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Henning Kroll
Torben Schubert

On universities' long-term effects on regional value creation and unemployment

The case of Germany

Fraunhofer
ISI

Contact:
Fraunhofer Institute for Systems
and Innovation Research ISI
Competence Center "Policy and Regions"
Breslauer Strasse 48
76139 Karlsruhe, Germany
Phone: +49 / 721 / 6809-138
Fax: +49 / 721 / 6809-176
E-Mail: christine.schaedel@isi.fraunhofer.de
URL: www.isi.fraunhofer.de

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Contents Page

Tables and Figures

Abstract: It is widely believed that universities exert notable effects on their regional socio-economic environment. So far, much of the empirical evidence supporting this claim is based on case studies. While such studies often give a detailed picture of the contributions of individual universities for their specific environments, almost no figures are available for effects of Higher Education Institutions (HEI) on the macroeconomic or economy-wide level. This paper seeks to fill this gap by using spatial panel-data models in order to identify the impact that HEIs have on value creation and unemployment in Germany. Other than prior studies, we do not seek to identify only direct effects (e.g. demand side effects caused by HEI investment) but we seek to identify the effects in terms of wider knowledge generation. Corresponding with this broad view we find evidence of strong effects on regions' GDP. HEIs contribute to Germany's GDP with € 600bn per annum, i.e. about one fourth of the total value creation. 92% of this effect, however, is due to spillovers between regions. Thus the spatial distribution of the effects is rather flat. We also find that while in the short-run HEIs increase the unemployment rate, they lower it by on average 3.5% in the medium to long-run.

1 Introduction

The discussion on the regional impact of Higher Education Institutions (HEI) has a long tradition, dating back to papers written in the 1970s by e.g. (Caffrey and Isaacs (1971), Brownrigg (1973), and Boot and Jarrett (1976). Since the late 1980s, an increasing political interest in universities' economic contribution to their environment has added further momentum to the debate (Bleaney et al. 1992; Elliot et al. 1988; Feldman 1994; Florax 1992; Goldstein 1989; Goldstein et al. 1995; Henderson et al. 1998). Today, it remains vivid with a view to both the identification of channels of interaction and the quantitative estimation of socio-economic effects (e.g. Drucker/Goldstein 2007; Uyarra 2010). With a view to the latter, a continued political and academic interest in more robust results has continued to prompt an output of both conceptual contributions (Garrido-Yserte/Gallo-Rivera 2010; Pastor et al. 2013; Segarra Blasco 2003) and numerous case studies for individual universities (Boston University 2003; Canterbury City Council 2001; Luque et al. 2009; Morral 2004). With some notable exceptions like Goldstein and Drucker (Goldstein/Drucker 2006) and Goldstein and Renault (2004), however, few contributions have sought to take the methodological ambition of measuring impact beyond the level of case studies.

Importantly, most studies that have focused on the tangible and directly measurable impacts of HEI found that effects of HEIs on local economies are positive but not overwhelmingly large (e.g. Goldstein/Renault 2004; Goldstein/Drucker 2006). This, however, should be put into perspective from two angles: First, difficult to measure non-tangible outputs are known to be highly important (Florax 1992) and may not yet fully be covered in the available research designs. Second, time lags between academic outputs and economic impacts are known to be considerable (Stokes/Coornes 1998), not least because of co-evolutionary processes that need time to take effect. Most studies – an exception is e.g. Goldstein and Renault (2004) – used cross-sectional data. In some, there are good arguments to assume that available analyses of HEIs effects might have underestimated HEIs long-term impacts on macroeconomic variables.

In light of this assumption, this paper presents a broad-based empirical approach trying to identify the average contribution of HEIs' activities to regional socio-economic development in Germany for the period 2000-2009. By means of spatial panel models based on secondary data, our study identifies the average measurable effects that the presence of university investment, university employment, students, and successful graduates display on regional income and unemployment – thus putting to the test some commonly made assumptions regarding universities' regional contribution from a macroeconomic point of view.

Hence, the presented analysis adds a new angle to a so far often case-study centred debate. Moreover, it does not only capture the impact of academic activities within a certain region's boundaries but also that of those in its adjoining vicinity. Finally, we control both for observable regional characteristics and for unobserved regional heterogeneity by allowing for the existence of regional fixed effects.

We therefore take into consideration important caveats raised by the conceptual literature, that put much emphasis on HEI socio-economic impact's dependency on their regional situatedness (Boucher et al. 2003; Huggins et al. 2008; Huggins et al. 2012; Lawton Smith 2007; Lawton Smith/Bagchi-Sen 2012; Power/Malmberg 2008; Uyarra 2008; Uyarra 2010) as well as on the role of interregional spillovers (Drucker/Goldstein 2007).

2 Conceptual Model

2.1 Outline

In the following we develop a framework to guide our quantitative measurement of the economic impacts of HEIs on their economic environments. We explain three basic complexities that need to be taken into account when analysing the economic impacts of HEIs: multidimensionality of outputs and impacts, the heterogeneity of the regional environments, and regional spillovers. Because of these complexities most university impact studies so far have tried to analyse the effects on case study designs with the objective of providing specific answers to specific questions. While the great strength of this literature is the high degree of contextual detail, the price comes in the form of limited generalisability. Often policy-driven papers are at risk of providing parochial answers to parochial questions (Stokes/Coornes 1998). Despite some notable efforts (including Goldstein/Renault 2004; Goldstein/Drucker 2006), the issue of the macroeconomic contribution that universities deliver through their role as regional engines – or at least catalysts – of growth and employment has remained somewhat under-researched.

In this paper we intend to contribute to closing this gap by developing a framework that allows for the quantitative identification of HEIs' overall macroeconomic effects while taking into account the multidimensionality of their outputs, the heterogeneity of their regional environment, as well as the ensuing spillovers between regions.

2.2 Conceptual Framework

The general tone of the existing literature on universities' regional impacts is to highlight the importance of case specificity which renders the quantitative estimation of average effects across regions very difficult (cf. Lawton Smith/Bagchi-Sen 2012).

Undoubtedly, a study on the effects of HEIs on their local economic environment should take these complexities into account. Nonetheless, we do not aspire to contribute to the ongoing methodological debate about university-specific case studies (Garrido-Yserte/Gallo-Rivera 2010; Pastor et al. 2013). Instead, we intend to effectively control for potential sources of heterogeneity in order to derive robust aggregate measures of average economic effects across regions – an approach that has in principle been proven feasible and relevant by prior studies (Drucker/Goldstein 2007).

2.2.1 The Multidimensionality of HEI Outputs and Impacts

In more than three decades of academic debate, it has become broadly acknowledged that HEIs generate a variety of different outputs, from tangible ones such as publications and patents to less tangible ones such as regional leadership, influence on regional milieu, and knowledge infrastructure production (Florax 1992; Goldstein et al. 1995; Goldstein/Drucker 2006; Jansen et al. 2007; Schmoch et al. 2010; Schubert 2009; Stokes/Coornes 1998).

Through a broad range of transfer and interaction channels (Abreu et al. 2009; Benneworth et al. 2009; Koschatzky et al. 2011) these effects are translated into first order impacts. These mechanisms are usually highly complex (Garrido-Yserte/Gallo-Rivera

2010; Howells 2005). Understanding them better is an important task study (cf. D'Este et al. 2013; D'Este/Iammarino 2010; Dornbusch et al. 2012; Malmberg/Maskell 2002; Uyarra 2008), but not at centre stage here because it would overburden our study.

For the purpose of this study, it shall therefore suffice to make a first reference to the established set of first order impacts (cf. Figure 1) which by Florax (1992) and later Stokes and Coornes (1998) has been appropriately and instrumentally grouped into *short-term, expenditure-based demand-side effects* and *long-term, knowledge-based supply-side effects*.

These first order effects, in turn, will prompt second order impacts on macroeconomic outputs (Florax 1992; Garrido-Yserte/Gallo-Rivera 2010) – among them in particular regional value creation (Huggins et al. 2008) and unemployment (Beeson/Montgomery 1993; Gottlieb 2001; Link/Rees 1990). It is this overall, final socio-economic impact that this study sets out to measure.

Most of the literature has highlighted that because of HEIs' positive contributions in terms of both *short-term, expenditure-based demand-side effects* and *long-term, knowledge-based supply-side effects* (positive) second-order value creation effects will inevitably be the result.

The impacts on unemployment, in contrast, appear less predictable and indeed, less conclusive evidence is available from the literature. While one line of reasoning would argue that a decrease in unemployment will result from increases in productivity, innovativeness and thus competitiveness, several mechanisms are likely to confound this relationship. As Stokes and Coornes (1998) have argued, there is likely to be a notable time-lag with regard to knowledge-based supply-side effects. Furthermore, even expenditure-based effects will at first only result in an increase of value added which – due to their often expectably temporary nature – may or may not translate into an increase in employment. Second, the impact of technological progress on unemployment is in fact far from clear. While it stands to reason that employment perspectives would improve for the highly qualified, it is for example less clear that the unqualified labour force would automatically benefit from an increase in technological competitiveness as the skill-biased technological change hypothesis exemplifies (cf. Berman et al. 1998).

Consequently, it seems instrumental to illustrate how our empirical approach derives from its overall conceptual framework. To that end, the following paragraphs summarise some key assumptions on the transfer of university outputs into first order impacts and into second order impacts in turn.

Short-term, expenditure-based demand-side effects

Consumption: With a view to regional value creation, most studies suggest that university employment may trigger relevant, albeit fleeting, effects through the disbursement of wages (Stokes/Coornes 1998). Likewise, a minor diminishing effect with a view to regional employment appears possible but not very likely given the overall small share of HEI personnel in the regional labour force. Furthermore, many studies have demonstrated that a large local student population can trigger notable demand side effects on both local income and regional employment. As students display one of the highest consumption propensities among all societal groups (low income, high income prospects) they constitute a dynamic ingredient for all regional economies. Potential crowding-out effects of student jobs on local employment are likely to be compensated by this general dynamic.

Investment: With a view to regional value creation, HEIs' general investment (e.g. in buildings and other, non-sophisticated infrastructure and equipment) is likely to trigger demand and thus multiplier effects in the local economy. In a similar vein, it has the potential to prompt notable decreases in regional unemployment through additional procurement with local contractors. Positive supply side effects are less likely but cannot be excluded, e.g. through the university's nature as a demanding customer.

Long-term, knowledge-based supply-side effects

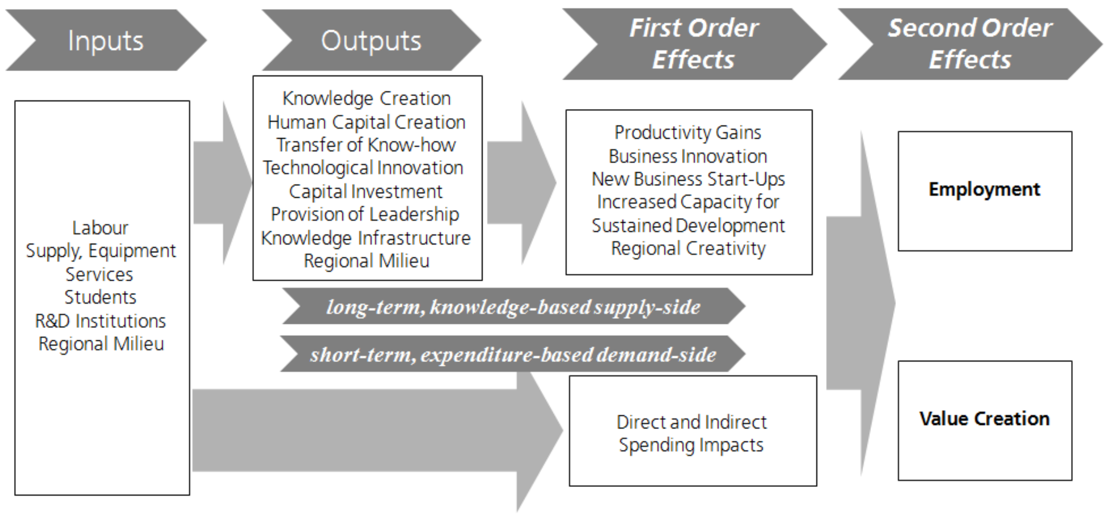
Human capital creation: A constant stream of well-educated local graduates is likely to cause positive supply side effects in the regional economy if it is attractive as a working environment for well-qualified staff. With their technical and managerial knowledge, graduates have significant potential to increase the innovativeness, creativity and productivity of local firms and to allow them to increase their sales, profit margin, and to pay higher wages. Moreover, some of them may decide to start new firms that add further dynamism to the local economic environment (Florax 1992; Goldstein et al. 1995). In their first years after graduation, however, many graduates tend to experience frictional unemployment. A steady stream of graduates may therefore pose an at least temporary challenge to regional labour markets. Along similar lines, some recent studies have identified a structurally negative relationship between the number of degrees awarded by local universities and the level of average earnings, attributing this to oversupply (Goldstein/Renault 2004).

Knowledge Production: Knowledge creation as an output of HEIs' research activities is known to create positive supply-side effects on the regional business sector. Many studies have empirically proven the existence (though not the nature) of this process in multiple contexts (Charles 2003; Cowan/Zinovyeva 2013; Goldstein/Renault 2004;

Huggins et al. 2008; Huggins et al. 2012; Huggins/Johnston 2009; Lawton Smith 2007; Lawton Smith/Bagchi-Sen 2012). Some have argued that it has become stronger with both universities' increasing self-awareness of their third role and the increasing knowledge-orientation of modern economies (Goldstein/Renault 2004). With a view to the labour market, however, imaginable transfer channels for potential effects appear somewhat circuitous – from knowledge absorption to improved competitiveness to improved performance to intensified hiring.

Beyond these measureable impacts relating to the three classical missions of HEIs (teaching, research, and knowledge transfer), Figure 1 highlights the importance of HEIs' broader socio-economic role and their engagement in regional communities (Benneworth et al. 2009; Florax 1992; Gunasekara 2006; Uyarra 2008). While these outputs are clearly of crucial importance, they are considerably more difficult to measure and their impact in terms of first and second order impacts is hardly predictable. Empirically, recent studies have found that their impact was less obvious than originally thought (Goldstein/Renault 2004). Hence, we will not directly account for these factors in the context of this study.

Figure 1: Inputs to, Outputs from and Regional Effects of Universities' Activities



Source: own figure, based on: Goldstein et al. (1995); Stokes and Coornes (1998); Segarra i Blasco (2003)

2.2.2 The importance of the socio-economic environment

In the last decade, a broad strand of literature has improved our conceptual understanding of external framework conditions which enable or inhibit universities' development of links with their regional environment.

Besides many other arguments, the generation of economic impacts require actual linkages between regional economic actors and HEIs. In particular, the establishment of HEIs' interactions with their regional industrial partners but also the density of networks in the region has been identified as a key contingency (Boucher et al. 2003; Huggins/Johnston 2009). In the absence of those, 'latent demand' does not translate into actual demand and is of little factual utility, not least as universities do fairly often not create the type of knowledge applicable or absorbable by regional firms (Huggins et al. 2008; Power/Malmberg 2008).

In summary, Huggins et al. (2008) argue that for interactions to emerge both the firms' capacity to make use of the academic outputs as well as the HEIs ability to produce economically relevant outputs are necessary conditions. Empirically, however, they find considerable variety with regard to both the capability of universities to effectively transfer their knowledge and that of regional businesses to effectively absorb such knowledge. Consequently, the evolution of the regional transfer networks needed to translate outputs into first order impacts can be considered as contingent on, firstly, regional universities general familiarity with the business sector, and, secondly, the knowledge-orientation of that very private business sector.

Empirically, the literature finds that mismatches between the needs of the local economy on the outputs produced by regional HEIs are fairly common – as are their detrimental effects on the HEIs overall economic impacts. One common finding in this regard thus is that universities' impact depends on the degree of technological activities in the regional business sector, as only firms with a certain technological absorptive capacity can derive relevant value from complex academic knowledge (Cohen/Levinthal 1990; Lambert 2003; Power/Malmberg 2008). Moreover, universities themselves are prone to select their co-operation partners based on their relevance and reputation rather than their geographic location (Huggins et al. 2012).

Based on this discussion we will include two key contingencies, where the first measures the industrial partners' technological strength and the second proxies the HEIs familiarity with transferring knowledge-related assets to industrial partners.

2.2.3 The role of regional Spillovers

As illustrated by a broad academic discourse originating from Jaffe (1986) and Jaffe et al. (1989) knowledge (and other) spillovers are a key ingredient for all supply-side, productivity enhancing processes in the field of science-industry or, broader, science-society interaction.

As has convincingly been argued, many universities select their collaboration partners based on other forms of proximity (Boschma 2005) than regional adjacency. Consequently, many interaction channels through which university activities are translated into both first and second order impacts are as such regionalised only to some, possibly quite limited, degree (D'Este et al. 2013; D'Este/Iammarino 2010; Huggins et al. 2012; Power/Malmberg 2008) – and may even less be adequately captured by an analysis within administrative boundaries. Beyond these general conceptual caveats, empirical studies on universities' impacts have found evidence of strong regional spillovers, indicating a relatively flat spatial gradient of impacts that stretches to neighbouring regions (Drucker/Goldstein 2007).

Consequently, this study will acknowledge these facts and seek to integrate many of them by allowing for spillovers in our empirical modelling.

2.3 Derivation of Hypotheses

As illustrated in the preceding section, the conceptual literature on university's contribution to their regional socio-economic environment refers to a broad range of channels originating in a similarly broad range of university activities. The foregoing discussion has emphasized the complexity of these channels often precluding directly a straightforward prediction concerning the direction of each of the measured HEI outputs on each of the economic impact variables. We therefore regard it as quite problematic to formulate research hypotheses regarding the relationship of each output and each impact. Rather we focus on the overall effects of HEIs on the two outcome variables.

Concerning GDP the bulk of existing analysis highlights the positive impact of HEI investment, employment, student population, scientific knowledge, and graduates (for summaries cf. (Drucker/Goldstein 2007; Florax 1992). As argued above, these findings can conceptually be justified by both demand and supply side effects. With respect to the effects of unemployment the empirical literature appears more ambiguous because of e.g. long time-lags and skill-biased technological change processes. In relatively flexible labour markets, however, readjustment (e.g. downward pressure on wages on low-skilled groups) will induce a tendency towards full employment. Therefore, the negative effects of HEIs on unemployment are likely to be transitory. In the long-run, the unemployment reducing effect of higher competitiveness should therefore prevail:

> *H1: Key HEI outputs will display a significantly positive effect on regional value creation.*

H2: Key HEI outputs, in particular the education of graduates, will display a significantly positive effect on employment in the long-run, but a negative one in the short-run.

As argued in the preceding discussion, there are important contingencies moderating the general effects (cf. Boucher et al. 2003; Charles 2003; Goldstein/Renault 2004; Huggins et al. 2012; Power/Malmberg 2008). Our argument posited that both the technological orientation of regional firms as well as the familiarity of regional universities with industrial partners will positively moderate the impacts on the macroeconomic outcomes.

H3: a) In regions with a high technology-orientation of the local industry the HEIs positive effects on value creation and employment are stronger. b) In regions where local HEIs generate higher shares of their income from private firms the positive effects on value creation and employment are stronger.

Finally, we follow the large body of literature that highlights the central importance of regional spillovers in all knowledge-transfer related issues as well as some concrete recent findings from nationwide studies on HEI's regional impact. Consequently, we assume the following:

H4: A large part of HEIs' positive effects on value creation and employment spillover to neighbouring regions.

3 Methodology

3.1 Data sources

The data used in this paper is taken from a variety of sources, most of which are publicly available. In detail, HEI data are taken from German Higher Education Statistics ("Hochschulstatistik") provided by the Federal Statistical Office (DESTATIS). To the degree that the data was available online, it was taken from the Genesis database (www.destatis.de). In some cases, the Federal Statistical Office was contacted directly to provide further data. Likewise, regional data was either taken from the Federal Statistical Office's or EUROSTAT's online sources. In general regional economic data was for the German Counties ('Landkreise'), in EUROSTAT's terms on the NUTS 3 level. We added publication and patent data to this publicly available data on the NUTS 3 level. The publication data was calculated using an in-house-version of Thomson Scientific's proprietary Science Citation Index (SCI) and Social Science Citation Index (SSCI). The patent data was calculated based on the PATSTAT/ REGPAT database, which is in a raw version distributed by the European Patent Office (EPO) and the OECD. We focused on applications at the EPO patents because of their great importance. Hence, our analysis is based on more than 400 regional units ranging from 229.4km² to 5,468km² (35.7km² counting cities), with an average size of 880km², or 34 km across. Few exceed the size of 2.000km², or 51km across.

3.2 Dataset construction

Several obstacles to constructing panel data set from these sources had to be overcome. First, although most of the data is publicly available either at EUROSTAT or DESTATIS it usually comes in a large number of dispersed Excel-sheets that use unharmonized formats and layouts. Hence, these sheets had to be manually reformatted to a common layout such that they could be imported to an ACCESS database. Second, regionalisation of the patent and publication data must be based on the information in the address fields (postal codes). This information is raw and had to be extracted, reformatted and evaluated to generate regional patent and publication data on the NUTS-3 level. This work was done by algorithms that make use of specific concordance tables that linked the postal codes to NUTS-3 regions. Third, Higher Education Statistics are institutional data for individual HEIs, not regional data. Therefore, the first step was to create a dataset with the individual HEI as the observational units where we linked the publication and patent data. This dataset was in a second step aggregated over the NUTS 3 regions. Fourth and finally, a last point of interest concerns missing data. In principle, we collected data for the period from 1993-2011. However, the data was largely complete for both regions and HEIs only after 2000. Because missing HEI data would have led to distorted regional aggregations for the 1990s, the data set was limited to the years 2001-2011, which still gives a reasonably long panel dataset.

3.3 Identification strategy

3.3.1 The general modelling approach

The objective is to identify macroeconomic effects from the level of individual HEIs on their local specificities. Case study designs therefore do not lend themselves to the identification of these overall effects. We will therefore propose a panel data regression approach that is able to identify these overall effects while accounting for regional specificities and controlling for unobserved heterogeneity.

3.3.2 The choice of the regression model

In spatial econometrics spillovers are usually identified by the inclusion of spatial lags. A couple of models variants have been proposed for estimation. In order to choose between them LeSage and Pace (2009) have proposed the spatial Durbin Model as default and then test model restrictions to find out about the correct specification. However, as Gibbons and Overman (2012) show in finite samples tests for the correct specification, usually this approach will have poor discriminatory power, because the implied reduced forms of the equations differ only marginally, rendering the identification in finite samples weak. Gibbons and Overman (2012) thus propose to estimate the reduced form model which incorporates a spatial lag on the explanatory variables.

The real complexity they argue, lies, however, in endogeneity. The most important sources of endogeneity are simultaneity and unobserved heterogeneity. While simultaneity can only be dealt with in experimental designs – a paradigm that Gibbons and Overman (2012) consequently argue for – the use of panel data can effectively control for unobserved heterogeneity (e.g. caused by unobserved cultural differences, institutions, etc.).

We thus propose the use of a fixed effects panel data regression, which additionally includes spatial lags of the explanatory variables.[1] Comparing this model to earlier approaches in the literature, the fixed effects approach can be thought of as a generalized version of the differencing approach used in Goldstein and Renault (2004) based on what they call a quasi-experimental design. We also include spatial errors, where appropriate specification tests have shown that both fixed effects and spatial errors are relevant.[2]

1 In order to derive the spatial lags we have used bird's distance with a continuous decay function with a parameter of 2. We have also tested other parameters but the results were relatively stable with respect to these changes. This does not come as a surprise, because the spatial lags implied by differing decay parameters are usually highly correlated (LeSage/Pace 2009).

2 Test results for the Baltagi-Song-Jung-Koh LM tests as well as for the Hausman tests for spatial panel data models are available upon request.

3.4 Variable selection

3.4.1 Dependent Variables

Against the background of the hypotheses, universities' contribution to their socio-economic environment has to be captured from a double perspective: first, with a view to "regional value creation" and, second, with a view to the "regional labour market".

Firstly, one dependent variable needs to capture value creation. While earlier studies have tried to focus on individual level income such as "average annual earnings per non–farm worker" (Goldstein/Drucker 2006) we argue that an at least equally convincing case can be made for focusing on value creation, measured through regional GDP per capita. In brief, we attempt to measure economic benefit, rather than gains in terms of wealth. Against the background of our double focus on value creation and labour market, we consciously accept the somewhat more generalist perspective that this approach entails. Moreover, we do not specifically correct for any trends and developments (e.g. inflation or structural change), as those will be stochastically eliminated within our modelling approach.

Secondly, one dependent variable needs to capture developments on the labour market. A suitable measure in this field could be "unemployment rate" or "total employment." Both of these have distinctive characteristics, in particular with respect to an implicit focus on economic potential in one (total employment) and a more obvious focus on social inclusion in the other (unemployment rate). As the central focus of the first model(s) is on economic development (GDP per capita rather than average personal income), we chose to put the focus of the second model(s) dependent variable more specifically on a social perspective. Consequently, we chose "unemployment rate" as a dependent variable.

In summary, our double strategy will seek to measure HEIs' impact on their socio-economic environment by making a clear distinction between effects that are primarily of an economic nature and effects more directly of a social nature.

3.4.2 Key independent variables

As outlined above, our conceptual approach takes into account outputs prone to produce both "backward" (demand-side, expenditure driven) and "forward" (supply side, knowledge driven) effects (Segarra Blasco 2003; Stokes/Coornes 1998). While it may be correct for methodological reasons to avoid a mixture of both in case studies (Brown/Heaney 1997; Garrido-Yserte/Gallo-Rivera 2010) the contrary seems to be the case for cross-section studies aiming to measure impacts on as broad a basis as possible.

Consequently, we will cover a range of independent variables which have, among others, been discussed by Florax (1992), Goldstein et al. (1995), Lambooy (1997), and Pellenbarg (2005).

On the demand side the variables are number of students, HEI investment, and number of staff. On the supply side we include number of publications, number of graduates, and third party funds, where all variables are taken as per capita values.[3]

3.5 Control variables

Size of the region: Evidently, the effect of universities' multiple types of activity will be different in regional economies for which they are a key point of reference from those in regions in which they are one player among many and neither the innovative nor the economic dynamics substantially depend on their contribution (Drucker/Goldstein 2007). With a view to the literature, this has been evidenced for demand side effects in particular but is equally likely to have some impact on the occurrence of supply side effects as well. We use absolute employment as a measure of size of the region.

Degree of technology orientation of the regional economy: With a view to many prior studies, it appears evident that the intensity of regionalised supply side effects will depend on the absorptive capacity of the local industry. Only where regional enterprises are capable of translating research results or the capabilities of hired graduates result in gains in innovativeness and productivity increases in regional income and employment can be expected. "High-tech employment" and "number of local patents" have been included as proxies for regional techno-economic development. As the empirical literature argues, there are many more 'ordinary' regions than technological leaders (Doloreux/Dionne 2008; Howells 2005; Huggins et al. 2012; Tödtling/Trippl 2005).

Peripherality of the regional economy: Conceptual studies have argued that the capacity to make use of research results and human capital transfer depends on more than just the co-presence of modern industries and universities. Instead, a certain form of institutional thickness is required that is typically found absent in peripheral regions. While prior empirical studies have reported ambiguous findings on the impact of this issue, many of them confirm that, in some way, peripherality matters. For the purpose of this study, we use the share of agricultural employment as a measure of peripherality due to the lack of accessibility, absence of qualified workforce and limited infrastruc-

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3 Beyond those variables other authors have suggested indicators like "number of regional start-ups", "creative contributions", "research expenditure", and "university patents". In this study, we decided against these due to problems in data availability (start-ups, creative contributions) or methodological issues (research expenditures, university patents).

ture that often characterises predominantly agricultural regions. Spatially remote regions with a strong focus on tourism, in contrast, are often more accessible, endowed with better qualifications and more developed in terms of infrastructure. Hence, this measure would be less suitable for the purposes of this study.

Net migration: Many of the potential supply side benefits of additional graduates will be lost if their propensity to leave the regional economy soon is high. Migration can therefore be understood as a potential proxy for brain drain, not least as studies on the regional effects of student migration and human capital have so far not produced consistent conclusions (e.g. Blackwell et al. 2002; Felsenstein 1995; 1996; 1999; Goldstein/Luger 1992; Huffmann/Quigley 2002; Malecki 1997). On the other hand, high immigration rates may bring the local labour market closer to equilibrium, with the result that any potential supply side effects of university activities are marginalised.

4 Results

Table 8 in the appendix contains the summary statistics. For the sake of conciseness we refrain from discussing them in detail, but instead turn directly to the main results.

We will only briefly present the underlying regression tables as a point of reference. The discussion of the results is based primarily on the overall effects for a hypothetical *average region* Table 4-Table 7, where we mean with average, that this region has HEI activities equal to the mean values for the activities in the sample. The reason for that is that scaling issues, the presence of differing time lags and the presence of spatial lags makes a direct interpretation of the regression coefficients tedious. We differentiate between the total effect (TE), direct effect (DE) and the indirect effect (IE).[4]

Table 1 presents the models for GDP per capita and two versions of the model for unemployment. As discussed earlier, effects on unemployment are likely to take longer to manifest. We have therefore estimated both a baseline model with a one year time lag and an alternative specification including the three year lags. Table 2 and Table 3 present the regression concerning the interaction effects with the regional technology intensity as measured by EPO patents per capita as well as regression concerning third party funds from industry.[5] All models also include the spatial lags for all variables explaining the reasons.

4 Calculating the marginal effects is mathematically straightforward but somewhat awkward. The formulae are found in Appendix 2.

5 For reasons of presentational conciseness, we only present the one year lag for unemployment in these models. Nonetheless, the results for the extended model including the three year lag have been determined and are qualitatively similar.

Table 1: Baseline regressions for GDP and Unemployment

Dependent Variable	GDP p.c.			Unemployment rate			Unemployment rate		
	Estimate		t-value	Estimate		t-value	Estimate		t-value
University characteristics									
Graduates p.c. (l1)	119,4200	***	6,7686	-14,4370		-0,9204	-45,3030	**	-2,2039
Investment p.c. (l1)	-0,5537		-0,7196	-3,5839	***	-5,2570	-2,6718	***	-3,6976
TPF p.c. (l1)	-2,4442		-1,0891	-0,8339		-0,4167	0,4755		0,2301
Students p.c. (l1)	10,7280	**	2,4000	32,8770	***	8,3040	27,3150	***	5,5521
Staff p.c. (l1)	10,1560		0,7129	38,9420	***	3,0639	15,8650		0,8891
Publications p.c. (l1)	142,5900	***	2,5974	-17,5320		-0,3622	2,6140		0,0528
Graduates p.c. (l3)							10,4530		0,4146
Investment p.c. (l3)							-2,2567	***	-2,9082
TPF p.c. (l3)							-12,0950		-1,4687
Students p.c. (l3)							8,2911		1,5192
Staff p.c. (l3)							36,7490	*	1,8977
Publications p.c. (l3)							-58,7410	***	-5,7048
Regional controls									
Net migration	66,8720	**	2,3383	-63,9090	**	-2,5119	-74,4960	***	-2,8938
Regional employment	0,0325	***	7,0723	-0,0139	***	-3,3114	-0,0148	***	-3,5121
Share hightech employment	0,0290		0,9012	-0,0799	***	-2,7988	-0,0641	**	-2,2469
Share agricultural employment	-14,6450	*	-1,8528	20,2630	***	2,9042	22,5740	***	3,2368
Spatial lags									
Graduates p.c. (l1)	258,1800		1,0910	-967,8700	***	-3,0790	-546,6500		-1,5739
Investment p.c. (l1)	-17,8550	**	-2,0950	-10,7490		-1,0275	-14,6840		-1,4463
TPF p.c. (l1)	79,9150	**	2,3686	-81,2870	**	-1,9800	-81,1750	*	-1,9533
Students p.c. (l1)	-60,4240		-1,4066	-90,6600		-1,5896	-94,9640		-1,4076
Staff p.c. (l1)	453,6800	***	5,5146	569,4900	***	5,0596	182,6000		1,3772
Publications p.c. (l1)	-59,6250		-0,1507	3844,6000	***	6,3524	2459,5000	***	4,0963
Graduates p.c. (l3)							-1114,5000	***	-2,6378
Investment p.c. (l3)							26,6890	**	2,4441
TPF p.c. (l3)							-365,2200	**	-2,2346
Students p.c. (l3)							-49,1490		-0,8344
Staff p.c. (l3)							916,5900	***	6,2695
Publications p.c. (l3)							-143,4700		-1,0097
Net migration	74,4790		0,3636	-590,0300	**	-2,1658	-806,4000	***	-3,1054
Regional employment	0,2679	***	5,3175	-0,1116	*	-1,7156	-0,0999		-1,0962
Share hightech employment	-0,0822		-0,6120	-0,0572		-0,2974	-0,0541		-0,2973
Share agricultural employment	-255,4500	***	-4,1107	57,2660		0,5615	63,6250		0,6780
Year dummies	YES			YES			YES		
N	429			429			429		
T	19			19			19		
R2	0,9864			0,9560			0,9564		
rho	0,2900			0,9600			0,8600		

It is important to note that all models have very high fit yielding R^2 values of above 0.9. This demonstrates that despite the fact that there is substantial heterogeneity between regions most of it can be controlled for by using fixed effects regression cancelling out time constant unobserved heterogeneity. It also suggests that *time-varying* unobserved heterogeneity is probably limited at least in our nine year period. Accordingly, a series of Ramsey RESET tests did not indicate the presence of neglected unobserved factors. This considerably increases the credibility of our regression based approach. A second interesting observation relates to the spatial error coefficient, which with around 0.9 in the case of unemployment is about three times higher than in the GDP models. Obviously, regional shocks to unemployment have a much more profound effect on the neighbouring regions than shocks to regional production.

Table 2: Regressions for GDP and Unemployment with Patent Intensity as Moderator

Dependent Variable	GDP p.c.			Unemployment rate		
	Estimate		t-value	Estimate		t-value
University characteristics						
Graduates p.c. (l1)	202,1000	***	9,6563	-10,8500		-0,5815
Investment p.c. (l1)	0,7169		0,7204	-6,1065	***	-6,9439
TPF p.c. (l1)	2,8063		1,1660	-3,1986		-1,4805
Students p.c. (l1)	-1,2254		-0,2475	33,0940	***	7,5309
Staff p.c. (l1)	3,5790		0,2198	49,9910	***	3,4326
Publications p.c. (l1)	139,6200	**	2,5568	-23,3930		-0,4822
Graduates p.c. (l1)#Patents p.c.	-31234,0000	***	-7,3528	-4889,8000		-1,2931
Investment p.c. (l1)#Patents p.c.	-90,8340		-0,3945	1003,1000	***	4,9367
TPF p.c. (l1)#Patents p.c.	-299,6500		-1,3565	194,8400		0,9975
Students p.c. (l1)#Patents p.c.	4672,2000	***	5,7988	-758,5200		-1,0637
Staff p.c. (l1)#Patents p.c.	9424,4000	***	4,1223	-3349,0000	*	-1,6588
Publications p.c. (l1)#Patents p.c.	13845,0000	*	1,9088	8801,0000		1,3721
Regional controls						
Net migration	57,7750	**	2,0387	-63,5050	**	-2,5021
Regional employment	0,0410	***	8,8120	-0,0174	***	-4,0854
Share hightech employment	0,0167		0,5217	-0,0787	***	-2,7546
Share agricultural employment	-13,5380	.	-1,7223	21,9420	***	3,1394
Patents p.c.	21,2490		0,5697	-18,9580		-0,5681
Spatial lags						
Graduates p.c. (l1)	190,3100		0,7766	-1156,6000	***	-3,4320
Investment p.c. (l1)	-13,5170		-0,9292	-14,3580		-0,9102
Tfp p.c. (l1)	35,6790		0,8864	-192,4700	***	-4,1498
Students p.c. (l1)	-14,0550		-0,2853	0,9178		0,0145
Staff p.c. (l1)	568,5000	***	4,0247	1167,6000	***	7,3911
Publications p.c. (l1)	-87,4800		-0,1975	3927,9000	***	6,4156
Net migration	118,3900		0,5895	-761,6500	**	-2,8325
Graduates p.c. (l1)#Patents p.c.	-37032,0000		-0,9443	74801,0000	*	1,6657
Investment p.c. (l1)#Patents p.c.	465,4500		0,1556	947,1200		0,3004
Tfp p.c. (l1)#Patents p.c.	3637,0000		1,0767	8930,3000	**	2,4178
Students p.c. (l1)#Patents p.c.	-7891,3000		-0,7717	-24402,0000	**	-2,1563
Staff p.c. (l1)#Patents p.c.	-22284,0000		-1,1016	-90548,0000	***	-4,1916
Publications p.c. (l1)#Patents p.c.	34919,0000		1,4817	101410,0000	***	2,7390
Regional employment	0,2676	***	5,0653	-0,2294	***	-3,1990
Share hightech employment	-0,1484		-1,1345	-0,2846		-1,5230
Share agricultural employment	-274,0300	***	-4,4100	171,3700	.	1,7248
Year dummies			YES		YES	
N	429			429		
T	19			19		
R2	0,9868			0,9564		
rho	0,2300			0,9200		

Table 3: Regressions for GDP and Unemployment with Third Party Funds from Industry as Moderator

Dependent Variable	GDP p.c.			Unemployment rate		
	Estimate		t-value	Estimate		t-value
University characteristics						
Graduates p.c. (l1)	115,8000	***	5,2192	-9,8559		-0,5004
Investment p.c. (l1)	0,4322		0,3810	-5,6498	***	-5,6559
TPF p.c. (l1)	0,3271		0,1081	-3,9698		-1,4772
Students p.c. (l1)	6,8491		1,2288	26,4000	***	5,3593
Staff p.c. (l1)	37,7010	.	1,7956	66,7900	***	3,5996
Publications p.c. (l1)	150,7200	***	2,6841	-2,7211		-0,0548
TPF industry p.c. (l1)	0,3154	***	3,2886	0,0266		0,3145
Graduates p.c. (l1)#TPF industry p.c. (l1)	-0,3883		-0,1127	0,3878		0,1280
Investment p.c. (l1)#TPF industry p.c. (l1)	-0,1150		-0,7036	0,2708	*	1,8885
TPF p.c. (l1)#TPF industry p.c. (l1)	-0,3510		-1,2570	0,1875		0,7642
Students p.c. (l1)#TPF industry p.c. (l1)	0,8944		1,1993	0,8317		1,2719
Staff p.c. (l1)#TPF industry p.c. (l1)	-3,0189		-1,1075	-4,9440	**	-2,0700
Publications p.c. (l1)#TPF industry p.c. (l1)	6,6088		0,5640	-5,1762		-0,5040
Regional controls						
Net migration	64,2520	**	2,2419	-63,7040	**	-2,4939
Regional employment	0,0368	***	7,8209	-0,0121	***	-2,8472
Share hightech employment	0,0210		0,6470	-0,0870	***	-3,0324
Share agricultural employment	-12,6160		-1,5952	18,4120	***	2,6352
Spatial lags						
Graduates p.c. (l1)	-1,1142		-0,0029	-1138,5000	**	-2,3939
Investment p.c. (l1)	-22,6960		-0,8786	41,8780		1,5522
Tfp p.c. (l1)	191,9100	***	4,3170	-201,0500	***	-3,8181
Students p.c. (l1)	-66,0660		-0,7350	-68,4240		-0,6776
Staff p.c. (l1)	222,8800		0,8708	1977,2000	***	7,4218
Publications p.c. (l1)	-785,0300		-1,4647	3131,5000	***	4,3526
TPF industry p.c. (l1)	2,4437		1,5021	0,0663		0,0421
Net migration	-196,2300		-0,8644	-1112,6000	***	-3,8899
Regional employment	0,2004	***	3,6488	-0,2350	***	-3,1685
Share hightech employment	-0,0684		-0,5220	-0,1400		-0,7564
Share agricultural employment	-197,3200	***	-3,0294	9,6621		0,0979
Graduates p.c. (l1)#TPF industry p.c. (l1)	-0,5610		-0,0025	486,0800	**	2,1093
Investment p.c. (l1)#TPF industry p.c. (l1)	0,5981		0,0338	-36,8430	**	-2,0344
Tfp p.c. (l1)#TPF industry p.c. (l1)	-87,3610	***	-3,7247	73,9510	***	3,2603
Students p.c. (l1)#TPF industry p.c. (l1)	9,4454		0,1447	-86,9160		-1,3015
Staff p.c. (l1)#TPF industry p.c. (l1)	132,7900		0,5916	-1155,3000	***	-5,2707
Publications p.c. (l1)#TPF industry p.c. (l1)	1092,8000	***	3,5683	950,1600	**	2,7163
Year dummies	YES			YES		
N	429			429		
T	19			19		
R2	0,9867			0,9563		
rho	0,21			0,9076		

We now turn to the hypotheses, where the corresponding marginal effects are included in Table 4-Table 7, where we base the average effects only on those variables for which the regression coefficients were significantly different from zero.

In H1 we stated the expectation that HEIs exert a positive effect on regional value creation through a variety of channels ranging from direct demand stimulation in terms of higher investment or consumption to more indirect channels including human capital supply and knowledge transfer. We find H1 strongly corroborated, indicating that the HEIs in Germany contribute to an increase of GDP per capita of 7.855€ (TE). In absolute terms this effect is considerable. By multiplying the GDP per capita effects with Germany's population we find the direct effect on absolute GDP € 676bn per year.

With regard to the effect on unemployment, in H2 we argued that the unemployment reducing effects are likely to be more pronounced in the long run. The results in Table 5 indeed confirm this picture. In the short run, we find that the impact of HEIs activities increases local unemployment by 5.86 percentage points on average. When we additionally consider the three year lag, however, HEIs activities reduce local unemployment by 3.4 percentage points. Thus, there is indeed a transitory negative effect, which is offset by a positive long-run effect.

Table 4: Average direct and indirect Effects on GDP (at sample mean)

	DE	IE	TE
Graduates p.c. (l1)	302,12		302,12
Investment p.c. (l1)	-0,07	-406,64	-406,64
TPF p.c. (l1)		4729,92	4729,92
Students p.c. (l1)	0,62		202,65
Staff p.c. (l1)	0,62	2729,62	2729,62
Publications p.c. (l1)	297,43		297,43
Total	600,71	7052,90	7855,09

Table 5: Average direct and indirect Effects on Unemployment Rate (at sample mean)

		Lag 1			Lag 1+Lag 3	
	DE	IE	TE	DE	IE	TE
Graduates p.c. (l1)/(l1/l3)		-0,04	-0,04	-0,11	-3,75	-3,87
Investment p.c. (l1)/(l1/l3)	-0,07		-0,07	-0,10	0,61	0,51
TPF p.c. (l1)/(l1/l3)		-4,81	-4,81		-4,71	-4,71
Students p.c. (l1)/(l1/l3)	0,62		0,62	0,52		0,52
Staff p.c. (l1)/(l1/l3)	-0,08	3,43	3,35	0,16	-0,30	-0,14
Publications p.c. (l1)/(l1/l3)		6,80	6,80	-0,12	4,35	4,23
Total	0,47	5,38	5,86	0,34	-3,80	-3,46

In H3a we highlighted that the size of the impacts on production and unemployment are likely to be stronger when the regional economic structure is characterized by higher technology intensity, because the local absorptive capacity concerning knowledge and outputs produced by HEIs is larger. Consequently, we analyzed whether the effects on unemployment and GDP per capita are moderated by regional patent intensity (patents per capita) and re-estimated our models from Table 1 allowing for interactions of the HEI variables with their local environments' patent intensity (in practice mostly borne by firms). We then re-estimated the average effects taking into account the significant interaction effects and evaluated them at the sample mean, sample min, and sample max for the patent intensity (see Appendix 2). What we indeed see in Table 6 is that in particular the effects on GDP per capita are positively moderated by the local environments' patent intensity. While the marginal effect at the mean is 917€, the effect at the minimum is somewhat lower with 803€. However, in particular highly patent-intensive regions profit strongly from the universities' activities. Here the increase in GDP per capita lies at 4.769€.

For the unemployment rate, in contrast there seems to be a slight upward trend increasing from 0.72 at the moderator minimum to 1.00 at the maximum. However, this effect seems relatively limited. Concerning H3a, we can thus conclude that regional technological capacity amplifies the positive HEI impacts on GDP. In contrast, H3a cannot be corroborated for the unemployment rate, where the effect is relatively small in total and runs into the wrong direction.

Table 6: Average Effects moderated by Patent Intensity (at moderator mean, min, and max)

	GDP p.c.			Unemployment rate		
	DE (mean)	**DE (min)**	**DE (max)**	**DE (mean)**	**DE (min)**	**DE (max)**
Graduates p.c. (l1)	395,70	510,61	-3470,60			
Investment p.c. (l1)				-0,09	-0,12	0,89
TPF p.c. (l1)						
Students p.c. (l1)	128,99	0,62	4448,25	0,63	0,63	0,63
Staff p.c. (l1)	59,45	0,29	2050,00	0,20	0,22	-0,52
Publications p.c. (l1)	333,83	291,97	1742,21			
Total	917,97	803,49	4769,86	0,73	0,72	1,00

Finally, concerning H3b we hypothesized that third party funds from industry would amplify the positive effects exerted by the HEI activities. No such effect can be found for the GDP in Table 7. In this case, only one of the interaction terms is significant. Therefore the estimates of the impacts are identical at the mean, minimum, and maximum. With respect to unemployment there seems to be indeed an overall effect running into the predicted direction. This indicates that HEIs contribute more to a reduction in unemployment in regions where the HEIs receive more third party funds from the industry, even though this effect is not overwhelmingly large.

In summary, we cannot corroborate H3b for HEIs' impact on regional GDP per capita, but do find the predicted effect for their impact on the local unemployment rate.

Table 7: Average Effects moderated by Industry Third Party Funds (at moderator mean, min, and max)

	GDP p.c.			Unemployment rate		
	DE (mean)	DE (min)	DE (max)	DE (mean)	DE (min)	DE (max)
Graduates p.c. (l1)	292,95	292,95	292,95			
Investment p.c. (l1)				-0,11	-0,11	0,03
TPF p.c. (l1)						
Students p.c. (l1)				0,50	0,50	0,50
Staff p.c. (l1)				0,27	0,29	-0,28
Publications p.c. (l1)	314,39	314,39	314,39			
TPF industry p.c. (l1)	290,46	290,46	290,46			
Total	897,80	897,80	897,80	0,66	0,67	0,25

Finally, in H4 we hypothesized that large parts of the positive effects predicted in H1 and H2 are due to regional spillovers. To identify these, we have subdivided the total effects in the direct effects as measured by the coefficients of the main variables and those of their spatial lags in Table 1. The results can be found in Table 4 for the GDP and Table 5 for the unemployment rate. As concerns direct and indirect effects for the GDP we find that only a relatively small fraction of the overall effect actually remains in the region. In particular, we find that on average only an increase of 600€ in GDP per capita can be attributed to local universities in a strict sense (i.e. those located in the same administrative region), while the largest share of increase (7.052€) is due to neighbouring effects, i.e. those caused by universities in adjoining regions.

In summary, this suggests that the presence of HEIs does not only benefit the host but also the neighbouring regions. A similar picture emerges for the unemployment rate, where we now focus on the overall effect as defined by the sum of the one and three year lags. While the total effect is, as already noted, around -3.46 percentage points, the unemployment reducing effect is even stronger for the neighbouring regions (-3.8 percentage points). This implies that the direct effect is positive 0.3 percentage points is still positive and significant. This has an important distributive component concerning the benefits. In particular, it is the neighbouring regions that benefit from the HEIs. The host regions have to cope with increased unemployment rates also over longer periods, even though the effect is relatively small.

5 Concluding discussion and limitations

This paper represents one of the first attempts to quantify the regional contribution of HEIs in macroeconomic terms while taking into account the multidimensionality of academic outputs, the moderating influence of the local environment, and the importance of regional spillovers. Our results indicated that the contributions HEIs make to regional economic activities are large and amounted to up to € 628bn p.a. in Germany in the period 2000-2009. We also showed that, in the mid-to long term, they reduce local unemployment by about 3.5 percentage points. Overall, these figures represent quite sizable positive effects on the regional economic environment and underline the great importance of the HEIs for the economic development.

While this seems in contradiction to earlier findings suggesting positive but, compared to other factors, small economic impacts, it is likely that this has to do with either the conceptual design e.g. when case studies do not fully grasp the complete interaction channels as Thanki (1999) highlights or due to differences in outcome measures. In this context, Goldstein and Renault (2004) find only very limited impacts on the average worker's income, while we analyse the impact on the overall value creation (including among other things also capital income). In fact, although not presented, we have run models with per capita available income and could not find any impacts, which could be reasonably explained by the fact that conceivable positive effects (e.g. higher share of high-paid workers) are offset by negative effects (e.g. higher share of low income groups such as students). A second reason is that we incorporated the spillovers, where we showed that concerning GDP, only about 10% were 'contained' locally while the remaining 90% spilled over to neighbouring regions. Goldstein and Renault (2004) do not analyse these effects. In that respect the large contributions of HEIs to economic activities (25% of Germany's GDP) that our study has identified do not seem unreasonable, because this figure is in technical terms to be understood as a comparison with a hypothetical situation in which a certain HEI-hosting region never had such institutions nor profited from HEI-spillovers from neighbouring regions.

In policy terms our results have a couple of key-messages. First, we make a forceful point for the continuous financial support for HEIs as drivers of economic growth and, in the long-run at least, employment. Second, spillovers also give important insights into the geographical distributions of the economic rents, where we show that all regions gain from HEIs, even those without own HEIs. Politically, this is important because it demonstrates that the regional benefits neighbouring regions experience are on average much higher than the disadvantages that might occur through the concentration of activities in the focal regions. Third and concerning the environmental contingencies, the results indicated that in particular HEIs in regions with higher patent intensity (as a proxy for regional technological strength) contribute positively to economic well-being in terms of higher GDP and lower unemployment. On the policy level this finding implies that a region's capability to draw benefits from the academic activities, at least in the short run, strongly depends on the existing technological capacities bound in the local firms. Therefore, technologically less advanced regions will not benefit as much as technologically stronger regions. Thus, the foundation or expansion of HEIs as regional development projects will be particularly effective in regions that have strong technological competences but it may be much less so in underdeveloped regions. This implies that the set-up of HEIs on the "green field" is at least in the short term unlikely to be very effective, even though it may well become so in the long run.

Despite these highly relevant insights our approach has some limitations, which ultimately calls for further research and reconfirmation.

Firstly, we largely abstract from the identification of direct channels transforming academic outputs to macroeconomic effects. While on the one hand this allows us to comprehensively estimate effects through the long-run evaluation of structural co-variation patterns at the regional level, on the other it weakens the clear causal interpretability of our results. Against this background, our results should be interpreted as indicative of long-run economic potentials rather than exactly identified causal effects that would result in experimental research designs. Research exploiting truly natural experiments – e.g. policy changes that effect only certain regions in a cross-section – could prove very helpful to establish this link.

Secondly, although by using a 10 period panel data set we are effectively able to control for unobserved regional heterogeneity, the panel is much too short to say much about how much time the identified economic effects take to materialise. More specifically, the co evolutionary relationship between HEIs and regional firms that shapes the size and direction of measurable economic effects is likely to extend over decades, possibly even longer periods. Compared to these dimensions our panel dataset represents a relatively short snap shot. Therefore, our results should not be used to calculate short-term rents that would accrue from e.g. a decision to found a HEI somewhere. Instead, our analysis gives a rough indication of the likely long-term rent potential without, however, specifying what "long-term" means. For many policy-decisions requiring (short-term) cost benefit analyses our analysis might therefore be of somewhat less than direct utility.

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7 Appendix

7.1 Appendix 1

Table 8: Basic Descriptive Statistics[6]

	Mean	S.D.	Min.	Max.
Graduates p.c.	0,0025	0,0056	0,0000	0,0438
Investment p.c.	0,0203	0,0573	-0,0262	0,8559
TPF p.c.	0,0415	0,1194	0,0000	1,3371
Students p.c.	0,0189	0,0422	0,0000	0,3189
Staff p.c.	0,0043	0,0117	0,0000	0,1235
Publications p.c.	0,0021	0,0033	0,0000	0,0363
TPF industry p.c.	0,0092	0,0283	0,0000	0,2653
Patents p.c.	0,0015	0,0029	0,0000	0,0504
Net migration	-0,0001	0,0013	-0,0081	0,0139
Regional employment	94,0180	120,1515	18,4000	1667,9000
Share hightech employment	0,0468	0,0153	0,0136	0,0909
Share agricultural employment	0,0328	0,0252	0,0014	0,1452

7.2 Appendix 2

The average direct impact for each variable in Table 4 is simply its coefficient multpilied by the mean. So for example for students per capita we obtain the following formula:

$$DE_{stud} = \beta_{stud} \overline{stud}$$

The indirect effect is based on the coefficient for its spatial lag multiplied by the mean of the spatial lag.

$$IE_{stud} = \beta_{spatstud} \overline{spatstud}$$

The total effect is just the sum of the direct and the indirect effect: $TE_{stud} = DE_{stud} + IE_{stud}$. These effects can be added for all variables to sum total effects of all HEI activities.

A little more generality is needed for the case of the unemployment model including the one and three year lag simultaneously (right side of Table 5) and the interaction models in Table 6 and Table 7. In the first case we have

6 Minimum zero values occur for regions without HEIs.

$$DE_{stud} = \left(\beta_{stud,-1} + \beta_{stud,-3}\right)\overline{stud}$$

The indirect effect is based on the coefficient for its spatial lag multiplied by the mean of the spatial lag.

$$IE_{stud} = \left(\beta_{spatstud,-1} + \beta_{spatstud,-3}\right)\overline{spatstud}$$

In the interaction model e.g. taking the regional patent intensity we only calculate the direct effect at the sample mean, min, and max, which are given by

$$DE_{stud} = \left(\beta_{stud} + \beta_{patstud}\,\overline{pat}\right)\overline{stud}$$

$$DE_{stud} = \left(\beta_{stud} + \beta_{patstud}\,\mathrm{min(pat)}\right)\overline{stud}$$

$$DE_{stud} = \left(\beta_{stud} + \beta_{patstud}\,\max(pat)\right)\overline{stud}$$

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