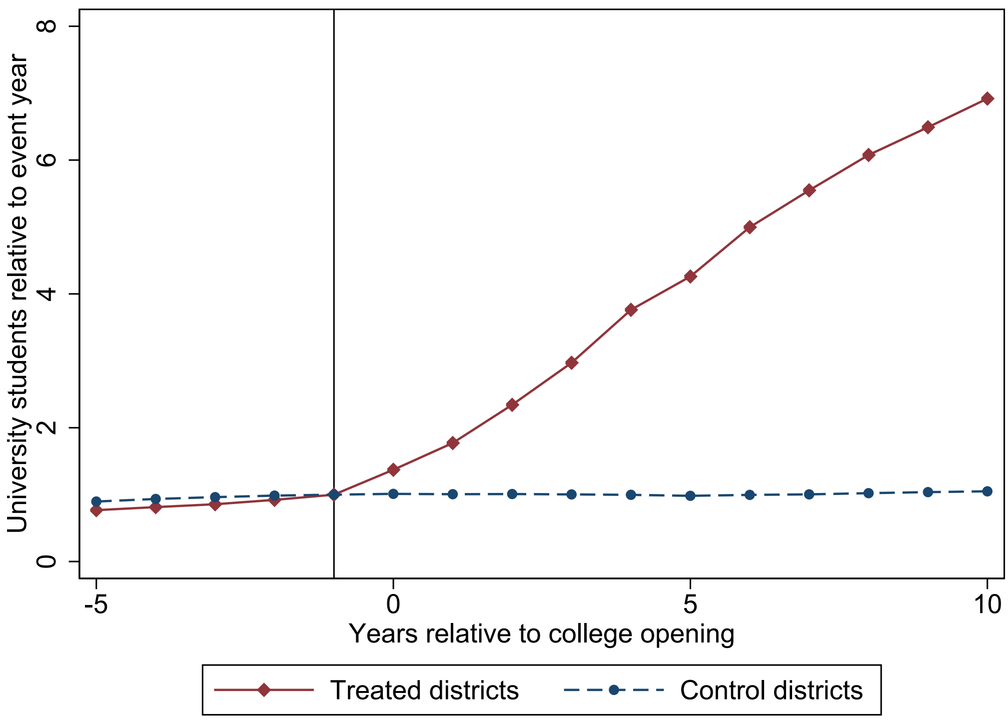
4 Empirical Results

4.1 Student Population and High-Skilled Employment

We start out by demonstrating that a college opening indeed increased the number of college students in the region. A rise in the local student population is an important indicator of the exact timing of the treatment. A rise in the student population is also a prerequisite for a positive supply shock of high-skilled labor in the region.

Figure 1 traces the average number of college students in treated and control districts. Prior to the college openings, there are on average about 300 university students in treatment districts and about 2,000 students in control districts.[17] We see a substantial increase in the number of students in the event region starting from the year of the college opening. Ten years after the college opening, the student population in the treatment regions has increased by about 1,600. In control regions in contrast, the student population remains roughly constant over this period.

Figure 1: Number of Students in Treatment and Control Districts



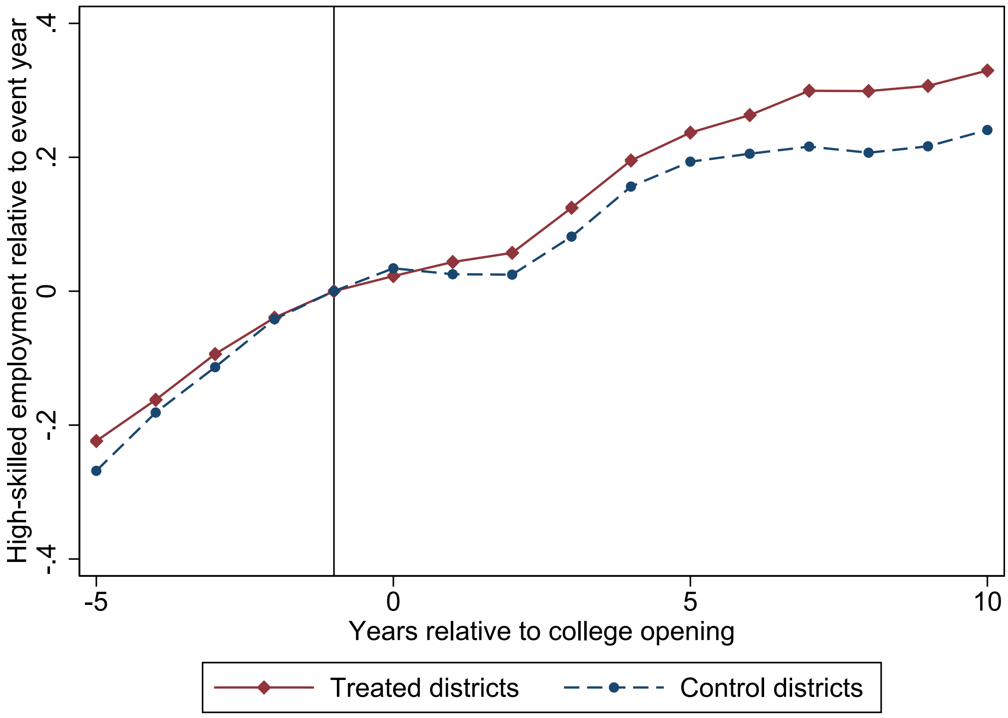
Note: Average number of full-time students enrolled in universities of treatment and control districts. The year before the university opening is normalized to 1.

[17]Four districts already had another college or university before the new opening which explains the positive student population prior to the treatment we analyze.

We also estimate the difference-in-differences model as in equation (1) using the number of students relative to the number of employees in the region as the outcome variable. Column (1) of Table 2 shows that new technical colleges lead to a large and significant increase in the share of students: Five years after the college opening the student population increases by 1.6% of total district employment, which is about 24% of all employees with a college degree. The effect further accumulates over time. Eight to nine years after the college opening the share has increased to 2.6% of local employment, an increase in the share of high-skilled workers in the region of about 34%.

In a next step we examine whether the college opening actually induces a positive shock in high-skilled labor. If most students leave the region after they finish their college degree to work and live elsewhere, a college opening would not affect the skill structure of the local workforce considerably. In that case, we would not expect to find any sizable impact of a college opening on the local economy.

Figure 2: High-Skilled Employment in Treatment and Control Districts



Note: Average number of college graduates employed full-time in treatment and control districts. The year before the university opening is normalized to 0.

Figure 2 traces the evolution of full-time employment of high-skilled workers in event and control regions relative to the year prior to the college opening ($\tau = -1$). High-skilled employment increases slightly in treatment districts one to two years after the college opening compared to control districts. Four to five years after the college opening, when the first cohort of college graduates enters the labor market, the number of high-skilled workers grows much faster in the event regions compared to control regions. Note that there is a slight upward trend in the number of high-skilled workers in both treatment and control regions prior to the opening which reflects the substantial growth in college graduates over this period.[18] Column (2) of Table 2 shows that eight to nine years after the college opening local high-skilled employment has increased by about 12%.

Table 2: Effects on Student Population and Employment Levels

	Share Student/Employed (1)	High-skilled Employment (2)	Total FT Employment (3)	Employment Education (4)	Employment w/o Education (5)
Period (τ=-4/-5)	0.002	0.015	0.010	0.010	0.010
	(0.001)	(0.022)	(0.013)	(0.038)	(0.013)
Period (τ=-2/-3)	0.001	0.005	0.000	-0.012	0.001
	(0.001)	(0.012)	(0.006)	(0.026)	(0.006)
Period (τ=-1)					
Period (event year, τ=+1)	0.003***	-0.003	0.006	-0.013	0.007
	(0.001)	(0.016)	(0.008)	(0.028)	(0.008)
Period (τ=+2/+3)	0.009***	0.028	0.017	-0.024	0.018
	(0.002)	(0.029)	(0.014)	(0.047)	(0.014)
Period (τ=+4/+5)	0.016***	0.031	0.023	0.057	0.023
	(0.003)	(0.028)	(0.019)	(0.070)	(0.019)
Period (τ=+6/+7)	0.021***	0.078*	0.031	0.064	0.031
	(0.004)	(0.040)	(0.026)	(0.083)	(0.026)
Period (τ=+8/+9)	0.026***	0.115**	0.041	0.120	0.040
	(0.005)	(0.054)	(0.031)	(0.085)	(0.032)
Event Period Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	714	714	714	714	714

Note: The table reports the estimates of the regression described in equation 1. The dependent variables are the ratio of students over total district employment (column 1), the logarithm of the number of full-time workers with a university degree (column 2), and the logarithm of full-time employment (total and by sector, columns 3-5). The unit of observation is district-year. Standard errors are clustered at the district level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Overall, the evidence on the student population and high-skilled employment highlight that the opening of a new college generates a sizable positive shock to the supply of high-skilled labor to the local economy. The timing of the shock to high-skilled employment in the local economy supports our identification strategy. High-skilled employment exhibits strong growth

[18]Between the mid-1980s and the 2000s, the number of students at technical colleges increased by more than 25% and hence, more than the student population in regular universities (see Beck and Wilhelm, 2003).

about four years after the opening when the first cohort of students graduates and enters the local labor market. If high-skilled employment had increased earlier in the region, this would have been an indication of local demand shocks affecting both high-skilled employment and the decision to open a new college in the region. Alternatively, this would raise doubts whether the observed increase might just reflect the number of high-skilled jobs created in the college with no further effect on the local economy. We now turn to the question how the college opening affected local labor markets.

4.2 Regional Employment

To trace the effects of a college opening on the local economy, we estimate variants of the regression model in equation (1) where the dependent variables are the logarithm of full-time employment in the district, log employment of medium- and low-skilled workers and the share of employment in a given skill group over total district employment. All variables refer to employment of full-time workers and are measured relative to the calendar year before the college opening in the event and control districts.

The effects on total district employment are shown in column (3) of Table 2. The estimates are noisy but the coefficients are positive and picture an increase in overall employment after the college opening. Eight to nine years after the reform the estimate hints at an increase of employment of 4% in treatment districts. However, the coefficient is imprecise and not statistically significant. Some of the additional employment might be jobs created by the college itself. In order to assess the effect on the local economy net of the new college jobs, we estimate equation (1) for the education sector and all other sectors separately.

The estimates for full-time employment in the education sector are indeed larger than for the other economic sectors but again not statistically significant (see columns (4) and (5) of Table 2). The absence of an effect on employment in the education sector is not too surprising given that the new technical colleges are relatively small compared to the total educational sector (including schools at all levels) in the district, especially in the first years after their opening. Moreover, given that employment by the technical colleges represents only about 0.1% of total district employment, the results on total employment do not change if we exclude the educational sector.

Table 3: Effects on Employment by Skill Group

	Log Employment			Employment Share		
	Low-skilled (1)	Medium-skilled (2)	High-skilled (3)	Low-skilled (4)	Medium-skilled (5)	High-skilled (6)
Period (τ=-4/-5)	0.018	0.006	0.015	0.002	-0.002	-0.000
	(0.019)	(0.016)	(0.022)	(0.003)	(0.004)	(0.001)
Period (τ=-2/-3)	-0.002	-0.001	0.005	0.000	-0.000	-0.000
	(0.013)	(0.007)	(0.012)	(0.002)	(0.002)	(0.001)
Period (τ=-1)						
Period (event year, τ=+1)	0.002	0.006	-0.003	-0.000	0.000	-0.000
	(0.015)	(0.007)	(0.016)	(0.002)	(0.002)	(0.001)
Period (τ=+2/+3)	0.029	0.016	0.028	0.001	-0.002	0.000
	(0.021)	(0.013)	(0.029)	(0.002)	(0.003)	(0.001)
Period (τ=+4/+5)	0.030	0.021	0.031	0.000	-0.002	0.002
	(0.029)	(0.018)	(0.028)	(0.003)	(0.004)	(0.002)
Period (τ=+6/+7)	0.025	0.029	0.078*	-0.002	-0.003	0.005*
	(0.039)	(0.025)	(0.040)	(0.005)	(0.006)	(0.002)
Period (τ=+8/+9)	0.034	0.037	0.115**	-0.003	-0.004	0.007**
	(0.043)	(0.031)	(0.054)	(0.006)	(0.007)	(0.003)
Event Period Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	714	714	714	714	714	714

Note: The table reports the estimates of the regression described in equation 1. The dependent variables are the logarithm of full-time employment by skill group (columns 1-3) and the ratio of full-time workers in given skill group over total full-time employment (columns 4-6). The unit of observation is district-year. Standard errors are clustered at the district level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 presents the results separately by skill groups. Columns (1) and (2) suggest that the college opening does not harm employment of low- and medium-skilled workers. On the contrary, eight to nine years after the college opening employment of low- and medium-skilled workers in the region has increased by 3-4% though the estimates fail to reach statistical significance at conventional levels. The right-hand side of the table shows that the college opening encourages a skill upgrading in the local economy where the share of college graduates in total employment increases by 0.7 percentage points from a base level of 5.5% (see columns (4) to (6) of Table 3).

We next ask whether the additional high-skilled employment occurs in incumbent plants or in new plants. Table 4 shows that the share of employment in newly established plants does not increase significantly more in treatment districts than in control districts after a college opening. However, the share of high-skilled labor in new establishments relative to total high-skilled employment in the district increases significantly in the long-run. Eight to nine years after the college opening, the share of high-skilled employment in new plants has increased by 0.5% (see column (2)). Newly established plants thus contribute to the educational upgrading

Table 4: Effects on Employment in New Establishments

	Employment Relative to District		Employment Structure	
	FT Employment (1)	High-skilled (2)	High-skilled Share (3)	R&D staff (4)
Period (τ=-4/-5)	0.000	0.002	0.006	-0.001
	(0.001)	(0.003)	(0.008)	(0.002)
Period (τ=-2/-3)	-0.001	0.000	0.008	0.003
	(0.002)	(0.004)	(0.010)	(0.003)
Period (τ=-1)				
Period (event year, τ=+1)	0.002	0.001	0.001	0.002
	(0.002)	(0.003)	(0.009)	(0.002)
Period (τ=+2/+3)	0.002	0.005	0.017	-0.000
	(0.002)	(0.003)	(0.013)	(0.002)
Period (τ=+4/+5)	-0.001	0.000	0.003	-0.000
	(0.001)	(0.003)	(0.013)	(0.003)
Period (τ=+6/+7)	-0.001	-0.001	0.000	-0.004
	(0.002)	(0.004)	(0.009)	(0.004)
Period (τ=+8/+9)	0.002	0.005**	0.018**	0.001
	(0.002)	(0.002)	(0.007)	(0.003)
Event Period Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes
Observations	714	714	714	714

Note: The table reports the estimates of the regression described in equation 1. The dependent variables are the ratio of employment in new establishments over total full-time employment (for all workers or high-skilled workers only, columns 1-2) and the ratio of full-time high-skilled workers or full-time workers in R&D occupations in new establishments over total full-time employment in new establishments (columns 3-4). The unit of observation is district-year. Standard errors are clustered at the district level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

of the labor force in treatment districts, possibly because new firms locating in the treatment region are more innovative firms. Yet, we find no evidence that the number of employees engaged in R&D increased in new establishments. Overall, however, most of the additional employment in the treated regions is created in incumbent plants.[19]

Taken together, the evidence on local employment indicates that a college opening facilitates skill upgrading without negative consequences for the employment of less skilled workers. Hence, the additional supply of high-skilled workers does not just replace less-skilled workers with no effect on total employment. The very moderate effects on the employment of workers without a college degree suggest modest local multiplier effects. Given the relatively small size of the new

[19]The employment effects when new establishments are excluded are very similar to the overall effects. For instance, the estimate for log high-skilled employment in a regression on incumbent establishments is equal to 0.111 compared to 0.115 from Table 2.

technical colleges, the absence of a sizable boost for local goods and services is not surprising. We next ask whether local wages by skill group decrease or not in response to the positive labor supply shock to the local economy.

4.3 Average Wages in the Region

To investigate the effect of a college opening on local wages, we re-estimate the regression model in equation (1) where the outcome variable is now the log average wages of full-time workers. Table 5 shows that average wages in the district do not change much in response to a college opening. In particular, we do not observe any negative effect on wages of university graduates despite the increase in employment for this skill group (see column (4)). The coefficient even turns positive eight to nine years after the college opening, when treated districts experience the largest increase in high-skilled labor. Unfortunately, the data available to us do not currently allow us to distinguish the effects on high-skilled wages for different age groups. Wages typically increase with labor market experience and firm seniority. Since we expect a larger inflow of young high-skilled workers with little or no labor market experience in the district, our results could mask some positive effects on the wages of high-skilled workers in different age and experience groups. Column (2) and (3) of Table 5 show that the wages of low- and medium-skilled workers were largely unaffected by the college opening relative to the control region.

Overall, the evidence suggests that an increase in the supply of high-skilled workers does not reduce wages, which points to a positive adjustment on the labor demand side in response to college openings. We also do not find evidence for spillovers on medium-skilled and low-skilled workers. The skill upgrading without negative wage effects in the local economy indicates labor demand adjustments like changes to the output mix or to technology used in production in response to a college opening. To investigate this further and separate these two channels, we need to analyze the data at the industry- or plant-level.

5 Discussion and Conclusion

Exploiting the opening of new technical colleges in Germany during the 1980s and early 1990s, this paper shows that universities have a significant impact in the local economy. Our empirical strategy combines a matching procedure with a time-varying difference-in-differences approach

Table 5: Effects on Log Average Wages by Skill Group

	All Skill Groups (1)	Low-skilled (2)	Medium-skilled (3)	High-skilled (4)
Period (τ=-4/-5)	0.000	0.003	0.001	-0.010
	(0.004)	(0.006)	(0.004)	(0.011)
Period (τ=-2/-3)	0.000	-0.001	0.001	-0.006
	(0.003)	(0.004)	(0.002)	(0.008)
Period (τ=-1)				
Period (event year, τ=+1)	-0.002	-0.004	-0.001	-0.004
	(0.003)	(0.005)	(0.002)	(0.009)
Period (τ=+2/+3)	-0.001	-0.000	-0.001	0.001
	(0.004)	(0.007)	(0.004)	(0.012)
Period (τ=+4/+5)	0.002	0.001	-0.000	0.003
	(0.006)	(0.010)	(0.006)	(0.011)
Period (τ=+6/+7)	0.003	-0.018	-0.001	0.000
	(0.008)	(0.013)	(0.007)	(0.013)
Period (τ=+8/+9)	0.012	-0.005	0.005	0.014
	(0.010)	(0.015)	(0.009)	(0.016)
Event Period Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes
Observations	714	714	714	714

Note: The table reports the estimates of the regression described in equation 1. The dependent variable is the logarithm of average gross daily wages of full-time workers. The unit of observation is district-year. Standard errors are clustered at the district level, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

to find suitable control regions to regions that had a college opening. We have three main findings. First, the opening of a technical college substantially increases the regional student population. This results in a large positive shock of high-skilled labor to the district when the first cohorts enter the local labor market. We find that high-skilled employment in the region increases by 12% eight to nine years after the opening. Second, we find some evidence of a positive, albeit imprecisely estimated, effect on the employment of workers without a college degree. Third, we find that wages of high-skilled workers do not decrease in the medium-run indicating a shift in local demand, especially for high-skilled workers. The employment and wage effects remain if we exclude all employees working in education, suggesting that a college opening has an impact on the local economy beyond additional jobs in teaching and research. The large increase in employment and the lack of a drop in wages point to sizable adjustments on the labor demand side. We find no large increase in employment at new establishments, suggesting that most of the adjustments happen in incumbent firms either through changes in the output mix or through changes in the technology used in the production process.

While our analysis focuses on the short- to medium-run effects of a college opening, the insights gained have important implications for regional policy. First, opening a new college is indeed an effective strategy to increase the skill level of the regional workforce. Second, we do not find evidence of adjustment costs in terms of lower wages or employment of such a large shock in high-skilled labor.

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A Further Tables and Figures

Table A1: List of Treatment Colleges

College	City	District	Opening Year
FH Braunschweig-Wolfenbüttel	Wolfsburg	Wolfsburg	1988
Hochschule Esslingen, Hochschule Nürtingen-Geislingen	Göppingen, Gesilingen	Göppingen	1988
Hochschule Heilbronn	Künzelsau	Hohenlohekreis	1988
FH Furtwangen	Villingen-Schwenningen	Schwarzwald-Baar-Kreis	1988
Hochschule Albstadt-Sigmaringen	Albstadt-Ebingen	Zollernalbkreis	1988
Westfälische Hochschule Gelsenkirchen	Bocholt	Borken	1992
FH Westküste	Heide	Dithmarschen	1993
Hochschule Kaiserslautern	Zweibrücken	Zweibrücken	1994
Technische Hochschule Ingolstadt	Ingolstadt	Ingolstadt	1994
Technische Hochschule Deggendorf	Deggendorf	Deggendorf	1994
Hochschule Hof	Hof	Hof	1994
FH Neu-Ulm	Neu-Ulm	Neu-Ulm	1994
Hochschule Bonn-Rhein-Sieg	Sankt Augustin	Rhein-Sieg-Kreis	1995
Westfälische Hochschule	Recklinghausen	Recklinghausen	1995
Ostbayerische Technische Hochschule Amberg-Weiden	Amberg	Amberg	1995
Ostbayerische Technische Hochschule Amberg-Weiden	Weiden	Weiden	1995
FH Aschaffenburg	Aschaffenburg	Aschaffenburg	1995
Hochschule Trier	Birkenfeld	Birkenfeld	1996
Hochschule für angewandte Wissenschaften Ansbach	Ansbach	Ansbach	1996
Hochschule Koblenz	Remagen	Ahrweiler	1998
Hochschule Kaiserslautern	Pirmasens	Pirmasens	1988

Figure A1: Geographic Location of Treatment and Control Districts