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THE IMPACT OF HIGHER EDUCATION INSTITUTION-FIRM KNOWLEDGE LINKS ON ESTABLISHMENT-LEVEL PRODUCTIVITY IN BRITISH REGIONS.

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The impact of higher education institution-firm knowledge links on establishment-level productivity in British regions

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Abstract

This paper estimates whether sourcing knowledge from and/or cooperating on innovation with higher education institutions impacts on establishment-level TFP and whether this impact differs across domestically-owned and foreign-owned establishments and across the regions of Great Britain. Using propensity score matching, the results show overall a positive and statistically significant impact although there are differences in the strength of this impact across production and non-production industries, across domestically-owned and foreign-owned firms, and across regions. These results highlight the importance of absorptive capacity in determining the extent to which establishments can benefit from linkages with higher education institutions.

JEL codes: D24, I23

Keywords: Universities; University-Industry knowledge links; Firm-level productivity

1. Introduction

According to the 2001 UK Government White Paper on enterprise, skills and innovation, universities are “the seedbed for new industries, products and services and are at the hub of business networks and industrial clusters of the knowledge economy” (DTI, 2001). In line with the Lambert Review (2003) of business-university collaboration, the 2003 White Paper (leading to the 2004 Education Act) was more specific, stating “…knowledge and skill transfer between business and higher education is of great importance in England’s regional economies. Universities have a role in fostering the establishment and growth of new companies; in working with existing companies both on the application of the latest technology and the successful application of more tried and tested technologies; and in working with business to develop the skills of the workforce at technical and professional levels. At their best, these links should be highly interactive, with each partner well aware of what the other can offer, and of what their needs are" (BERR, 2003, par. 3.1). To help achieve this outcome, universities in the UK have in recent years been able to access £651m of funding from the Higher Education Innovation Fund (which ran from 2001-9) to promote knowledge transfer and innovation.[1]

This implies that the UK government (like many other global governments[2]) regards the generation of knowledge spillovers between universities and firms as one of the main purposes of universities. Although some question whether universities should become too geared towards this type of activity (see, e.g. Bowie, 1994) on the grounds that the costs to society of compromising the university's role as an independent third party and free disseminator of information outweigh the benefits from close connection between universities and industry, others perceive there is a lack of such connections that must be remedied (Fortier, 1999). Rather than tackle the issue of the correct direction for university research, this paper questions the presupposition implicit in this debate that linkages between universities and firms are directly beneficial to industry.

Specifically, this paper estimates whether both sourcing knowledge from and/or cooperating on innovation with higher education institutions (henceforth HEIs)[3] impacts on establishment-level total factor productivity (TFP) using a dataset created by merging the UK government's Community Innovation Survey (CIS) with the Annual Respondents Database (ARD). It also considers whether this impact

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[1] Other government schemes have also been available to encourage university-business innovation – for example, the LINK scheme (which started in 1986); the University Challenge Seed Fund (early 1990s); and Knowledge Transfer Partnerships (originally established as Teaching Company Schemes in 1975), of which there were over 1,000 in place in 2008.

[2] For information at the OECD level, see their programme on higher education in city and regional development (www.oecd.org/edu/imhe/regionaldevelopment) which covers support and outcomes across a large number of countries.

[3] The actual questions used to define HEI collaboration are Q.16 and Q.18 (see http://www.bis.gov.uk/policies/science/science-innovation-analysis/cis/cis4_questionnaire for details).

differs across domestically-owned and foreign-owned establishments and across the regions of Britain. We also provide some evidence on whether higher graduate employment (as a measure of human capital) impacts positively on TFP at the establishment-level.

The next section provides a brief review of the literature; the third section discusses the dataset that will be used in the empirical analysis and gives some basic characteristics of the group of establishments that collaborate with HEIs; the fourth section sets out the econometric model to be estimated and describes the estimation strategy; the fifth section provides our statistical results; and the final section concludes.

2. Literature Review

Many studies have investigated the relationship between university-firm knowledge links and innovation. One of the earliest papers in this literature was by Mansfield (1991) who showed that, in a random sample of 76 large American firms in seven manufacturing industries, about 10%of the product and process innovations could not have been developed without recent academic research. The more recent literature in this area has tended to employ econometric methods in an attempt to estimate causal relationships between university-firm knowledge links and innovation. For example, Becker (2003), using German data, finds that the use of knowledge resources from universities and research institutions increases the probability of process innovations but has no impact on the probability of product innovations, while joint R&D with universities has a positive impact on the probability of both product and process innovations. Thorn *et al.* (2007), using a dataset of Chilean and Columbian firms, find that collaboration between firms and universities increases the probability of introducing a new product.

In contrast, there have been significantly fewer studies that analyse the impact of university-firm knowledge links on productivity rather than innovation. Belderbos *et al.* (2004), using the Dutch CIS, estimate the impact of various types of R&D cooperation on the growth of labour productivity, and the growth of sales per employee of products that are new to the market. Their results show that cooperation with universities had no statistically significant impact on the former measure but a positive and significant impact on the latter. One criticism of their model is that no effort is made to control for the consequences of self-selection into the group of firms that entered into cooperative agreements.

As part of a study seeking to understand the causes of the growth of innovative activity in the US in the 1990s, Branstetter and Ogura (2005) estimate the impact on TFP of the intensity with which firms cite academic scientific research in their patent applications. This can be regarded as a measure of firm-university knowledge linkages. Using fixed effects estimation, they find a positive and statistically significant impact of the science research citation measure on TFP. Medda *et al.* (2005), using a selection model, investigate the impact of collaborative research with different partners on the growth of TFP using a dataset of Italian manufacturing firms. They find no statistically significant effect of collaborative research undertaken with universities but a positive impact of collaborative research with research centres and other firms. The authors suggest this is the result of firms collaborating with universities on basic research, the effects of which will take longer to show than the dataset allows for.

Arvanitis *et al.* (2008) estimate the impact of university-firm knowledge and technology transfer on both innovation and labour productivity using Swiss data. Recognising the endogeneity of both knowledge and technology transfer, they use instrumental variables. Their first equation shows that knowledge and technology transfer between firms and universities has a positive impact on the probability of innovating; the second shows that knowledge and technology transfer activities has a positive direct impact on labour productivity. However, also included in the second equation is an innovation variable. As the coefficient on this variable is positive and statistically significant, there is also an indirect impact on labour productivity.

In sum, there is as yet no clear consensus as to the impact of university-firm knowledge links on productivity. This is unsurprising given the relatively few studies in this area. It should also be noted that it is difficult to draw a priori expectations for the empirical analysis below, because of the different econometric methodologies and measures of university-firm knowledge links employed in these studies.

3. Data

The dataset we use has been created by merging the results from the 2007 CIS (the fifth such survey conducted in the UK and covering the period 2004 to 2006) with the ARD for 2006. The former gives information on the innovative activities of some 14,872 UK establishments or reporting units; while the latter consists of returned financial data on a stratified sample of reporting units from the Annual Business Inquiry (ABI) which can be used to calculate Gross Value Added (GVA), factors inputs, and thus TFP. Reporting units are the smallest units of a firm which can provide the full range of information required for completion of the ABI survey (see Robjohns, 2006), and merging took place at this level, with all the relevant CIS establishments successfully linked to the ARD.[4] Table 1 lists the variables in the dataset that will be used in the empirical analysis below.

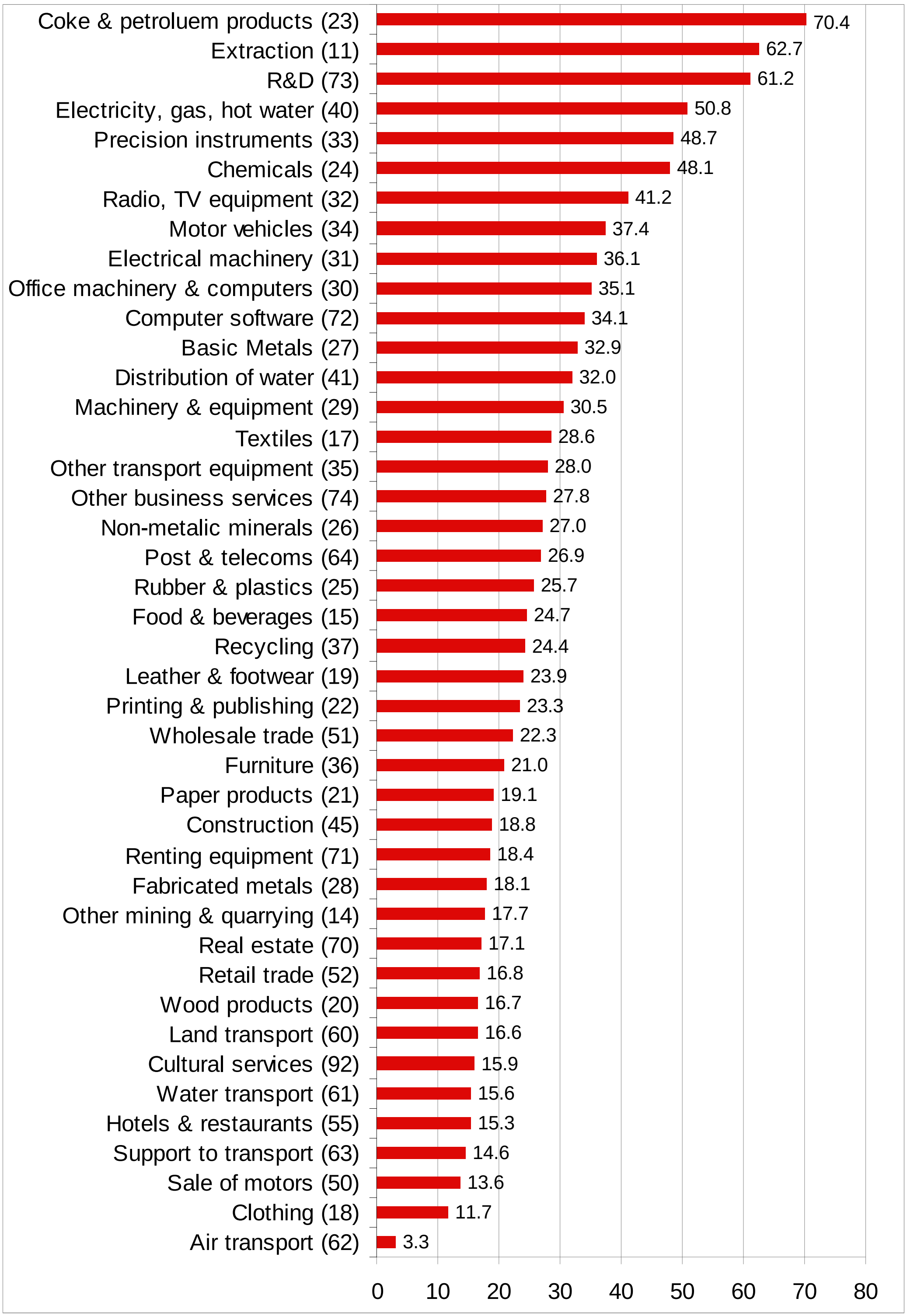
[4] Some industrial sectors are omitted from the ARD – such as agriculture and much of financial services.

Table 1. Variable Definitions

Variable	Definition	Source
Turnover	Establishment turnover in 2006	CIS5
Intermediate Inputs	Establishment intermediate inputs	ARD
Knowledge sourced from HEIs	Dummy coded 1 if HEIs were used as information source for the establishment's innovation activities; or establishment co-operated with HEIs at regional, national or international level	CIS5
Employment	Number of employees in the establishment	ARD
Capital	Plant & machinery capital stock for establishment in 2006 (source: Harris and Drinkwater, 2000, updated)	ARD
Foreign ownership	Dummy coded 1 if the establishment was owned by a foreign enterprise	ARD
Exporting	Whether the establishment sold goods and services outside the UK (coded 1) or not in 2006	CIS5
Age	Age of establishment in years	ARD
Size of graduates workforce	Proportion of employees educated to degree level or above in the establishment	CIS5
Herfindahl	Herfindahl index of industry concentration (5-digit level)	ARD
Diversification	% of 5-digit industries (from over 650) located in ONS defined travel-to-work area in which establishment is located	ARD
Single-plant enterprise	Whether the establishment was a single-plant enterprise	ARD
Knowledge sourcing strategies	Whether the establishment used the following strategies in sourcing R&D (coded 1): 1-Not used; 2 "Make only"; 3 "Buy only"; 4 "Co-operate only" 5 "Make & Buy" 6 "Make & Co-operate" 7 "Buy & Co-operate" 8 "Make & buy & co-operate"	CIS5
Industry	Whether the establishment was located in a particular industry SIC (2-digit)	CIS5
GO regions	Whether the establishment was located in a particular GB region	CIS5
Weight	Population weights based on the ratio between population employment and sample employment	CIS5

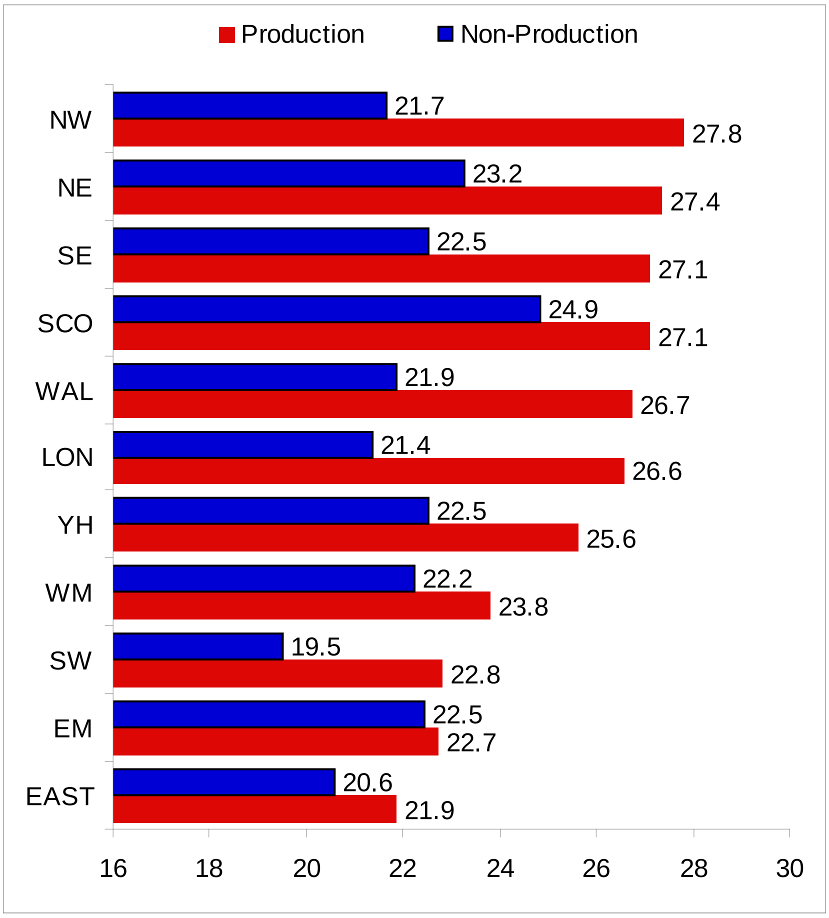
As an overview of the dataset available, Fig. 1 shows the percentage of establishments that collaborate with HEIs by industry. Overall, 22.8% of British establishments collaborated; however, there is considerable variation across industries. Over 60% of establishments in the coke and petroleum products, extraction and R&D industries collaborate with HEIs on innovation-related activities; with a second tier consisting of the electricity, gas and hot water, precision instruments and chemicals industries with around 50% of establishments linking with HEIs. At the opposite end of the spectrum is the air transport industry in which only 3.3% of establishments collaborate.

Fig. 1. Percentage of enterprises collaborating with HEIs in Great Britain between 2004 and 2006 by 2-digit SIC industry



Source: weighted CIS5

Fig. 2. Percentage of enterprises sourcing knowledge from HEIs in Great Britain between 2004 and 2006 by Government Office region and broad sector

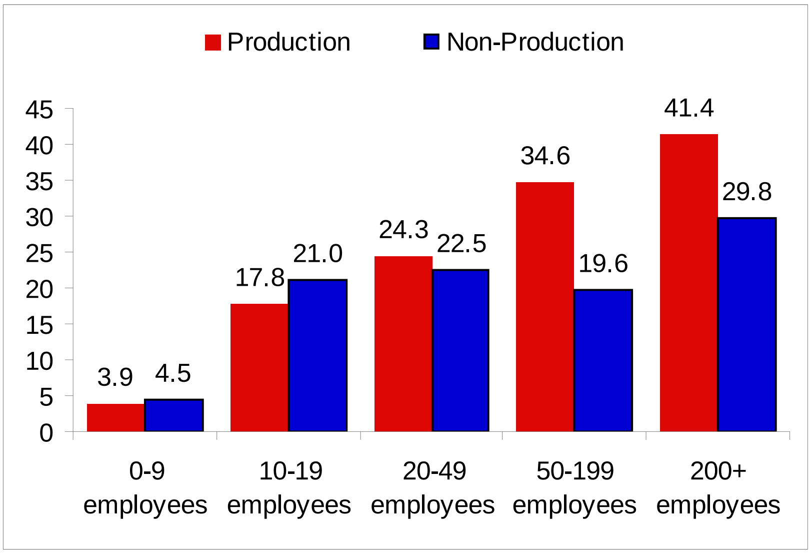


Notes: NW – North West; NE – North East; SE – South East; SCO – Scotland; WAL – Wales; LON – London; YH - Yorkshire and Humberside; WM – West Midlands; SW- South West; EM – East Midlands; EAST – Eastern England

Source: weighted CIS5

In all regions, the percentage of establishments that collaborate with HEIs is lower in service than production industries (see fig. 2). In the production sector, the North West and the North East had the largest proportion of establishments that collaborated with HEIs, which is somewhat surprising given the relatively poorer economic performance of these regions vis-á-vis the South East and London (see ONS, 2009). Indeed the South East had only the third largest percentage of establishments in the production sector that collaborated with HEIs, although the differences across the top five regions are very small (only 0.8%). The Eastern region and the East Midlands had the smallest levels of linkage in the production industries, some 6% below the North West. Turning to the service sector, Scotland had the highest percentage of establishments that collaborated with HEIs, at almost 25%. In comparison, the South West of England had the lowest level at less than 20%.

Fig. 3. Percentage of establishments sourcing knowledge from HEIs in Great Britain between 2004 and 2006 by size and broad sector



Source: weighted CIS5

Sourcing information from HEIs and/or cooperating on innovation activities depends on the size of the establishment (Fig. 3). In the production sector, there is a very clear trend towards greater collaboration by larger establishments; in non-production industries, the trend is not as clear with establishments employing between 50 and 199 employees collaborating less than establishments with between 10 and 49 employees. However overall in non-production industries it is apparent that the trend remains for larger establishments to have a greater propensity to collaborate with HEIs.

4. Econometric Model

The basic model estimated is the following production function:

$$y_i = \alpha + \beta_E e_i + \beta_K k_i + \beta_x x_i + \beta_{HEI} HEI_i + \beta_{HEI*FO} HEI * FO_i + \varepsilon_i , \qquad (1)$$

where y_i is the log of GVA for establishment i;[5] e_i is the log of employment; k_i is the log of the capital stock; x_i is a vector of control variables; HEI_i is a dummy variable that equals 1 if the establishment collaborates with HEIs and $HEI*FO_i$ is an interaction variable between HEI_i and the foreign ownership dummy, FO_i. The latter variable is included because, a priori, we assume that the impact of collaborating with HEIs may differ across domestically-owned and foreign-owned firms. The x_i variables consist of most of the other variables listed in Table 1, and together these provide an indication of the impact of TFP in each establishment (Harris, 2005).

To test for differences in the impact of collaborating with HEIs across the regions of Britain, a second equation is estimated in which the variables in (1) are interacted with 10 region dummies constructed using the Government Office Regions variable. The excluded benchmark region is the North East of England. A general-to-specific methodology is adopted so that regional interactions that are not significant are dropped if they are not statistically significant at the 10% level. To aid in interpretation, it should be noted that establishments may collaborate with HEIs in their own region, in other regions and internationally. The results cannot therefore be regarded as evidence on the relative performance of universities across the regions of Britain.

Because establishments that collaborate with HEIs are potentially a self-selected group of the population of establishments, they are likely to have different characteristics from establishments that do not collaborate with HEIs. This makes causal inference difficult as these differences in characteristics will likely lead to

[5] GVA is obtained by subtracting intermediate inputs from turnover (see Table 1).

differences in productivity performance that are unrelated to whether collaborating with HEIs have any impact on TFP (see, for example, Blundell and Costa Dias, 2009, for a more detailed exposition of self-selected bias).

Assuming that all relevant characteristics are observed, differences in characteristics across treated and untreated groups can be controlled for using a correctly specified regression. However, in practice, finding the correct specification is difficult. This is a serious problem as estimating an incorrectly specified equation will generate biased estimates of the treatment effect (see, for example, Blundell, *et al.*, 2005). This sensitivity to specification arises because the estimate of the dependent variable for treated firms, in the event that they did not receive treatment, is entirely dependent on the specification of the model for values of the covariates for which only firms that received treatment are observed.

One solution to this problem is to create a matched sample in which treated and untreated establishments are observed for all values of the covariates. This was done here using propensity score matching (see Dehejia and Wahba, 2002), which involved estimating probit models of treatment status including all variables that determine both productivity and whether an establishment collaborates with HEIs, and then matching on the estimated predicted values.[6] The advantage of propensity score matching over other forms of matching is that it overcomes the difficulties of matching on a large number of variables (Zhao, 2004).

It is important to note that matching only avoids bias due to differences in the observable covariates across treated and untreated groups. If there are differences in the distribution of unobservable covariates across treated and untreated groups, estimates obtained using this strategy are biased and an instrumental variables approach is preferable. Unfortunately, it has not been possible to find suitable

[6] The results from the (weighted) probit model estimated – that fed into the matching approach using PSMATCH2 in STATA – to create the matched sample for equation (1) are available in an unpublished the appendix. Different models were estimated for each specification and sector.

instruments using the dataset at hand. The validity of the estimates are therefore based on the conditional independence assumption (see, for example, Imbens and Wooldridge, 2009, for more details) which states that, having controlled for the observable covariates, any differences in the distribution of productivity is the result of having sourced knowledge from HEIs.

5. Results

Table 2 gives the results for production industries from estimating equation (1) (i.e., the baseline model – column 1) and a second model (cf. column 2) in which all variables are interacted with region dummies (with those with the highest p-values greater than 0.1 removed sequentially, and the final model tested against the initial model to ensure that the hypothesis is accepted that all the omitted variables are jointly-zero). Note, the estimated coefficients for other variables for the baseline model are provided in the appendix.

Looking at the baseline model first (column 1), for production industries the coefficient on the HEI variable is positive and statistically significant which implies that collaborating with HEIs increased TFP by around 16.3%,[7] while the coefficient on the interaction variable between collaborating with HEIs and foreign ownership is negative and statistically significant. This large difference in the impact of collaborating with HEIs suggests that foreign-owned firms operating in the UK production sector that collaborated with HEIs were on average technology-seeking enterprises and did not (as expected) exploit any ex-ante technological superiority (see Fosfuri and Motta, 1999; Love, 2003; Cantwell *et al.*, 2004; Driffield and Love, 2007). The positive and statistically significant coefficient on the variables measuring

[7] The dependent variable is logged, and therefore the coefficient on the treatment variable has to be transformed using the formula: $\exp(\hat{\beta}) - 1$.

the proportion of graduates in the establishment labour force provides evidence that, in accordance with expectations, employing more graduates leads to higher TFP.[8]

Table 2. Weighted OLS Estimates of Equation (1) using a Matched Sample of Establishments from Production Industries, GB 2006

Dependent variable: *ln* GVA	(1)	(2)
HEI Linked	0.151*** (0.055)	0.151*** (0.054)
HEI Linked × Scotland	–	-0.285* (0.150)
HEI Linked × Foreign Ownership	-0.208** (0.090)	-0.282*** (0.098)
HEI Linked × Foreign Ownership × Yorkshire/Humberside	–	0.470*** (0.177)
HEI Linked × Foreign Ownership × East Midlands	–	0.360** (0.176)
HEI Linked × Foreign Ownership × Scotland	–	0.402** (0.201)
Graduates	0.445*** (0.086)	0.286*** (0.095)
Graduates × North West	–	0.484* (0.269)
Graduates × South East	–	0.599** (0.294)
Graduates × London	–	0.618** (0.290)

Robust standard errors in parenthesis; */**/*** denotes significance at the 10%/5%/1% levels

Column 2 of Table 2 gives the results from the regional model. The coefficient on the HEI variable does not change, and the only regional interaction that is significant relates to Scotland. This suggests that indigenous enterprises in Scotland that source knowledge from HEIs actually have lower TFP (of around 12.5%); while foreign-owned subsidiaries benefit (their TFP was nearly 31% higher).[9] This result is in line with evidence on the Scottish innovation system provided by Roper *et al.* (2006, Fig. 4.3); they found that knowledge links between HEIs and indigenous

[8] The elasticity is given by $\hat{\beta} \times \overline{\mathrm{X}}$ (here 0.445 × 0.191), i.e. 0.085. This indicates that doubling the proportion of graduates (e.g. to around 48% for the average of production establishments in the matched sample) would increase TFP by 8.5%.

[9] I.e. exp(0.151-0.285+0.402) – 1.

Scottish firms were very weak, while links with foreign-owned subsidiaries were strong.

The coefficient on the interaction between the HEI and foreign ownership variable is more negative in the regional model than in the baseline model. This is the result of the large positive coefficients on the interaction between HEI linkage and foreign ownership for Yorkshire-Humberside, East Midlands and Scotland. This shows that the finding that foreign-owned establishments in the production sector do not benefit from collaborating with HEIs does not apply to all regions. There also appears to be some heterogeneity in the impact of employing graduates on TFP across regions. The coefficients for the North West, the South East and London composite variables are all positive and statistically significant indicating that employing more graduates in these regions leads to a much larger increase in TFP than in other regions (possibly indicating at least in part a headquarters effect, given that a large proportion of foreign-owned firms will have their UK headquarters in these regions).

Table 3 gives results from estimating the same models for the non-production sector. Column (1) covers the baseline model and shows that there is also a positive and statistically significant impact of linking with HEIs; the latter leads to an increase in TFP overall of some 11%. However, there is a major difference between production and non-production industries when foreign ownership is interacted with HEI collaboration; the coefficient on this composite variable is positive and statistically significant in the non-production sector (overall foreign-owned firms with an HEI link were some 36.5% more productive). This suggests foreign-owned firms are exploiting their prior technological advantages with the assistance of knowledge gained from HEIs. As for production industries, employing more graduates has a positive and significant impact on TFP (the elasticity associated with the parameter estimate obtained is 0.14, indicating that doubling the proportion of graduates would increase TFP by 14%).

Table 3. Weighted OLS Estimates of Equation (1) using a Matched Sample of Establishments from Non-Production Industries, GB 2006

Dependent variable: *ln* GVA	(1)	(2)
HEI Linked	0.104** (0.045)	0.263*** (0.053)
HEI Linked × West Midlands	–	-0.528*** (0.159)
HEI Linked × East	–	-0.302* (0.157)
HEI Linked × London	–	-0.299** (0.134)
HEI Linked × Scotland	–	-0.293** (0.130)
HEI Linked × Foreign Ownership	0.207** (0.095)	-0.066 (0.099)
HEI Linked × Foreign Ownership × West Midlands	–	0.611** (0.310)
HEI Linked × Foreign Ownership × East	–	0.628*** (0.222)
Graduates	0.443*** (0.063)	0.466*** (0.064)
Graduates × West Midlands	–	0.386** (0.188)

Robust standard errors in parenthesis; */**/*** denotes significance at the 10%/5%/1% levels

In terms of different regional impacts, non-production HEI linked enterprises in the West Midlands, Eastern England, London and Scotland did not benefit from such interactions (cf. column (2) of Table 3); the overall impact is close to zero (except for the West Midlands where TFP was 23.3% lower). For foreign-owned enterprises that collaborated with HEIs, when regional interactions are taken into account we find that overall there is no statistical difference in TFP for foreign-owned firms, except in the West Midlands and Eastern England (where TFP was between 32-69% higher).

Lastly, the impact of graduates in the workforce on TFP barely changes between columns (1) and (2); only the interaction involving the West Midlands is significant in the non-production sector.

6. Conclusion

This paper has sought to estimate the impact of collaborating with HEIs on TFP using a dataset created by merging the CIS with the ARD. Using a matched sample created by propensity score matching, the results show that collaborating with HEIs had, on average across all regions, a positive and statistically significant impact on TFP, although there are differences in the strength of this effect across production and non-production industries and domestically-owned and foreign-owned firms.

There are also large differences in the estimated impact across regions. In both production and non-production industries, domestically-owned establishments in Scotland do not benefit from collaboration with HEIs to the same extent as domestically-owned establishments in the rest of Britain. This is also true of establishments in Eastern England, the West Midlands and London in non-production industries. Foreign-owned establishments in the production sector in Yorkshire-Humberside, the East Midlands and Scotland receive a larger productivity boost from collaborating with HEIs than foreign-owned establishments in other regions of Britain. In non-production industries, foreign-owned establishments in the West Midlands and Eastern England received a larger TFP benefit than establishments in the rest of Britain.

As stated above, the results that relate to Scotland support the assessment of the Scottish innovation system provided by Roper *et al*. (2006). The latter point to the lack of absorptive capacity in domestically-owned Scottish establishments as the primary cause of the weak linkages between such establishments and HEIs, and this is also likely to be the major determinant in the variation in the size of the TFP benefit received from collaborating with HEIs across other regions. That is, unless these firms can internalise the benefits from accessing outside knowledge (from HEIs), then the impact of HEI-firm linkages will continue to be truncated. Clearly more (possibly case-study) research is needed that examines the link between absorptive capacity and university-business linkages, and the extent to which this can explain the results obtained in this paper.

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Appendix

Table A1. Weighted OLS Estimates of Different Versions of Equation (1): baseline model, GB 2006

Dependent variable: *ln* GVA	Production		Non-Production	
	Full Sample	Matched Sample	Full Sample	Matched Sample
Knowledge sourced from HEIs	0.186***	0.151***	0.102*	0.104**
	(0.070)	(0.055)	(0.052)	(0.045)
HEI * Foreign Ownership	-0.417***	-0.208**	0.140	0.207**
	(0.117)	(0.090)	(0.096)	(0.095)
ln Employment	0.953***	0.971***	0.822***	0.847***
	(0.031)	(0.024)	(0.017)	(0.019)
ln Capital	0.052**	0.075***	0.151***	0.162***
	(0.024)	(0.021)	(0.014)	(0.015)
Foreign Ownership	0.604***	0.398***	0.501***	0.352***
	(0.083)	(0.066)	(0.058)	(0.072)
Exporting	0.077	0.173***	0.180***	0.201***
	(0.063)	(0.055)	(0.043)	(0.045)
ln Age	-0.163***	-0.223***	-0.240***	-0.190***
	(0.047)	(0.048)	(0.026)	(0.030)
Size of Graduate Workforce	0.462***	0.445***	0.429***	0.443***
	(0.121)	(0.086)	(0.069)	(0.063)
ln Herfindahl	0.015	0.016	-0.079***	-0.062***
	(0.019)	(0.015)	(0.011)	(0.013)
ln Diversification	0.020	0.032	0.111***	0.131***
	(0.026)	(0.023)	(0.019)	(0.024)
Single	-0.337***	-0.328***	-0.281***	-0.421***
	(0.059)	(0.051)	(0.047)	(0.054)
R^2	0.584	0.719	0.561	0.633
No. of observations	4153	2699	9817	4280

A full set of knowledge sourcing strategy, industry and region dummies are included but not reported. Robust standard errors in parenthesis; */**/*** denotes significance at the 10%/5%/1% levels