Examining the roles of universities in place-based industrial strategy: which characteristics drive knowledge creation in priority technologies?

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Examining the Roles of Universities in Place-Based Industrial Strategy: Which Characteristics Drive Knowledge Creation in Priority Technologies?

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Abstract

Industrial Strategies designed to promote innovation in a set of priority technologies through university-industry collaboration essentially institutionalise a Triple Helix approach to economic development. Yet, treating universities as a generic resource leaves a question mark as to which institutions are most likely to be most useful. In addition, prior evidence of uneven regional distribution of research income in these technologies suggests that place-based interventions may merely lock in pre-existing inequalities. Therefore, by controlling for spatial and temporal variations among UK universities, this paper examines whether their ability to generate knowledge in these priority technologies is dependent upon their entrepreneurial or engaged nature, and strategic orientation. Using data from the UK Higher Education Business and Community Interaction Survey, the analysis finds that entrepreneurial activities such as higher levels of licensing income, start-ups and patents are associated with higher levels of research income in these priority technologies. Furthermore, higher levels of income from engagement with businesses through collaboration and contract research are also associated with higher research income in these priority technologies, while strategic orientation has no effect.

1. Introduction

The current approach to Industrial Strategy in the UK is based on three clear criteria: 1) the identification of a set of priority technologies as a focus for innovation, (healthcare, medicine, clean energy, battery technologies, driverless cars, space technology, and artificial intelligence), 2) the promotion of formal collaborations between firms and UK universities in order to utilise their knowledge and expertise to develop new products and processes based on these technologies, and 3) the need to 'rebalance' and 'level-up' the economy across all regions (BEIS, 2017). This approach to industrial strategy is clearly influenced by proponents of the fourth industrial revolution, who view enabling technologies such as those identified above as underpinning smart specialisation strategies which promote innovation through their utilisation (McCann and Ortega-Argilés, 2015; D. Bailey, Pitelis and Tomlinson, 2018). In addition, explicitly harnessing the knowledge and expertise of multiple actors including government, universities, and business institutionalises a Triple Helix approach to economic development (Ranga and Etzkowitz, 2013; Fini *et al.*, 2018; Reischauer, 2018; Steenkamp, 2019), while the concurrent aim of re-balancing the economy clearly highlights an opportunity for place-based policies to promote its objectives (Fothergill, Gore and Wells, 2019; Johnston and Wells, 2020).

As there has been little systematic examination of the roles of universities in place-based industrial strategies within the extant academic literature, the UK context provides an opportunity to explore this more deeply. Despite repeated references to universities within recent policy documents, little evidence is presented to outline how universities may successfully engage in this process. Indeed, universities are diverse organisations which vary in terms of their size, resources, specialisms, research capacity, and engagement capabilities (Martin and Turner, 2010; Laursen, Reichstein and Salter, 2011; Hewitt-Dundas, 2012; Huggins, Johnston and Stride, 2012). We argue that the institutionalised Triple Helix approach to industrial strategy draws implicitly on two ideal types of university, the 'entrepreneurial university,' focussed on commercialisation activities such as licensing income, patenting, and developing spinouts (Slaughter and Leslie, 1997; Philpott *et al.*, 2011; Perkmann *et al.*, 2013), and the 'engaged university' which focuses on the co-creation of knowledge through collaborative research, the provision of training activities, and the use of facilities and equipment (Breznitz and Feldman, 2012; Trippl, Sinozic and Lawton Smith, 2015; Sanchez-Barrioluengo and Benneworth, 2019). Yet, no consideration is given to which of these types or characteristics may be important.

In addition, the location of the universities may promote behaviours, resources, networks, culture, and competences that stimulate innovative and entrepreneurial behaviours (Huggins and Thompson, 2013, 2019); underlying factors that may also provide an explanation for the uneven spatial distribution of research funding in the priority technologies, suggesting that research, knowledge, and expertise in some technologies may be not be equally available to all regions (Johnston and Wells, 2020). Therefore, an institutionalised Triple Helix approach may instead lock in spatial inequalities rather than reduce them. Consequently, this paper addresses an important question: given the spatial inequalities in the distribution of cutting-edge research funding, do the characteristics of universities alone signal their ability to generate cutting-edge knowledge in the priority technologies?

Utilising data covering the ten-year period from 2006/07-2016/17 from the UK's Higher Education Business and Community Interaction (HE-BCI) Survey, this paper employs a panel model with temporal and spatial fixed effects that specifies that the ability to generate knowledge in the priority technologies is a function of the university's entrepreneurial and engagement activities and strategic orientation. By controlling for spatial and temporal influences, the paper presents a systematic analysis of the factors that influence a university's ability to generate cutting-edge knowledge. Controlling for these effects reveals that income from entrepreneurial activities such as licensing IP, patenting, and creating spinouts are all positively related to cutting edge-knowledge generation. Importantly, income from collaborative and contract research are also positively related to cutting-edge knowledge generation, suggesting that a combination of entrepreneurial and engaged characteristics are important. However, the strategic orientation of the university does not have a significant effect.

Given these findings, we argue that examining the generation of cutting-edge knowledge at the regional level may mask the importance of the universities' organisational characteristics. Therefore, place-based policymaking should seek to promote university-industry collaborations where the university partner is engaged in both entrepreneurial and engagement activities, regardless of their location, in order to ensure that university-industry collaboration matches businesses with the most appropriate university partner. Consequently, an institutionalised Triple Helix approach to place-based industrial strategy needs to ensure that global knowledge networks are utilised in the course of promoting local innovation.

The paper is structured as follows: Section 2 presents the conceptual and theoretical background through a discussion of the role of universities in the industrial strategy. Section 3 outlines the data used in the empirical analysis and the analytical techniques employed. Section 4 presents our findings, while Section 5 concludes and discusses their implications.

2. Conceptual and Theoretical Background

2.1 Industrial Strategy and the Fourth Industrial Revolution

Over the last 20 years there has been growing interest in the enabling features of industrial strategy at international (Barca, McCann and Rodríguez-Pose, 2012), national (Fagerberg, 2018), and regional levels (D. Bailey, Pitelis and Tomlinson, 2018). Modern approaches to industrial strategy are based around the idea that a fourth industrial revolution facilitated by technological advances is driving the re-organisation of economic activity, enabled by an institutional configuration that supports these changes (Block and Keller, 2011; Bailey, Cowling and Tomlinson, 2015; Andreoni and Chang, 2016; Schwab, 2017; Reischauer, 2018). Consequently, proponents of the fourth industrial revolution highlight the influence of 'enabling technologies' such as advances in information technology, materials engineering, and medicine that promote significant change across the whole economy (Ciffolilli and Muscio, 2018; Lepore and Spigarelli, 2020).

From a regional development perspective, the fourth industrial revolution is viewed as permitting the implementation of smart specialisation strategies through the utilisation of these new technologies in regionally embedded industries (McCann and Ortega-Argilés, 2015; D. Bailey, Pitelis and Tomlinson, 2018). The smart specialisation process involves the identification of key priorities for regions and then building on their strengths through promoting innovation in a broad sense, i.e. the introduction of new products, processes, and technologies (European Commission, 2012). Indeed, it is argued that smart-specialisation is most effective where a region can build on pre-existing knowledge with respect to particular technologies (Montresor and Quatraro, 2019) in conjunction with the flexibility to enable regular adaptations based on changing conditions in order to ensure regional economies are constantly responding to change (Foray *et al.*, 2012). Therefore, the intellectual link to place-based policy making is clear (Morgan, 2017).

Furthermore, smart specialisation promotes a systemic approach to innovation, implemented through combining knowledge and capabilities from a range of actors (Pugh, 2014, McCann, 2013). Therefore, this conceptualisation of the regional economic development process institutionalizes a triple helix approach (Reischauer, 2018; Steenkamp, 2019), underpinned by relationships and collaborations between the state, universities, and industry (Comunian, Taylor and Smith, 2013; Ranga and Etzkowitz, 2013; Faria, Mixon and Upadhyaya, 2019; Galan-Muros and Davey, 2019).

2.2 Universities and Place-Based Industrial Strategy: The UK Context

The cornerstone of the UK's Industrial Strategy is the identification priority technologies including driverless cars, batteries, clean energy, medicine, healthcare, space technologies, robots, and artificial intelligence. These technologies form the basis of future innovation efforts designed to increase expenditure on R&D as a percentage of GDP from 1.7% to 2.4% by 2027 (HM Government, 2017). Through promoting partnerships between universities and business, industry organisations, innovation organisations, the strategy gives credence to Reischauer's (2018) argument that the fourth industrial revolution promotes triple helix approaches to economic development, in particular singling out universities as an important resource for knowledge generation and promising to develop 'innovation clusters' around universities to bring together 'world-class research, business expertise, and entrepreneurial drive' (pg. 67).

Reference is made to universities in three of the six themes; 1) the development of knowledge in the key technologies; 2) the commercial exploitation of the science base; and 3) supporting 'local innovation ecosystems'. The implication is that high quality university research is widespread throughout the UK, suggesting an aim that is inclusive of all universities and regions, with 98 references made to 'universities' compared with only two references to 'leading universities'. Therefore, the strategy is clearly based on the assumption that all universities can contribute to the generation of knowledge and research in the priority technologies, while the emphasis on the local innovation ecosystem belies a place-based approach to policymaking.

Given the policy focus on university-industry collaboration, we argue that policymakers place a clear emphasis on both the 'entrepreneurial' and 'engaged' characteristics of universities, which stress their focus on industrial collaboration activities (Clark, 1998; Kirby, Guerrero and Urbano, 2011; Centobelli *et al.*, 2019; Sanchez-Barrioluengo and Benneworth, 2019). While an increasing orientation towards, and engagement in, industrial collaboration, or third mission activities, is a key characteristic of both entrepreneurial and engaged universities, they cannot be considered to be an isomorphic construct (Philpott *et al.*, 2011; Kitagawa, Sánchez Barrioluengo and Uyarra, 2016; Fuller, Beynon and Pickernell, 2019). Indeed, as Philpott et al (2011) highlight, a university's entrepreneurial/engaged characteristics are more of a continuum than a dichotomy.

First examining the entrepreneurial university, these institutions are seen as embedded in the economic and social fabric of society, taking an active role in economic development through reacting to the new demands made on them by the evolving economy, expanding and rethinking their strategies in order to set agendas accordingly (Clark, 1998; pg. 4-5). The entrepreneurial university is typically viewed as both an incubator and catalyst for development through acting as a conduit for the exploration and exploitation of knowledge (Etzkowitz, 2003; Metcalfe, 2010; Kirby, Guerrero and Urbano, 2011). Consequently, the entrepreneurial university has an economic focus which places greater emphasis on commercialisation activities, or so called 'hard' factors such as generating income from Intellectual Property (IP), patenting and the creation of spin-out firms, (Perkmann *et al.*, 2013).

Therefore, the implicit assumption is that the entrepreneurial characteristics of universities, focussing on commercialisation, may promote greater embeddedness within the industrial base enabling them to generate higher levels of knowledge in the priority technologies. This assertion is tested through Hypothesis 1:

> **Hypothesis 1:** commercialisation activities such as licencing, patenting, and the creation of spinout firms will have a positive influence on the generation of cutting-edge knowledge in UK universities.

The 'engaged university' shares these characteristics but has a subtly different focus, combining commercialisation activities with industry engagement, or so called 'soft factors', such as collaborative research with industrial partners and providing facilities and technical and training services to firms (Perkmann *et al.*, 2013; Sanchez-Barrioluengo and Benneworth, 2019). Consequently, the engaged university also has a social focus, contributing to regional development through a broad range of activities (Breznitz and Feldman, 2012; Trippl, Sinozic and Lawton Smith, 2015; Thomas and Pugh, 2020). These engagement activities embeds the university into the ecosystem allowing an understanding of the needs and requirements of other actors (Breznitz and Feldman, 2012; Sanchez-Barrioluengo and Benneworth, 2019) and act as an anchor institution (Goddard *et al.*, 2014). The idea that these broader engagement activities are the key to generating cutting-edge knowledge is examined in Hypothesis 2.

> **Hypothesis 2:** business engagement activities such as collaborative research and providing facilities, technical and training services will have a positive influence on the generation of cutting-edge knowledge in UK universities.

The strategic orientation of the university is often overlooked in terms of their knowledge generation activities (Giuri *et al.*, 2019). Indeed, the entrepreneurial and engaged nature of universities can vary according to the priorities placed upon them by the institutions themselves (Bercovitz and Feldman, 2006). Furthermore, as there is no consensus on how third mission activities should be carried out, (Knudsen, Frederiksen and Goduscheit, 2019), how the attitudes of academics and the incentives provided to them may affect outcomes (Guerrero, Urbano and Fayolle, 2016), or how technology transfer should be organised (Giuri *et al.*, 2019). Therefore, the strategic orientation of a university cannot be ignored when it comes to understanding their propensity for creating cutting edge knowledge. This is outlined in Hypothesis three:

> **Hypothesis 3:** The strategic orientation of university, incentivising and organising third mission activities has a positive effect on the generation of cutting-edge knowledge in UK universities.

3. Data and Analysis

3.1 Data and Variables

We utilise data from both the Higher Education Business Interaction Survey (HEBCI), an annual survey of universities income from various activities and the UKRI's Gateway to Research database, a searchable source of all publicly funded research projects in the UK. The HE-BCI survey is a comprehensive annual survey of industrial collaboration activities undertaken by UK universities.

Given the survey is undertaken annually, is completed by technology transfer officers, and universities are legally obliged to complete it, it provides a detailed and reliable insight into the industrial collaboration activities of UK universities. Indeed, due to its comprehensive nature, and publicly available nature (see https://re.ukri.org/knowledge-exchange/the-he-bci-survey/), the HEBCI Survey is widely used as a data source in academic studies of UK universities (Guerrero, Cunningham and Urbano, 2015; Zhang *et al.*, 2016; Fuller, Beynon and Pickernell, 2019; Sanchez-Barrioluengo and Benneworth, 2019). While previous analysis has been restricted to observing individual years, our analysis utilises data across the period 2006/07-2016/17 to provide a more thorough examination through examining fluctuations in income over the period.

The Gateway to Research website (https://gtr.ukri.org/), a searchable database of publicly funded research projects in the UK, was used to identify all research projects related to the priority technologies. A two-stage systematic search strategy was then used to identify relevant projects; the first stage examined both the title and abstract to determine the focus. Following this, we then searched the project abstracts to identify whether the focus was the production of new knowledge and technology, and those where the focus was on application. For example, using this technique we were able to distinguish between projects that sought to develop new satellite technology, components, or equipment for satellites and those which sought to use satellites to examine phenomena (e.g. remote sensing). Through this process, we identified 5,532 projects, which accounted for more that £2.4bn of research funding between 2006/07-2016/17. These projects were broken down as follows: robots 242; Artificial Intelligence 238; Driverless Cars 20; Space and Satellite Technology 606; Clean Energy 140; Healthcare 1515; Medicine 2173; and Battery Technology 598.

The HEBCI survey was also the primary source of data for explanatory variables designed to capture the types of business engagement activities in which each university engaged. Following Benneworth and Sanchez-Barrioleungo (2019) we examine commercialisation through activities as IP income, number of patents and number of spinouts created and engagement activities through total income from consultancy, contract research, collaborative research, CPD activities, the utilisation of equipment and resources within the university and regeneration activity, In addition, we enhance our model through capturing the strategic intent of each university towards industrial collaboration using data from Part A of the HEBCI survey. Therefore, several dummy variables were developed from answers to questions examining the primary focus of a university's external engagement strategy (businesses or otherwise), the existence of strong incentive for academics to engage with businesses, the existence of a majority owned subsidiary for commercial exploitation of knowledge, and whether the university possesses an incubator facility for new businesses.

Table 1 – Overview of Explanatory Variables

Variable	Description	Characteristic
Consultancy Income (CONS)	Income from projects designed to provide expert advice without creating new knowledge	Engagement Activity
Contract Research (CONT)	Income from projects designed to meet the specific needs of contracting partners	Engagement Activity
Collaborative Research (COL)	Income from projects which attract public funding and a contribution from a non-academic collaborator	Engagement Activity
CPD Income (CPD)	Income from the provision of training programmes to those already in work for the purposes of career development	Engagement Activity
Income from Facilities/Equipment	Income from utilisation of a university's physical resources by non-academic organisations	Engagement Activity

(FAC)		
Regeneration Income (REGEN)	Income for projects that are designed to be economically, physically and/or socially beneficial	Engagement Activity
IP Income (IP)	Income from Patents, Copyrights, trademarks, licences granted, and registrations owned by the university before disbursements to other parties and net of VAT.	Entrepreneurial Activity
Spinoffs	Number of start-up firms registered by the university between 2006/07-2016/17	Entrepreneurial Activity
Patent portfolio (PAT)	Number of patents currently registered to the university or licensed to a third party.	Entrepreneurial Activity
Business Focus (BUS)	Are businesses the primary focus of the university's external engagement? Yes/No	Strategic Orientation
Strong Incentives for Commercialisation (STRONG)	Does the university have in place strong incentives for academics in terms of pecuniary rewards for business engagement activities? Yes/No	Strategic Orientation
Existence of Subsidiary for Commercialisation (SUB)	Does the university have a majority or wholly owned subsidiary responsible for commercialisation of knowledge? Yes/No	Strategic Orientation
Presence of Incubator (INC)	Does the university have an incubator for new start-ups? Yes/No	Strategic Orientation

Focussing on those institutions that were granted university status, i.e. the power to award their own degrees, prior to the 2006/2007 academic year 149 universities were included in the dataset as they had complete data for all variables over the time period. In addition, where mergers had occurred (for example, the Institute of Education merged with University College London in 2014, the University of Wales Trinity St David was formed from mergers of University of Wales Lampeter, Trinity University College, and Swansea Metropolitan University in 2013, and the University of South Wales was formed from the merger of the University of Glamorgan and University of Wales, Newport in 2013) all data were combined for the period.

3.2 Empirical Model and Estimation Strategy

To examine the influence of a university's business engagement and collaboration activities on its ability to generate knowledge in the priority technologies of the industrial strategy, we estimate by employing a linear unobserved random effects panel model. To analyse the impact of all effects adjusted for temporal and spatial fixed effects, we estimate the following functional form:

$$y_{it} = \alpha_t + \theta_j + x_{it}\gamma + z_i\beta + c_i + u_{it} \quad (1)$$

Where, y_{it} is the logged value of research income awarded to university *i* in projects within the priority technologies of the Industrial Strategy during time *t*. Time period dummy intercepts, α_t and regional NUTS1 dummy intercepts, θ_j control for temporal and spatial fixed effects respectively. x_{it} captures a vector of unit and time variant explanatory variables where, *Col* represents the log of total income generated by university i at time t through collaborative research projects with external organisations, *Cons* the log of the total value of consultancy research by university i at time t, *Cont* the total income generated through contract research income generated by university i at time t, *IP* represents the log of income generated from intellectual property by university i at time t , *Pat* represents the total number of patents possessed by university i at the end of time period t, and *Spinoffs* represents total number of start-up businesses created by university *i* (excluding graduate start-ups) during time period *t, CPD* the logged total value of all CPD courses run by university i during time period t, *Fac* the log of the total value of income from renting of equipment and facilities by university i during time period t, and *Regen* represents logged total income from regeneration projects, i.e. those with a specific socio-economic remit, by university i at time t. z_i is a vector of unit variant but time invariant variables including *Inc,* represents the presence of an incubator in university i, *SUB* captures whether university i has a subsidiary organisation for the commercialisation of knowledge, *BUS* represents whether university i is primarily focussed on business for its external engagement and *STRONG* captures whether university i reports offering academics strong incentives for commercialisation in terms of pecuniary rewards for business engagement activities. Composite errors (v_{it}) at time t in university i take the form of $c_i + u_{it}$, the sum of the unobserved individual heterogeneity (c_i) and idiosyncratic disturbances (u_{it}).

The model was estimated using Generalised Least Squares Random Effects (GLS-RE), with estimation based on a matrix-weighted average of a fixed effect which is generated by performing GLS on variables that have been multiplied by an idempotent matrix, transforming them into differences from their means. Further, a between-estimator is generated by performing GLS on variables that have been transformed into ones reflecting the difference between panel means and the variable means. We employed clustered robust standard errors (Whites heteroskesaticity-consistent estimator) to adjust for heteroskedasticity and first order autocorrelation.

Due to the spatial and temporal unevenness of university funding in the priority technologies (Johnston and Wells, 2020), a Wald chi squared test is also employed to test whether both year and regional coefficients are jointly equal to 0 respectively, which indicates that the inclusion of year and spatial fixed effects are required. Further applying the Lagrange Multiplier test (Breusch and Pagan, 1980) suggests that there are significant differences across universities, regions, and years thus Pooled OLS estimations were not suitable. It is acknowledged that there are several other estimation approaches to our unobserved effects model, namely fixed effects (FE). Given that both estimators measure the difference between the ratio of the squared sum of residuals over time, summed over all panels, to the sum of the squared errors, any time-invariant explanatories are then removed from the equation. In addition, examining the correlation matrix showed no issues with collinearity among explanatory variables (see Appendix 1).

3.3 Descriptive Statistics

Table 2 presents the descriptive statistics to provide an overview of the performance of the universities over the period. Between 2006/07 and 2016/17 each was awarded, on average, £16.6m in funding for research projects focused on the priority technologies identified in the industrial strategy. The distribution of this funding was negatively skewed with 52 of the 149 universities receiving no funding for research in these areas.

Income from third mission activities is substantial; On average, each UK university generated over £394m between 2006/07-2016/17 from these activities. Business research related activities such as contract and collaborative research are particularly lucrative, with average revenue for each university of £75m and £152m respectively over the period. Income from consultancy averaged nearly £62m, while income from CPD, facilities and equipment provision, and regeneration activities averaged £34m, £12m, and £34.8m respectively. Finally, IP income over the period averaged £8m per university. In terms of commercialisation activities, the average UK university had around 8 start-ups registered at any one time between 2006/07-2016/17 and had 108 patents in its portfolio.

Table 2 - Descriptive Statistics

Variable	Min	Max	Mean	SD	Time	
Total grants in Priority Technologies (Ln)	-2.30	17.78	4.14	8.01	2006-2017	N: 1639 n: 149 T: 11
CONS (Ln)	-2.30	12.02	6.95	2.85	2006-2017	N: 1639 n: 149 T: 11
CONT (Ln)	-2.30	12.66	6.79	2.85	2006-2017	N: 1639 n: 149 T: 11
COL (Ln)	-2.30	11.85	5.94	4.19	2006-2017	N: 1639 n: 149 T: 11
CPD (Ln)	-2.30	10.74	6.34	3.19	2006-2017	N: 1639 n: 149 T: 11
FAC (Ln)	-2.30	10.01	4.38	3.69	2006-2017	N: 1639 n: 149 T: 11
REGEN (Ln)	-2.30	12.35	4.71	4.26	2006-2017	N: 1639 n: 149 T: 11
IP (Ln)	-2.30	11.07	2.47	3.84	2006-2017	N: 1639 n: 149 T: 11
Spinoffs	0.0	104	8.58	14.51	2006-2017	N: 1639 n: 149 T: 11
PAT	0.0	3357	108.55	295.46	2006-2017	N: 1639 n: 149 T: 11
INC (1/0)	0.0	1.0	0.718	0.450	2006-2017	N: 1639 n: 149 T: 11
BUS (1/0)	0.0	1.0	0.577	0.494	2006-2017	N: 1639 n: 149 T: 11
STRONG (1/0)	0.0	1.0	0.194	0.390	2006-2017	N: 1639 n: 149 T: 11
SUB (1/0)	0.0	1.0	0.436	0.496	2006-2017	N: 1639 n: 149 T: 11

In terms of strategy, Table 2 also shows that over two-thirds of UK universities reported the existence of an incubator, and over half report that their strategic priorities for external engagement is the business community. However, only one fifth of UK universities report using strong incentives to encourage academics to commercialise the knowledge they create and fewer than half of UK universities (42%) have created a subsidiary organisation to commercialise their research.

4. Empirical Results

Table 3 reports the estimates from the panel model with both temporal and spatial fixed effects included. Models 1-4 present different iterations of the model to examine robustness, with the full specification presented in Model 5. The results from the panel models highlight the significant and positive effects of commercialisation activities such as IP income, patents held, and start-ups registered on research income in the priority technologies. Therefore, Hypothesis 1 is accepted as there is evidence that the entrepreneurial characteristics of a university have a positive influence on the generation of cutting-edge knowledge. Indeed, all entrepreneurial activities, i.e. those focussed on commercialisation 'harder' factors are significant, providing justification for the focus on the entrepreneurial university.

In addition, the results highlight the significant and positive coefficients on contract research income and collaborative research income, suggesting that some characteristics of the engaged university are also important in the generation of cutting-edge knowledge. Therefore, Hypothesis 2 is partially accepted as not all engagement, or 'softer' activities are found to be significant.

Table 3 – GLS Random Effects Panel Model Estimates with Temporal and Spatial Fixed Effects

Dependent Variable: log of research income in priority sectors					
	GLS Random Effects with Robust Panel Corrected Standard Errors				
	Model 1	Model 2	Model 3	Model 4	Model 5
COL (Ln)	0.322*** (0.049)	0.305*** (0.047)	0.309*** (0.048)	0.312*** (0.049)	0.286*** (0.049)
CONS (Ln)	0.063 (0.063)	-0.001 (0.064)	-0.011 (0.069)	-0.008 (0.069)	-0.008 (0.067)
CONT (Ln)	0.194*** (0.055)	0.155*** (0.054)	0.147*** (0.055)	0.149*** (0.055)	0.143*** (0.053)
IP (Ln)		0.353*** (0.079)	0.359*** (0.080)	0.360*** (0.080)	0.335*** (0.081)
PAT		0.003** (0.001)	0.003** (0.001)	0.003** (0.001)	0.003** (0.001)
Spinoffs		0.072*** (0.016)	0.073*** (0.017)	0.073*** (0.017)	0.071*** (0.016)
CPD (Ln)			-0.012 (0.059)	-0.012 (0.059)	-0.017 (0.058)
FAC (Ln)			0.088 (0.054)	0.091* (0.053)	0.087 (0.053)
REGEN (Ln)				-0.013 (0.041)	-0.019 (0.041)
INC					0.485 (0.781)

SUB					-0.305 (0.741)
BUS					1.220 (0.750)
STRONG					1.033 (0.861)
Constant	1.910 (2.948)	0.152 (2.012)	-0.166 (1.981)	-0.156 (1.974)	-1.249 (1.853)
Observations	1,639	1,639	1,639	1,639	1,639
Number of Universities	149	149	149	149	149
Regional Fixed Effects	Included	Included	Included	Included	Included
Year Fixed Effects	Included	Included	Included	Included	Included
R-squared	0.331	0.500	0.507	0.507	0.500
Chi-square statistic (Wald chi x^2)	119.19***	393.91***	428.82***	431.29***	466.13***
Breusch -Pagan LM (P-value)	0.000***	0.000***	0.000***	0.000***	0.000***

Notes: Dependent variable: log of total research funding in priority technologies in University (i) and time (t). * significant at 10% level' **significant at 5% level; *** significant at 1% level; Cluster-robust standard errors adjusted for heteroskedasticity and AR(1) reported in parentheses (Whites heteroscedasticity-consistent estimator); Spatial (at NUTS1 regional level) and temporal (year) fixed effects included but not reported; Estimations via GLS Random-effects.

However, while the significant relationships outlined above are positive, the coefficients suggest the relationships are in fact inelastic. For example, changes in both contract research and collaborative research income as well as number of start-ups bring about a less than proportionate change in research income. For example, where income from contract research is 10% higher, this equates to an additional 1.4% of research income from projects focussed on the priority sectors. Based on an average level of income of £16.6m over the period 2006/07-2016/17, this would result in extra revenue of £232,000. Furthermore, similar inelasticities are observed with respect to collaborative research income; where revenues from this source are 10% higher, an additional 2.9% of research income from projects focussed on the priority sectors, or around £480,000, is received over the period. Finally, while IP income is on average a much smaller proportion of third mission income, its influence on cutting-edge knowledge creation is the largest. While still inelastic, the results show that where revenues from this activity are 10% higher, an additional 3.4% of research income from projects in the priority sectors is received, worth, on average, £564,000 over the period.

With respect to the effects of the variables designed to account for the strategic orientation of the university in relation to commercialisation activities are not significant. Therefore, these policies do not appear to influence the ability of a university to generate knowledge in the priority technologies. Consequently, Hypothesis 3 is rejected.

5. Discussion

The results presented here suggest that knowledge generation in the areas identified as a priority in the industrial strategy appears to rely on universities whose characteristics that are more akin to the model of the entrepreneurial university (Clark, 1998; Kirby, Guerrero and Urbano, 2011). As such, greater levels of income from 'harder' third mission activities such as IP income, patents held, and the development of spinout firms (Perkmann *et al.*, 2013) are all indicative of universities that produce cutting-edge knowledge.

However, the generation of cutting-edge knowledge is not driven by solely by entrepreneurial activities as 'softer' engagement activities such as collaborative research and contract research (Perkmann *et al.*, 2013) are also found to have a positive influence. Therefore, we argue that *both* the entrepreneurial and engaged university models are useful for understanding the potential contribution of universities to the generation of cutting-edge knowledge in the context of the UK's Industrial Strategy. This lends further credence to arguments that the third mission activities of a university must be viewed as a spectrum rather than a dichotomy (Fuller, Beynon and Pickernell, 2019); understanding universities as entrepreneurial, engaged, or otherwise does not provide an adequate understanding of the complexity of their activities. Therefore, with respect to industrial strategy formulation, a blended approach to university involvement is required, relying on those who fit both the entrepreneurial and engaged models (Sanchez-Barrioluengo and Benneworth, 2019).

Therefore, this evidence confirms that when it comes to generating cutting-edge knowledge, universities are not isomorphic (Uyarra, 2010; Kitagawa, Sánchez Barrioluengo and Uyarra, 2016) and should not be treated as such by policymakers in the formulation of industrial strategies. In addition, the analysis presented here shifts the focus of policy formulation from understanding regional specialisations (Johnston and Wells, 2020) to identifying universities with the entrepreneurial and engaged characteristics that signal they are generating the required knowledge.

The policy implications of this finding are highlighting that place-based industrial strategy should be more specific in its approach to identifying appropriate university partners, i.e. those that fit the entrepreneurial and engaged model. This also suggests that these policies should not necessarily promote a reliance on 'local' knowledge, which may merely lock in spatial inequalities. Indeed, as Bailey et al., (2018) acknowledge, place-based smart specialisation policies are also driven by the 'relational embeddedness' of firms within networks, suggesting that active membership of broader complementary knowledge networks facilitated by trusted relations are the key to promoting economic development (Clarysse *et al.*, 2014; Bruneel, Spithoven and Clarysse, 2017). Therefore, while effective smart-specialisation builds on pre-existing knowledge within a region (Montresor and Quatraro, 2019), this may be best achieved through promoting collaborative partnerships with entrepreneurial and engaged universities regardless of their location.

Consequently, we argue that place-based industrial strategies should consider promoting collaborations based on relational proximities (Bathelt and Gluckler, 2011; Balland, 2012; Ter Wal, 2014; Balland, Belso-Martínez and Morrison, 2016), i.e. those built around the technological and organisational similarities between the firm and university partners (Gittelman, 2007; Marrocu, Paci and Usai, 2013; Chen and Xie, 2018; Johnston, 2020). This still allows regions to capture value and pursue smart specialisation strategies that are tailored to regional strengths (Bailey et al 2018), but crucially allows them to exploit global knowledge networks in order to avoid lock in (Bathelt and Cohendet, 2014). As such, institutionalised Triple Helix approaches to industrial policy can be designed to focus on the industrial specialisms of regional firms augmented with knowledge from the appropriate university partner, wherever they are located. Consequently, place-based industrial strategies can be designed to import knowledge from outside the region and ensure it is embedded into the regional ecosystem to add value to the regional economy (Bailey, Cowling and Tomlinson, 2015; Bailey, Pitelis and Tomlinson, 2018).

Finally, the analysis presented here has shown that the strategic orientation of a university is not a significant factor in determining the generation of cutting-edge knowledge. Therefore, it may be that the institutional set-up of UK universities is somewhat homogenous in terms of offering similar incentives, having an explicit focus on business engagement, operating incubator facilities, and creating a subsidiary dedicated to technology transfer and licensing. The implication of this finding is that the observed differences in commercialisation and engagement activities may result from the actions of individual academics rather than their institution's leadership (Abreu and Grinevich, 2013). Therefore, industrial strategy formulation should also consider the micro and meso levels of knowledge creation and transfer as well as the macro-level, contextual, level (Manniche and Testa, 2018).

6. Conclusions

The results presented in this paper highlight the fact that differences in the entrepreneurial and engagement activities among UK universities drive their ability to produce the cutting-edge knowledge. The results show that entrepreneurial activities such as licensing income, patenting, and creating spinouts are all positively related to cutting edge-knowledge generation. However, the only engagement activities with a positive relationship were collaborative and contract research. Therefore, as both entrepreneurial and engagement activities appear to be important, those universities that appear to be generating the required knowledge for innovation in sectors highlighted as a priority by the industrial strategy are those that combine these.

While an institutionalised triple helix approach is well motivated, particularly given the £2.4bn of research funding in the priority areas awarded to UK universities, the pursuit of smart specialisation through a focus on these technologies should aim to pursue and embed knowledge from the most appropriate university sources. Importantly, we argue this may not necessarily be a local university, highlighting the need for policymakers to not only look at different spatial scales and develop place-based solutions (OECD, 2017) but also to enable the importation and embedding of non-local knowledge. Therefore, pursuing smart specialisation to promote sustained regional development through capturing value from the national knowledge infrastructure requires that firms target the most appropriate universities as collaborative partners (Johnston and Huggins, 2021).

While our analysis has yielded significant insights at the institution level, one drawback is that we have not captured any of the micro-level factors which may influence these findings. For example, Abreu and Grinevich (2013) highlight the influence of individual characteristics such as age, position, and gender of the academic in their propensity to engage in entrepreneurial activities. These may be particularly important given the lack of significance of strategic orientation. Furthermore, while we have identified those universities which may be sources of relevant knowledge, we cannot infer anything around the capability and willingness of academics within those institutions to work effectively with the industrial partners (Perkmann, Neely and Walsh, 2011), nor the extent to which this means that industrial partners will judge the universities as credible partners (Johnston and Huggins, 2018). In addition, we call for further examination of potential path dependency of university knowledge generation, entrepreneurial, and engagement activities in order to examine how these may all evolve over time. Finally, we acknowledge that we have assumed that larger levels of income equate with higher levels of knowledge creation, but this does not necessarily capture its quality or impact. As such, we highlight the need for further work to examine these factors and how they may facilitate the implementation of institutionalised triple helix approaches to place-based industrial strategy.

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Appendix 1: Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
Research Income in priority sector (ln) (1)	-												
COL (ln) (2)	0.598***	-											
CONS (ln) (3)	0.402***	0.604***	-										
CONT (ln) (4)	0.529***	0.726***	0.708***	-									
IP (ln) (5)	0.615***	0.613***	0.474***	0.562***	-								
PAT (6)	0.429***	0.319***	0.235***	0.331***	0.468***	-							
Spinoffs (7)	0.580***	0.477***	0.394***	0.484***	0.567***	0.636***	-						
CPD (ln) (8)	0.272***	0.495***	0.570***	0.550***	0.357***	0.125***	0.215***	-					
FAC (ln) (9)	0.332***	0.300***	0.324***	0.323***	0.339***	0.207***	0.256***	0.282***	-				
INC (10)	0.268***	0.458***	0.411***	0.447***	0.343***	0.126***	0.253***	0.141***	0.236***	-			
SUB (11)	0.104***	0.225***	0.184***	0.233***	0.115***	0.156***	0.121***	0.152***	0.155***	0.220***	-		
BUS (12)	0.299***	0.434***	0.280***	0.334***	0.332***	0.206***	0.321***	0.204***	0.133***	0.369***	0.122***	-	
STRONG (13)	0.148**	0.167**	0.095***	0.118***	0.219***	0.121***	0.145***	0.110***	0.116***	0.119***	0.182***	0.180***	-

Notes: * significant at 10% level' **significant at 5% level; *** significant at 1% level