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Globalisation, localisation and glocalisation of university-business research cooperation: general patterns and trends in the UK university system

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Abstract

Contemporary university-business research interactions are inevitably affected by processes of localisation and globalisation. Where science itself as well as the business sector demand for advanced scientific knowledge is becoming less dependent on geographical distance, public funding authorities increasingly expect universities to engage and cooperate with firms located in the region. How do these opposing pressures affect general trends in national higher education systems? And which patterns and trends can one discern within individual research-intensive universities?

Addressing the second question, this exploratory study presents a new systematic way of looking at 'university-business interactions' in the UK university system. Examining the 48 largest universities, our analysis unfolds the geographical patterns and annual trends during the years 2008-2017. We focus our attention on their research cooperation interactions, but also incorporate data on cross sectoral mobility of researchers.

We collected our empirical data from the author affiliate addresses listed on their university-business co-publications (UBCs). The geographical distance between pairs of university-business addresses defines a series of expanding ‘distance zones’ according to where the business sector research partner is located. The zones range from an ultra-short distance (0-49 km from the university’s city) to ultra-long distances (located more than 4 999 km away).

Our econometric modeling of the UBC patterns shows that each distance zone is characterised by a slightly different set of explanatory factors. Some factors are important irrespective of the zone, notably the local region’s business sector R&D intensity and the university’s research size.

The annual growth trends in UBC quantities reveal a consistent overall trend towards higher levels of globalisation where partner firms are at least 500 km from the university. Five universities are significantly globalising. However, many universities also show an increase of UBCs with local firms, often within a 100 km range.

Engaging in both processes simultaneously, 23 universities seem to be ‘glocalising’ their research cooperation with the business sector. Further statistical analysis reveals that glocalisation and globalisation are driven by a different sets of factors.

Introduction

Localisation and globalisation

In the current era, where knowledge and human resources became more geographically distributed and universities more interconnected, many research-intensive universities are increasingly engaged in R&D partnerships with business enterprises abroad. Academia is no longer only about creating stocks and flows of scholarly knowledge – the transfer of technical expertise or advanced skills for economic utilisation and commercialisation has become a vital 'third mission'. In contrast, many universities are now also subjected to government pressures and political desire to contribute more to local and domestic economic development (e.g., Clark, 1998; Mejlgaard and Ryan, 2017). According to several high-profile policy documents that were released over the last 10 years, including the European Commission's Lamy report (Lamy et al., 2017), neither science-based university education nor research-based knowledge are flowing sufficiently rapid or effectively from research-intensive universities to R&D-active innovative firms.

It is unclear and under-researched how these processes of 'localisation' and/or 'globalisation' of knowledge creation and utilisation have impacted university research portfolios and priorities, particularly on their university-business R&D interactions. Since universities operate in a dynamic system of (conflicting) push and pull factors, those impacts will be university-specific – in part a result of their own organisational capabilities and constraints, partly because of external infrastructures and opportunities. How are the localisation and globalisation 'pull factors' affecting the way research-intensive universities are engaging with R&D-active firms? Can we measure and monitor changes in terms or geographic proximities? And if so which factors are major contributors to the evolving preferences for either local and/or global research partners in the business sector?

To address some of these understudied questions, we focus our attention on productive and successful research cooperation between academic researchers and business sector R&D partners. By examining general patterns and trends within research cooperation linkages, we unearth the role of spatial distance on these cross-sectoral collaborations, and its associated knowledge-based interactions and transfer processes. Our quantitative empirical analysis pays special attention to the 'human factor' of these productive interactions as captured by cross-sectoral labour mobility and/or multiple affiliations of individual academic researchers.

The next section describes the analytical framework we applied to conduct an case study of *university-business interactions* (UBI)[1] at universities in the United Kingdom.

[1] We will mostly apply the term 'business' to denote private sector business enterprises; occasionally synonyms will be used, such as 'firms', 'private sector' or 'industry'.

This quantitative, empirical study is specifically aimed at describing macrolevel patterns and trends in UBI localisation and globalisation.

Analytical framework

Distances between research partners: what is 'local'?

Many case studies have examined the role of (close) proximities and associated 'knowledge spillover' effects (e.g. Arundel & Geuna, 2004; Ponds et al., 2010; D'Este et al., 2013). While the increase in importance of geographic proximity and the 'globalisation of science' has been amply established in the research literature[2], the various case studies on the spatial proximity between universities and firms engaged in collaborative linkages – each using different methods and measures – show a wide range of distances between R&D partners.

As for the body of literature on smaller scale case studies, a wide range of average distances are found between universities and partner firms, depending on the geographical scope and industrial sector(s) involved. The study by Autant-Bernard et al. (2012) mentions an average distance of 1 175 km; D'Este & Iammarino (2010) reports an average distance of 354 km; Giuliani and Arza, who examined firms in the wine sectors of Chile and Italy, report distances of 169 km and 146 km respectively. Hewitt-Dundas & Roper (2011) found that about 50% of firms were collaborating with universities within 100 miles (161 km) range of their geographical location. Mansfield & Lee (1996) use a 100 miles range as a distance criterion to distinguish 'local' from 'non local' firms in the USA. Studies by Acs et al. (2002) show that positive innovation effects occur as far as 50 miles (80 km) distance from a metropolitan area's administrative boundaries.

Human resources and labour mobility

The human factor is increasingly seen as of pivotal importance as a source of creativity, ideation and scientific research. The human resource perspective is an essential dimension to understand UBI patterns. While early empirical studies focused their attention on research collaboration and commercialisation activities (e.g. Rothaermel et al., 2007), subsequent studies tend to emphasise micro-level 'individual' aspects and cover a wider range of interaction activities, rather than meso-level 'institutional' characteristics (D'Este & Fontana, 2007; Gulbrandsen et al., 2011; D'Este & Perkmann, 2011; Perkmann et al., 2013). Earlier research also

[2] In an era of internationalisation and globalisation, research-led universities are among the most globalised institutions in many civic societies. The numbers of academic researchers engaging with colleagues abroad is growing, as is the spatial distance between collaborators. Results from a macro-level study, comprising all science worldwide, shows that the average distance between co-publishing research partners has increased fivefold since 1980 to some 1 300 km in 2009 (Waltman et al., 2011).

indicates that prior employment or work experience in industry positively affects the propensity of academics to engage in university–industry collaborations and research commercialisation activities (Dietz and Bozeman, 2005; Clarysse et al., 2011; Abreu and Grinevich 2013; Bozeman et al., 2013). Additionally, UBI activities are likely to be more common among academics who define their research profile as 'applied' (Gulbrandsen and Smeby, 2005).

These boundary-spanning 'crossover' individuals, that straddle the public and private domain, are, most likely, familiar with the research practices in academic science, industrial R&D and business interests. They may often act as both linchpins who transfer tacit knowledge between organisations and sectors; they likely facilitate, drive or boost the exchange of knowledge between academic research and business sector R&D (Mangematin et al., 2014). Some may have a history of inter-sectoral job mobility, with prior employment in the business sector or on-going part-time employment by businesses (e.g. a board member or adviser of university spin-off firm). As such, these individuals can make the difference between success and failure in university-industry engagement and may help shape R&D commercialisation processes later on. In this 'pre-competitive' stages of the R&D process, results are still published in open scientific and technical literature. Researchers, engineers and scientists also publish research findings that are (possibly) industrially relevant and may ultimately become economically useful.

Unfolding UBI patterns requires a closer look at the 'human factor'. More specifically, the role of labour mobility of academic researchers who move between academia and industry, and how they may represent flows of knowledge, skills and know-how between these two institutional sectors. This heterogeneous group of individuals includes PhD graduates who have moved to jobs in industry but still publish (temporarily) with both their old and new affiliate address (Roach & Sauermann, 2010). Other academic researchers might have (had) part-time employment in the business sector throughout, or discontinued those full-time connections (either temporarily or permanently) to move into university positions; or, vice versa, (re)established their affiliate links with industry.

Some may hold simultaneous appointments in academia and a business; such (part time) external appointments of university staff are likely to be rare, but these individuals may signify relatively strong and institutionalised ties between academia and the R&D-active business sector (Yegros-Yegros and Tijssen, 2014).[3]

Academic researchers that cross over from the business sector are likely change agents within a university's UBI profile. The industrial orientation mindset of these 'boundary spanning' university researchers may contribute to their developing more

[3] We assume that such outside appointments are permitted under university rules and regulations (subject to the approval of direct line manager, head of department or the chair of the faculty board).

application-oriented research at universities, thus facilitating future interactions with industry.[4] As well contributing to scientific research and collaborations with industrial R&D partners, Fairweather and Paulson (1996) argue that the industrial experience of these 'crossover academics' can also enhance university teaching curricula.

While earlier research on university-industry mobility of academic researchers was framed within 'science and technology human capital' development (Bozeman et al. 2001), more recent studies focus on university-industry relations (Bozeman et al. 2013) or the role of mobility in research performance and prior jobs of academics in the private sector (Fernandez-Zubieta et al., 2015; Gulbrandsen and Thune, 2017). The inflow from industry into the university may vary from non-academic staff bringing 'practitioner' corporate-developed skills and experience into the university (for research and/or education) to prior academics (PhD student and postdocs) who have spent time in corporate R&D units. Some academics may switch between two sectors (once, or more regularly); others may have several part-time positions simultaneously – either temporary or permanent. At the level of professor, one would expect to find a concentration of multiple affiliations – where academics are part-time advisers or business consultants, or senior corporate R&D staff hold part-time professorships.

Close physical distance can be an important and beneficial factor: tacit knowledge is more easily exchanged if researchers share the same geographical location. The studies by Franzoni and colleagues (Franzoni et al., 2012; 2014) produce evidence that mobile and migrant researchers have 'mover's advantage' over non-mobile scientists, in terms of higher propensities to establish international links and collaborate with co-authors across several countries. Studies have shown that the labour mobility of knowledge workers (researchers, inventors) correlates positively with higher productivity levels (e.g. Zucker et al., 2002; Hoisl, 2007; Crespi et al., 2007; Lenzi, 2009), where prolific scientists and inventors tend to be more mobile than their colleagues and peers. Cross-sectoral mobility and/or holding multiple affiliations simultaneously in the industry and academia are likely to forge closer links between universities and business sector, which in turn creates knowledge and skills of industrial relevance and support UBI and related knowledge flows. However, mobility patterns of academics across both sectoral and national borders is yet to be mapped through large systematic studies.

Research questions

Acknowledging the fact that UBIs represent complex systems dynamics, and that any empirical study that attempts to unearth those factors that drive and shape UBI

[4] It remains an open question, however, of whether the presence of this increasingly industry focused orientation will have potential unforeseen negative consequences, such as an increased tendency to conduct research with the main intension of profitability as opposed to societal needs.

patterns and trends, faces inherent analytical limitations, this study presents a methodology and a statistical model to identify factors that have contributed significantly to observed patterns and trends. Our data analysis is driven by the following series of research questions:

- which contributing factors may explain observed UBI patterns, either with close-distance local firms or those with long-distance foreign firms?

- what is the relationship between a university's UBI profile and the business sector R&D environment their home municipality, metropolitan area or wider locality?

- how important is the 'human resources factor' within that relationship, more specifically the role of cross-sectoral mobility of 'boundary-spanning' academic research workforce?

- how are overall UBI patterns evolving within universities in terms of geographical proximity to partner firms? Is there indeed a general trend towards (further) globalisation, or are other structural developments taking place such as 'localisation' or 'glocalisation'?

Research methodology

University-business interaction data

Building on the findings of abovementioned studies we distinguish two aspects of UBI that are both captured in large bibliographic databases and measurable with empirical information: (a) university-business research cooperation; (b) mobility of university researchers. Our corresponding UBI information items are:

- *University-business co-publications* (UBCs), reflecting productive and successful research partnerships, where the organisational affiliations of participating researchers were extracted from the author address(es);

- *University-business mobile researchers* (UBM-Rs), individuals who have (or had) one or more university affiliation as well as and one or more affiliations in the business sector in recent years, with a special subset of individuals who hold simultaneous appointments in academia and a business enterprise: *university-business/multiple affiliated researchers* (UB/MA-Rs).

Where collaborative links between researchers reflect strength of relationships between organisations or countries, the labour market mobility of 'crossover

researchers'[5] serves as a marker of interconnected labour markets and overlapping organisational spaces of university and industrial R&D staff.

UBCs present a wealth of empirical information on collaboration patterns and trends between universities and businesses worldwide. Ponds et al. (2010) examine the relative importance of social proximity, as proxied by being partners in producing such co-authored research publications. These co-publications implicitly represent two intertwined dimensions of knowledge transfer mechanisms that occur with research cooperation arrangements. The 'knowledge stock' dimension represents capabilities, both in terms of inputs of the partners, the ability to cooperate (successfully), as well as joint results that are published as co-authored research publications. The 'knowledge flows' dimension represents interactions and processes before and during the research effort, which becomes partially manifest in the content and structure of the publication and the list of authors. These knowledge creation processes imply some degree of (in)formal research partnership, but also reflect associated knowledge exchanges and spill-overs of research-based components between universities and the business sector. As such, these co-publications can be seen as both an indicator of collaborative activity as well as impacts of academic 'brain power' on knowledge-intensive economies and economic sectors.

As a source of statistical data, UBCs offer a range of possibilities for studies of UBI patterns and trends within a university sector or individual research-intensive universities. UBC volumes and patterns are often affected by spatial proximity between firms and universities. One may assume that the ability to produce large quantities of UBCs reflects their attractiveness of specific universities as sources of research-based knowledge for science-intensive industries. Since business partners will engage in joint research with academics if they are sufficiently convinced of their research capabilities – in terms of quality, potential utilisation value, and (cost) effectiveness – UBCs therefore also partially reflect the degree in which universities are able to comply with quality standards and specifications imposed by industrial R&D.

UBC globalisation is driven and shaped by the interplay between macro-level trade-offs between close proximity partnerships and long-distance connections, and micro-level processes of mutual attraction and integration between academic science and corporate R&D (e.g. Bjerregard, 2010). The propensity to collaborate successfully with foreign corporate partners, and the chances of success, still heavily depends on the right R&D framework conditions, notably research capabilities, and pivotal positions in global R&D networks (e.g. Gertler and Levitte, 2005).

[5] The concept 'crossover researcher' was coined by Tijssen & Yegros (2016) and subsequently applied in the 'Pasteur Cube' model and corresponding taxonomy of individual researchers (Tijssen, 2018) as the subclass of 'crossover collaborator' researchers.

The scale and scope of those profiles, and the quality of that research (either 'discovery oriented' or 'applied') makes difference. Being a large research-intensive university, with a notable reputation among firms, clearly with raises the likelihood to produce large numbers of UBCs. Universities with an industry-aligned research specialisation profile have a much higher chance of successfully engaging with the business sector.

On the business sector side, UBCs in general tend to arise from cooperation with large, R&D-intensive firms in industrial or manufacturing sectors, or local science-based spin-off or start-up companies in a local science park. UBCs are also more likely to occur when universities cooperate with larger firms (and less so with small and medium-sized firms); the data therefore are biased in favour of successful science-based cooperation with large R&D-intensive firms. Some UBCs represent 'one-off' small-scale interactions, while others relate to large-scale R&D efforts in longstanding international consortia; some of those joint publications are co-authored with one or more colleagues in the business sector, others may carry multiple affiliate addresses of the author.

Information sources and measurement

Within this study, we investigate UBI trends at the university level and use individual researchers and their publications as the units of analysis. We focus on university-oriented research-based knowledge creation. Our current analytical framework is based on a 'successful science' logic and an associated 'research output' perspective. The performance indicators, unearthing collaboration and mobility patterns within UK academia, derive their information from research publications in scientific, scholarly and technical journals.

Using the affiliate address information made available in research publications opens up possibilities for designing metrics and associated indicators that enable large-scale, quantitative 'bibliometric' analysis of UBC patterns and trends (Lundberg et al., 2006; Tijssen et al., 2009; 2011). We extracted those publications from our in-house version of Thomson Reuters' Web of Science Core Collection (WoS) database (specifically, the SCI, SSCI and ACHI indexes within this collection). University researchers need to publish for career purposes and to share research outputs with colleagues and peers worldwide. As a consequence, many of their successful joint research projects, often including those involving active cooperation with corporate R&D staff, eventually lead to publications in journals, conference proceedings or other (printed or online) outlets.

Our in-house version of the WoS contains a number of enhancements compared to the original database. Among the most important improvements are: 1) consistent and accurate assignment of publications to universities, considering all the different

name variants in the database corresponding to the same university; 2) an in-house algorithm for the identification of citations that publications receive from subsequent publications; 3) an in-house publication-level classification which, based on citation relations, clusters together publications dealing with similar topics.

The major advantage of publication-based information is the ability to produce tangible and objective data that allows for large-scale, multi-level analyses and comparisons at the level of university sectors or individual universities, but also for micro-level tracking and tracing of individual researchers. But given the inherent limitations of this information source, UBC and UBM-R data are constrained in terms of accuracy and completeness, and are therefore treated as a (partial) proxy of university-business interactions and cooperation patterns.

Starting from the publication years 2008/2009, the WoS includes the direct link between the author and his/her corresponding affiliation(s). Based on this information, and our own classification of affiliations in universities or industry, we are able to identify the mobility of academic researchers across these two institutional sectors. We use an in-house author-identification algorithm (Caron and Van Eck, 2014) that identifies the set of publications produced by the same individual researcher, regardless of the different name variants used in the author's publications. The business sector is defined as those author affiliate addresses that refer to for-profit business enterprises, with the exception of those in the medical and health sector (Tijssen, 2011).

We track down UB/MA-Rs from the author address affiliations in UBCs. For each author participating in a UBC, we identify the organisation(s) to which they are or have been affiliated to in the pre-specified period of time (Yegros-Yegros & Tijssen, 2014). Some UBM-Rs may also feature in UBCs (as UB/MA-Rs or otherwise), but may also publish under their separate, consecutive affiliations – either the university or their (prior) business enterprise address. The number of UB/MA-Rs and UBM-Rs at the university is therefore related to UBC counts.

UBC counts provide statistical data for comparisons between universities. However, UBC frequency data are often size-dependent: large research universities tend to have many UBCs. When correcting for the size of the university, i.e. the total research publication output, the share of UBCs within that total output enables meaningful comparisons across universities.

A single UBC may include more than one university and more than one industrial partner. In these cases, we have assigned a complete publication to each of the involved organisations. In the UBC counting scheme, the frequency counts refer to the quantity of pairwise interactions that each university has had with businesses as represented through university-business co-authored publications. For sake of

simplicity, we refer to those counts as ‘UBC publications’. Multiple counting will occur when there are multitude of business sector affiliations are mentioned in the author addresses on the same UCB publication. As a result, a UBC can be assigned to several distance-categories simultaneously if the author addresses mentions two or more firms based at different geographical locations. Calculating the geographic distance between a university and each of the co-authoring business enterprises, is done by means of geo-coding and subsequent classification of companies according to their physical location.

Case study of the United Kingdom

Background studies

UBC output in the UK’s R&D system is a relatively well-researched topic, especially in terms of business sector innovation (e.g. Laursen and Salter, 2004) or knowledge transfer from universities (e.g. Abramovsky et al., 2007; Rosli & Rossi, 2016; Vick and Robertson, 2018). Results of these studies suggest that the engagement of universities in collaborative projects with the business sector, while remaining integrated in the academic scientific communities, constitute effective ways of knowledge transfer while creating network career structures at public/private R&D interfaces. Geographical proximity and co-location of universities and firms are a contributing factor.

A large UK survey, comprising of more than 20,000 respondents, looked at participation in different types of academic entrepreneurship (Abreu and Grinevich, 2013). Their set of exploratory variables in the analysis included previous work experience and prior employment in small firms or large firms. The result showed that prior industrial work experience, particularly from small/newly established firms, is positively related to engagement in commercialisation activities.[6] Focusing on boundary-spanning academic researchers, studies carried out in the UK have emphasised the crucial role that these ‘linked scientists’ (Lam, 2011) play in

[6] As for cross-sectoral international appointments, the factors influencing decisions to move abroad (i.e. to the UK) are likely very different from domestic career moves. Academic researchers moving (part-time or full-time) to foreign institutions or companies are more likely to be early career researchers seeking post-doc positions or permanent (tenured) employment. They are likely to encounter bureaucratic and other procedural and legal barriers at the national or institutional level, where rules and regulations may present serious obstacles to grant dual appointments to academics (in academia and the business sector) and may restrict the number and also the kinds of such appointments. Even though the global percentage of international academics is usually small in the academic labour force, this group is important: they are often the gate keepers and linking pins in international research networks or consortia. As such they may also act as drivers of ‘international consciousness’ at universities. Some of these international faculty are ‘global superstars’, others are early career academics who have obtained their doctorates abroad, or have perhaps done a postdoc overseas.

connecting academic knowledge and know-how to a firm's internal R&D. Staff mobility within this university-industry interface contributes to creating an 'overlapping internal labour market' (Lam, 2007) and a supporting 'hybrid organisational space' (Lam, 2011) that are likely to have positive impact on research commercialisation and academic entrepreneurship. Recent UK surveys[7] by Hughes and colleagues (Hughes et al., 2010; Hughes, 2011), and studies by Guerrero et al. (2015) indicate that socioeconomic impacts from UK universities are indeed significant.[8]

A recent study of UK universities, building on a database of 415 REF-based written impact case studies university-industry collaboration projects, identified the influence of partners' proximity on different types of impact (Peacock, 2019). Close-distance proximity was found to promote improvement in the partners' knowledge resources, whereas greater 'organisational proximity' (i.e. similarity between the activities and objectives of partners) tends to improve their economic resources.

The intent and ability to create such impacts is increasingly seen as a key performance measure of individuals, teams and organisations – for example, consider the emphasis within the UK's *Research Excellence Framework* (REF) and the proposed *Knowledge Exchange Framework* (KEF) on increasing efficiency and effectiveness in the use of public funding for knowledge exchange activities at UK universities.[9] Research England plans to run a pilot KEF with a representative cross-section of HEIs between February and April 2019. The on-going consultation round on the forthcoming KEF mentions that universities will be measured on their performance in seven 'perspectives': research partnerships; working with business; working with the public and third sector; skills, enterprise and entrepreneurship; local growth and regeneration; intellectual property and commercialisation; and public and community engagement (ResearchResearch, 2019).

Relatively little is known about the effect of geographical proximity and distances with regards to UBI patterns of UK universities and firms. Our guiding study was conducted by Laursen and colleagues (Laursen et al., 2011) who explore the effect of geographical proximity from the perspective of 8 724 firms located in the UK. Their

[7] A web-based survey of UK academics carried out between autumn 2008 and summer 2009 (22 000 individual academic responses drawn from all UK universities and in all disciplines; some 18% of a total population of over 125 000 academics surveyed).

[8] Recent studies of university-industry relationships within the UK indicate that university income from firms has grown in 2016 (up to £4.2 billion), while university spin-offs and start-ups also show strong growth (Matthews, 2016a). However, information derived from a UK-wide survey[8] suggests that the share of academic researchers engaged in commercial consultancy has significantly declined from 15% to 7% (Matthews, 2016b).

[9] KEF is managed by Research England, a new council within UK Research and Innovation (re.ukri.org), that oversees UK Research and Innovation's England-only functions which include grant funding to English universities for research and knowledge exchange activities.

findings indicate that firms' decisions to collaborate with local universities are influenced by both distance and the scientific quality of those universities. Co-location with top-tier universities promotes UBC; but if faced with the choice UK firms, especially the R&D-intensive ones, appear to give preference to the quality over distance. D'Este et al. (2013) examined the role of geographical proximity in the formation of university-business partnerships. Their results suggest that those UK-based firms that are located in spatially dense clusters of R&D-intensive industries tend to establish connections with universities largely independently of the university's location. However, firms outside such clusters are more inclined to engage with local universities. Although the UK university research system is an integral part of international and global R&D networks (Adams & Gurney, 2016), virtually nothing is known about research cooperation patterns with firms located abroad.

Contrasting the abovementioned UK related studies, our case study adopts the university perspective. It concerns the UBC patterns and trends at the largest research-intensive universities in the United Kingdom, and builds on our prior exploratory analysis of those universities (Tijssen et al., 2017).[10]

Data analysis

We apply our methodology and data analysis to universities selected from the 2017 edition of the Leiden Ranking (www.leidenranking.com). These 48 universities collectively account for the large majority of UBCs in the UK science base. All these universities are research-intensive, many are among the largest employers in their home towns, and several belong to the most high-profile universities worldwide in terms their international reputation and research performance. Some are also regarded as global powerhouses of university-business research cooperation and associated 'R&D excellence' (Tijssen et al., 2016; Tijssen and Winnink, 2018). See Table A1 for a list of the selected research universities.

As for the analysis of their UBI patterns and trends, our geographical entry-point is that of the NUTS1 area. This geographical entity is part of the NUTS classification system. The NUTS classification (*Nomenclature des Unites Territoriales Statistiques*) is a hierarchical system for dividing up EU territory into layers of geographical areas.[11] The NUTS system is designed for three purposes: the collection,

[10] Our choice of UBCs as the prime proxy measure of UBI aligns with one of the proposed metrics in the KEF framework, namely the proportion of research co-authorship with non-academic partners as a proportion of a university's total publication output.

[11] The OECD and the European Commission have jointly developed an alternative methodology to demarcate urbanised territories in a consistent way across countries: functional urban areas (FUAs). Each FUA consists of a densely inhabited city and of a surrounding area (commuting zone) whose labour market is highly integrated with the city. The OECD-EU approach creates a harmonised definition of cities, and their areas of influence, for international comparisons on topics related to

development and harmonisation of European statistics; socio-economic analyses of those areas; and EU policy making. The NUTS 2016 classification lists 104 areas at NUTS 1 level, 281 areas at NUTS 2 and 1,348 areas at NUTS 3 level.

The UK comprises 12 NUTS1 areas: North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East of England, Greater London, South East, South West, Wales, Scotland, and Northern Ireland. The size of the NUTS1 areas varies from 1,572 km² (Greater London) to 23,829 km² (Scotland), with corresponding circular diameters of some 40 km² to 150 km². Because of available of comparative statistical data, and a level of aggregation that captures the wider 'geographical area' surrounding a university, we opted for NUTS1 level rather than the NUTS2 and NUTS3 sublevels.

The three levels with the NUTS system are insufficiently fine-grained for measuring the geographical proximities between universities and firms. Our distance-based measurement system, based on physical distance between cities mentioned in author addresses in research publications, offers a greater degree of precision and more flexibility to design and fine-tune classification systems. A distance-based metric enables a tailored system that can operate independently of geographical borders and offering an exhaustive range of geographic zones – from a ultra-short distance 'local zone', marked by co-locations of universities and firm, to an ultra-long distance 'global zone' where partners could be located on different continents.

The farthest distance between any two cities on earth is about 20,000 kilometers. Applying a distance metric to pairs of author addresses in UBCs – where one address refers to the affiliated university and the other address to a firm – spans a statistical distribution of observed distances and the number of occurrences of each distance. For analytical purposes, this UBC 'distance density' distribution was reduced to a small set of mutually-exclusive zones, each demarcated by a lower and upper distance. **Table 1** presents the set of kilometer-based zones we applied in the UK case study. The distance cut-off points of each zone are partially informed by earlier empirical studies (mentioned above in subsection 2.2.1). [12] The criteria for the distinction between 'local' and 'global' were slightly arbitrary, where various zones were defined to accommodate the UK's NUTS1 regions, as well the country's geographic size and distances to overseas neighbouring countries.

urban development, but this classification system is inappropriate for statistical analysis on UBI across larger distances.

[12] Our five categories differ from the three categories used by Laursen et al. (2011) who define 'local' to include universities less than 100 miles from the firm. Their second and third categories are, 100-1000 miles, and more than 1000 miles.

Table 1. Distance-based categorisation of geographical zones

Distance zone	General description (UK specification)
0-49 km	local – very short distance (town, city, metropolitan area)
50-99 km	local – short distance (broader urban agglomeration or rural area)
100-199 km	local – moderate distance (regional area or neighboring countries)
200-499 km	local – long distance (broader regional area or neighboring countries)
500-4999 km	global – very long distance (domestic area, neighboring countries, Europe)
> 4999 km	global – ultra long distance (cross continental, worldwide)

Information sources

Additional to the Web of Science, our statistical data were extracted from three sources:

HE-BCI database – the *Higher education – business and community interaction*' survey (HE-BCI), administered by the UK *Higher Education Statistics Agency* (HESA), which collects comparative administrative information on UK universities with regards to items such as researcher head counts, expenditure, or commercially relevant outputs such as inventions, patents, license income, spin-off companies). The HE-BCI database provides data on income streams from the business sector, but lacks a geographical breakdown by funding recipient. Rossi and Rosli (2015) note that the performance indicators in HE-BCI do not adequately cover UBI-related knowledge transfer processes and researcher mobility.

ETER database – the *European Tertiary Education Register* (ETER) is an online source of comparative information on European higher education institutions, (www.eter-project.com). ETER provides descriptive information on their general characteristics and location as well as statistical data on the number of students, graduates, international doctorates, staff, fields of education, income and expenditure. The ETER coverage includes the EU-28 countries. The most recent data are provided for the academic year 2015/2016.

Office of National Statistics database – the *Office for National Statistics* is the executive office of the UK Statistics Authority. ONS is charged with the collection and publication of statistics related to the economy, population and society of the UK. Research and development (R&D) expenditure are also collected – either carried out or funded by business enterprises, higher education, government (including research councils) and private non-profit organisations. Our study uses statistical data on the R&D expenditure by the business sector in the UK by NUTS1 area.

Main empirical findings

General patterns in UBC profiles

Addressing the issue of UBC glocalisation, we conducted a comparative macro-level study of universities in the United Kingdom. Our descriptive empirical study focuses on identifying general patterns at the level of large research-intensive universities. We describe the most recent glocalisation patterns and trends as regards to their co-publication output with business enterprises. We identify several major contributing factors that may affect a university's trajectory to 'remain local' and/or 'go global'.

Across the 10-years period (2008-2017), each of the 48 universities produced an average of 1 664 fully-counted UBCs, 181 publications that list an UBM-R, and 81 publications with at least one UB/MA-R. We found that UBC publications represent an average 7.6% of all publication output per university, 2.0% of publications featured UBM-Rs, and 0.4% contained dual affiliation authors. The 23 members of the Russell Group produce slightly more UBCs (8.7% of their total publication output) and have more UBM-Rs (2.2% share), but the same share of UB/MA-Rs. These averages hide large differences between individual universities, each one characterised by its own unique organisation profile (mission and goals, available resources, research specialisation profile, motives and opportunities for cross-sectoral or long-distance research collaboration, and its history of the successful R&D partnerships with industry) as well as external determinants and contributing factors (geographical, cultural, political, economic or infrastructural).

Table A.1 in the statistical appendix presents the shares for each of the selected universities. *Imperial College London's* 13% share of UBCs in the total publication output is significantly higher than the 1.6% of the *London School of Economics and Political Science* (*LSE*). Where *Imperial College* is a broad and comprehensive university, like most other large universities, *LSE* specialises in social and behavioral sciences.[13]

Although the research specialisation is certainly an explanatory factor of UBC patterns and trends, a university's scale of research capabilities and activities is also an enabling factor – as well as its strategic priorities and UBC dedicated resources. Large research-intensive universities tend to be major partners and contributors to industrial and economic development in their cities and local areas; both in terms of

[13] UBI is much more likely to occur in an 'industry relevant' field of science. Our field classification system distinguishes the following five 'broad fields' of science: Biomedical and health sciences; Life and earth sciences; Mathematics and computer science; Physical sciences and engineering; Social sciences and humanities. The largest average shares of UBCs, across all 48 universities in 2008-2017, are found in the Biomedical and health sciences (9.6%) and Physical sciences and engineering (8.2%), while the Social sciences and humanities scores a mere 1.7%. UBM-Rs occur most in Life and earth sciences (0.95%), Biomedical and health sciences (0.94%), Physical sciences and engineering (0.91%), where Social sciences and humanities lags behind with 0.25%.

spending, producing high-quality graduates for local labor markets, as well as dedicated R&D relationships with local industry and science-based contributions to business-led innovations. Some of those UK universities are considered 'anchor institutions' in the sense of "major employers in their city and significant purchasers of local goods and services … magnified by multiplier effects" (Goddard et al., 2014, p. 309).

The extent to which some universities are much more engaged in R&D cooperation with the local business sector also reflects their city's or area's industrial and economic 'absorptive capacity'. Taking a closer look at explanatory factors of local UBCs, **table 2** compares the UBC 2016-2017 for UK's NUTS1 areas relative to local R&D expenditure levels.[14] Each NUTS1 area is represented by at least two of the 48 large research universities. Where the average UBC shares across the 12 areas range from 5% to 9%, the R&D expenditure data vary by a factor 10.[15] However, local R&D expenditure levels are clearly not the main contributing factor of a university's 'UBC intensity', i.e. the share of UBCs in total research publication output.[16] As for UBC localisation patterns, the relative low share of '% local' (varying between 5% and 12%) implies that large majority of the R&D business partners are elsewhere in the UK or abroad. Not surprisingly, UBC localisation rates are highest in the UK's R&D-intensive areas: Greater London and the South East. This spatial concentration is not only an outcome of pre-existing, place-based structural inequalities between UK universities, but also regional clustering and urban agglomeration effects in recent decades where universities in the city-region of London, Oxford and Cambridge benefit from the knowledge-demand of their immediate geographical surroundings. Overall, these UBC findings predominantly reflect globalisation processes, where the growth of university-business cooperation involves long-distance partners: in 11 out of the 12 areas about 50% of joint research at the universities involves cooperation with firms located abroad.

[14] We opted for NUTS1 territorial areas (rather than the lower-level NUTS2 or NUTS3 areas) to capture a larger range of 'local UCB' distance zones within the UK.
[15] The total R&D expenditures include funding of universities and other higher education organisations.
[16] Although part of the business sector funding is likely to flow to local universities by way of outsourcing research or consultancy contracts.

Table 2. UBC and R&D profiles of NUTS1 areas in the United Kingdom*,**

NUTS1 area (number of selected universities per area)	UBCs (frequency counts, 2016-2017)			R&D expenditures (£ million, 2016)	
	Intensity (%)	% global	% local	business sector	all sectors
South East (7)	7	56	12	4 693	6 665
East of England (3)	8	32	11	4 393	5 662
London (7)	5	56	12	2 296	4 899
East Midlands (3)***	8	47	7	3 958	4 856
West Midlands (2)***	8	51	7	3 958	4 856
North West (3)	7	54	9	2 346	3 165
South West (4)	8	48	8	1 500	2 159
Scotland (7)	7	55	8	1 072	2 331
Yorkshire/Humber (4)	7	54	7	750	1 401
Northern Ireland (2)	8	59	8	481	647
Wales (3)	9	49	10	435	716

* All statistics are non-weighted averages across all selected universities in the NUTS1 area.

** UBC data include multiple counts of publications corresponding to the number of firms mentioned in a publication's author addresses and whether or not those firms are located in different geographic areas.

*** The Office of National Statistics merged the Business sector R&D expenditure data for these two areas into one joint area.

These NUTS1 level data also show a slight positive statistical relationship between R&D regional expenditure levels and local UBC intensities, with Wales as a significant anomaly, which suggests that NUTS1 areas might not be the best way demarcate a university's local geographic environment. NUTS areas are administrative entities, which may differ very significantly by size and can be affected by many other non-R&D related features. Moreover, within-country research cooperation patterns and associated knowledge flows are hardly affected by such artificial geographic borders of such areas. Strong collaborative ties with local R&D-intensive industry may spill over to a dominant position as a knowledge-supplier to businesses in the wider surrounding area or neighboring areas (Ponds et al., 2010). Universities located in NUTS1 areas that border to other countries are also likely to create more international UBC connections (e.g. Northern Ireland and Ireland).
As indicated above, the level of R&D expenditure by the local business sector output counts and geographical location of a university are both major determinants of UBCs. But what are other common factors across all 48 universities? And how distant-dependent are those factors? By applying a distance-based measure we removed the analytical constraints of the NUTS classification system, thereby enabling a more accurate comparative framework for analysing each university's 'UBC zone'.

Table 3. Overview of quantitative information on universities

Performance indicators	Data source (reference year)	Unit of measurement
University-business interactions		
University-business co-publications	Web of Science (2016-2017)	Frequency counts
UBM researchers	Web of Science (2016-2017)	Frequency counts
UB/MA researchers	Web of Science (2016-2017)	Frequency counts
Local R&D environment		
Local business R&D expenditure	UK Office Nat. Statistics (2016)	£ million, 2016
Business sector income streams		
Business sector funding - total	ETER (2014)	Local currency (PPP)
IP revenues – total	HE-BCI (2014/2015)	£ million, 2016
Contract research – SMEs	HE-BCI (2014/2015)	£ million, 2016
Contract research – other (large) firms	HE-BCI (2014/2015)	£ million, 2016
Consultancy – SMEs	HE-BCI (2014/2015)	£ million, 2016
Consultancy - other (large) firms	HE-BCI (2014/2015)	£ million, 2016
Research		
Research publication output – total	Web of Science (2013-2017)	Frequency counts
Publication output – medical fields	Web of Science (2013-2017)	Frequency counts
Publication output – STEM fields	Web of Science (2013-2017)	Frequency counts
Top 10% highly cited publications	Web of Science (2013-2017)	Frequency counts
Technological development, entrepreneurship and innovation		
Inventions - disclosures	HE-BCI (2014/2015)	Frequency counts
Inventions - new applications	HE-BCI (2014/2015)	Frequency counts
Inventions - new patents	HE-BCI (2014/2015)	Frequency counts
Spin-off and start-up firms - new	HE-BCI (2014/2015)	Frequency counts
Spin-off and start-up firms - still active	HE-BCI (2014/2015)	Frequency counts

Addressing these two above questions, we apply a series of regression analyses to model our 2016-2017 UBC count data across the 48 universities.[17] **Table 3** presents the list of collected quantitative data for these analyses. In addition to the two UBI indicators (UMB-Rs and UB/MA-Rs), we introduce explanatory variables on 'Research' and 'Technological development, entrepreneurship and innovation', 'Business sector income streams' and on the 'Local R&D environment'. The choice for these variables was driven by prior empirical studies of UBC patterns in the UK and their recommendations for further research.[18] The distinction between small and medium-sized enterprises (SMEs) and other (large) firms enables a closer look at relationships between a firm's size and the propensity or ability to interact and cooperate with universities. The variable 'Top 10% highly cited publications' is meant to reflect a university's international scholarly impact and visibility. Although many other metrics exist (of lesser quality) we assume that this small selection of indicators and metrics is adequate to help identify common factors of UBI.

[17] Where the UBC data refer to 2016-2017, the time-period of the other indicators relates to prior years, thus incorporating the 1 or 2-year time-lag between conducting joint research and a co-authored publication.

[18] Four technical criteria were applied to select the final set of variables for further statistical analysis: data availability, precision, reliability, and comparability.

Table 4 presents descriptive statistics of each indicator, according to the measurement units presented in table 3.

Table 4. Descriptive statistics of performance indicators (n=48 universities)

	Mean (measurement units)	Standard deviation (measurement units)
University-business interactions		
UCBs – 0-49 km zone	44	67
UCBs – 50-99 km zone	28	40
UBCs – 100-199 km zone	36	43
UBCs – 200-499 km zone	66	68
UCBs – 500-4999 km zone	138	134
UCBs – beyond 4999 km zone	169	187
UBM-Rs	61	80
UB/MA-Rs	33	39
Local R&D environment		
Local R&D Exp. – business sector	2304	1562
Business sector income streams		
Business sector funding – total	30 863 848	48 011 939
IP revenues – total	2 589	6 338
Contract research – SMEs	8 493	11 510
Contract research – other (large) firms	841	1 092
Consultancy - SMEs	859	1 807
Consultancy – other (large) firms	1 674	2 021
Research		
Research publication output – total	5 230	4 607
Publication output – medical fields	3 797	4 254
Publication output – STEM fields	4 205	3 511
Top 10% highly cited publications	1 627	1 667
Technological development, entrepreneurship and innovation		
Inventions – disclosures	74	90
Inventions – new applications	40	46
Inventions – new patents	18	29
Spin-off and start-up firms – new	3	3
Spin-off and start-up firms – still active	22	18

Because the distribution of UBC quantities across the 48 universities shows right-skewed Poisson distributions, i.e. where the level of statistical variance exceeds the value of mean, we applied a negative binomial model in our regression analysis.[19,20]

[19] The negative binomial model is a generalisation of Poisson model, both assuming a probability function where only one process generates the data. If the conditional distribution of the outcome variable is over-dispersed, the confidence intervals for the Negative binomial regression are likely to be narrower as compared to those from a Poisson regression model. Although negative binomial models are not recommended for very small samples drawn from a population, we assume that our sample of universities is sufficiently large to produce meaningful general findings.

[20] The negative binomial regression analysis was conducted within 'Generalized Linear Models' module of IBM-SPSS statistical analysis package. We selected 'interaction effects' to define the

This estimation model has an extra parameter to account for over-dispersion. In our regression we examined interaction effects of the various variables. Our series of regression analyses is applied to the each of the separate UBC distance zones mentioned in table 1. The overall fit of the regression model and the effects of each variable, are presented in **table 5.**

Although direct causal relationships cannot be attributed to these aggregate-level model-based findings, five general observations emerge that help to describe UBC patterns with regards to geographic proximities:

1. the local area's level of business sector R&D appears to be a major common factor, which is surprisingly independent of the spatial distance to partner firms. This outcome strongly suggests that local R&D ecosystems and UBC environments are important conditions for universities to successfully engage with firms anywhere worldwide.

2. the importance of university's business sector orientation, as reflected by the various income streams from the business sector, is distance-dependent. While the two generic steams of revenues (either 'total funding level' or 'total IP revenues') fail to provide any added explanatory value across the entire range of distances, the breakdown by type of income stream and size of firms (SMEs or otherwise) seems relevant. Notably, that consultancy contracts are a particularly important explanatory factor of in ultra-short distance UBCs, and contracts with larger companies are also important in many longer-distance zones.

3. individual connections and affiliations of a university's researchers are a major explanatory factor, especially with regards to local UCB in zones up to 500 km. Multiple affiliation researchers (UB/MA-Rs) are important in closer distance relationships, up to 100km. Mobile researchers (UMB-Rs) seem to be of significance in all zones between 50 and 400 km, with a declining relevance as the distance to partner firms increases.

4. a university's research size, in terms of total publication output, is important in most distance zones, as is its level of research quality (proxied by highly cited research publications). The disciplinary specialisation profiles also make a difference: the degree of specialisation – either medical sciences and/or STEM fields – is a major explanatory factor of UBCs with foreign firms located at distance of 500 km or more.

model parameters, rather than the 'main effects' option, where the effect of each variable on UCB outputs is examined independently of the other variables.

5. the university performance in terms of technological development, entrepreneurship and innovation is also a relevant indicator, but the various metrics paint a divers picture. Innovation-related performance seems to be most important for long-distance UBCs, especially a university's ability to create spin-off and start-up firms with a high survival rate. As for short-distance UBCs, new applications of inventions seems to be a relevant common factor.

General trends: localisation, globalisation or glocalisation?

Having established that UBC profiles are affected by different distance-dependent configurations of internal and external factors, what are the effects on the how UBC growth patterns have evolved in recent years? Is UBC output across the 48 UK universities localising, globalising or glocalising? **Figure 1** shows the annual trends in the relative number of UBCs in the period 2008-2017. Each of the four 'local' zones show decline share in the total number of UBCs. **Table A.2** of the statistical appendix presents the 2016-2017 UBC data for the 48 universities, with a breakdown according to these local UBC zones. The two most localized universities are the *LSE*, *University of Cambridge* and *City University London*, where more than 20% of their UBCs involve business sector partners located within a 50 km zone. Extending the range to 100 km increases those shares to 30% or more. Owing to a agglomeration effects, most of the London-based universities typically have a 15% share of 0-49 km zone, and another 20% are within the 50-99 km zone. *University of Glasgow* is the least localised university – only 16% of the UBCs involve business sector research partners within 500 km. Low shares are also found at other 'peripheral' universities: *University of Edinburgh*, *University of Dundee* and *Queen's University Belfast*, all of which located at comparatively large distances from local R&D-active firms in the Greater London area or the UK industrial heartland. The UBC profiles of the London-based universities illustrate the comparative advantages of being located in a country's capital city – in the vicinity of many firms, but also benefitting from clustering effects of its science parks, technology centres, and innovation hubs (Minguillo et al., 2015). Close distance to high-tech industrial hot spots outside such metropolitan areas may also strongly affect UBC patterns, such as in the case of *University* of *Cambridge*.

UCBs in the long-distance globalisation category (> 4999 km) remained stable, at a very low level, during these 10 years. The 500-4999 km zone (UCBs with firms in Europe) primarily accounts for the growth. Overall, the absolute numbers of UBC publications has increased by 79% between 2008 and 2017 (overall CAGR = 9%).[21]

[21] Various determinants may have contributed to this increase. Most likely it is predominantly caused by the expansion of journal coverage of our bibliographic database (*Web of Science*), but also by a growing number of WoS-indexed publications from these 48 universities contain an author address referring to a business enterprise.

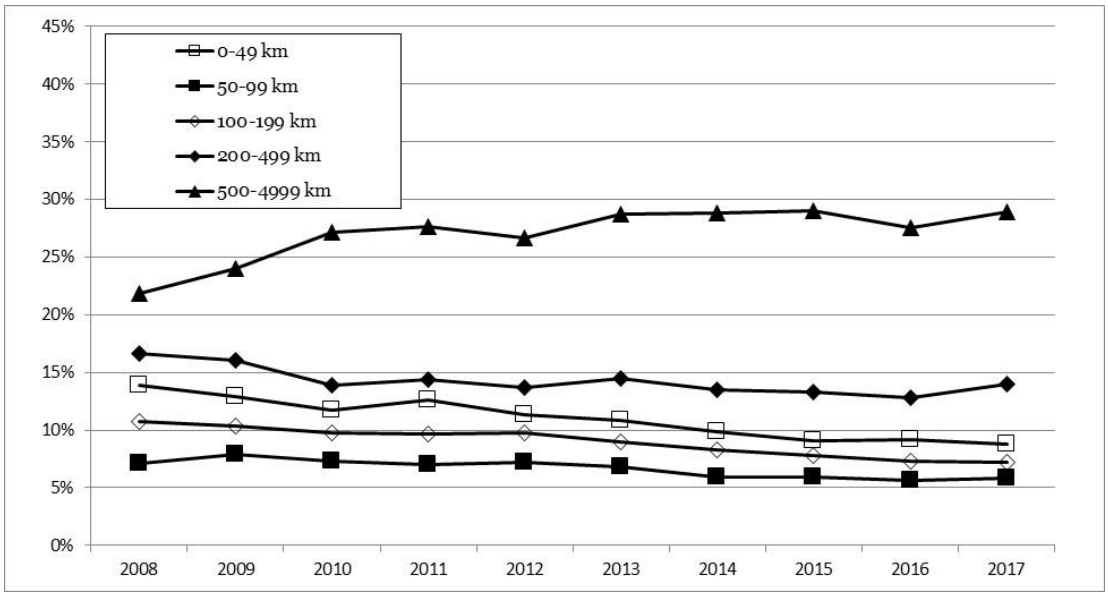
The UBC output growth volumes are displayed in **figure 2**. Indeed, UK universities are increasingly engaged in research cooperation with firms abroad, particularly within the 500-4999 km zone (CAGR = 12.1%). But the numbers of local UBCs with firms at much closer distances have also gone up, albeit at lower growth rates (CAGR 0-49 km = 3.3%; CAGR 50-99 km = 6.4%; CAGR 100-199 km = 4.0%). Overall, UBC output at UK universities has glocalised.

Table 5. Negative binomial estimation of UBC outputs (Type I interaction effects)

	Dependent variables (UBC output per distance zone)					
	0-49 km	50-99 km	100-199 km	200-499 km	500-4999 km	> 4999 km
University-business interactions						
UBM-Rs	2.07	2.38*	2.50*	2.67*	0.85	3.23*
UB/MA-Rs	2.51*	2.35*	1.39	0.00	1.04	0.00
Local R&D environment						
Local business R&D expenditure	9.95**	26.14**	15.52**	11.73**	28.30**	29.70**
Business sector income streams						
Business sector funding – total	1.44	0.08	0.04	2.23	1.53	2.20
IP revenues – total	0.10	1.46	0.11	2.19	1.05	0.85
Contract research – SMEs	1.48	0.00	0.11	0.01	3.08*	0.87
Contract research – other (large) firms	2.07	0.01	0.69	2.72*	0.06	2.69
Consultancy - SMEs	2.84*	0.22	0.11	2.38	0.06	0.88
Consultancy - other (large) firms	4.60**	0.03	2.76*	2.37	2.19	4.09*
Research						
Research publication output - total	5.15**	1.21	4.96*	3.74**	1.53	3.07*
Publication output – medical fields	0.05	1.13	0.65	2.60*	10.35**	11.71**
Publication output – STEM fields	0.30	0.07	0.65	1.73	3.80**	4.61**
Top 10% highly cited publications	1.51	2.60*	5.46*	3.41*	4.45**	6.99**
Technological development, entrepreneurship and innovation						
Inventions - disclosures	0.86	0.03	0.28	0.21	3.96**	1.00
Inventions - new applications	2.88*	0.13	1.45	0.91	0.68	0.25
Inventions - new patents	0.20	0.00	0.01	0.09	4.01**	1.46
Spin-off and start-up firms - new	1.05	0.24	1.46	2.42	4.68**	6.22**
Spin-off and start-up firms - still active	0.74	0.39	0.69	15.44**	30.83**	20.07**
Goodness of fit measures						
Log Likelihood	*-198.9*	*-182.70*	*-196.11*	*-250.67*	*-291.31*	*-296.27*
Akaike's Information Criterion	*433.7*	*401.40*	*428.21*	*537.34*	*618.62*	*628.55*

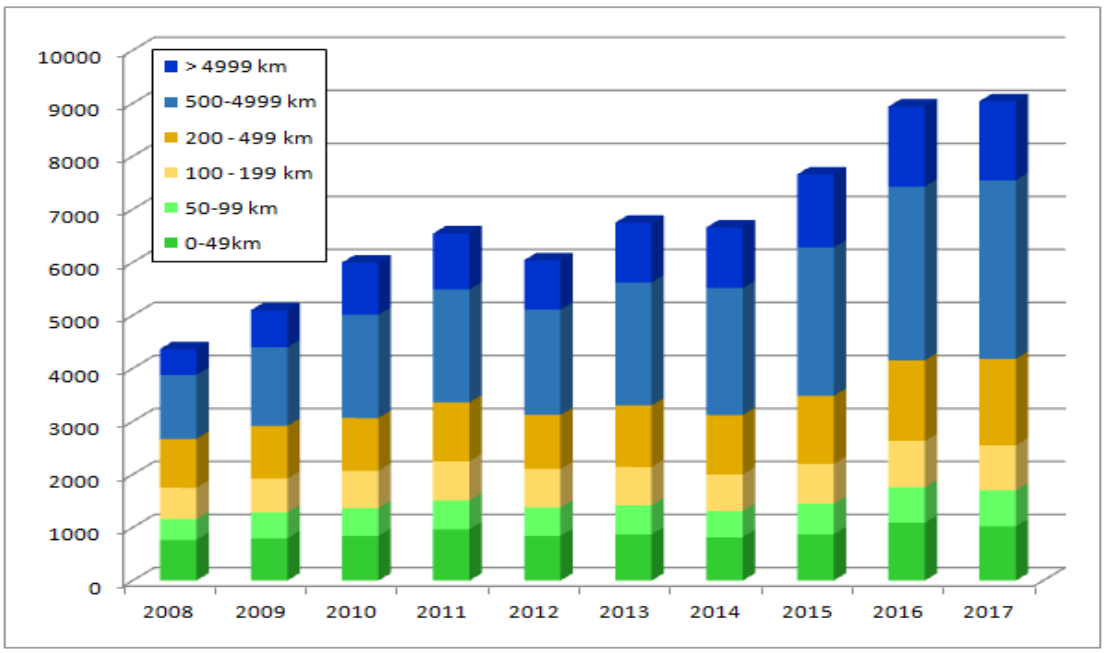
** $p \leq 0.05$; * $p \leq 0.10$

Figure 1. Annual trends in UBC shares by distance zone*



* The UBC data include multiple counts of publications corresponding to the number of firms mentioned in a publication's author addresses and whether or not those firms are located in different geographic areas.

Figure 2. Annual trends in the number of UBCs by distance zone*



* The UBC data include multiple counts of publications corresponding to the number of firms mentioned in a publication's author addresses and whether or not those firms are located in different geographic areas.

We conducted a discriminant analysis to identify possible common factors behind these growth rates. Universities were split into one of three categories based on their observed CAGR profiles across all zones.[22] The 'localising' category was not implemented due to lack of universities. Where 5 universities exhibited signs of 'significant globalisation' where both global zones had least 10% CAGR values, 18 showed signs of 'significant glocalisation' represented by growth rates in both local zones as well as the two global zones. The remaining 25 universities showed a variety of no/low growth rate patterns.

Table 6. Results of discriminant analysis: canonical loadings (n=46 universities)

	Canonical loadings 1	Canonical loadings 2
University-business interactions		
UBM-Rs	-1.71	2.47
UB/MA-Rs	0.72	-1.99
Business R&D environment		
Local business R&D expenditure	-0.33	-0.24
University science/technology park (0 – no; 1 - yes)	0.15	0.58
Business sector income streams		
Business sector funding - total	-0.33	0.30
IP revenues - total	0.43	0.88
Contract research - SMEs	0.11	-0.31
Contract research – other (large) firms	-1.11	1.10
Consultancy - SMEs	0.73	-1.14
Consultancy - other (large) firms	0.35	0.58
Research		
Research publication output - total	-3.14	-2.72
Publication output – medical fields	5.08	1.17
Publication output – STEM fields	4.91	-1.50
Top 10% highly cited publications	-5.44	1.58
Technological development, Entrepreneurship and innovation		
Inventions - disclosures	-0.10	0.18
Inventions - new applications	0.03	0.21
Inventions - new patents	0.94	-0.64
Spin-off and start-up firms - new	-0.77	0.50
Spin-off and start-up firms - still active	0.01	0.02
Group centriods		
Glocalising of UBC partners	2.26	1.91
Mixed or ambiguous profile of UBC partners	0.53	-0.73
Globalising of UBC partners	-1.37	0.48
Goodness of fit measures		
Eigenvalue	*1.47*	*0.79*
Canonical correlation	*0.77*	*0.66*
Wilks' Lambda	*0.23*	*0.56*
Chi-square	*52.7 (df = 40; sign = 0.09)*	*20.7 (df = 19; sign = 0.36)*

[22] Owing to the low numbers of local UCBs at some universities, the four 'local' zones where aggregated into two: 0-99 km (short-distance) and 100-499 km (intermediate/long distance).

We applied discriminant analysis to all universities to assess the factors that determine a university's membership of either the 'globalisation' or 'glocalisation' or 'mixed' category.

This model is composed of two discriminant functions, each based on linear combinations of the predictor variables that provide the best discrimination between these three groups and a multivariate test of the differences. We use the same set of variables as in the above regression analysis, but in view of the observed very significant importance of the local R&D environment on UBC patterns, we added two variables referring to the local environment: (a) whether the university is located in Greater London area, and (b) whether the local area contains a university science/technology park and/or innovation hub. Given the larger number of variables, and the observed diversity of contributions from each variable across the various distance zones, we applied with stepwise variable selection method to determine the most significant predictors.

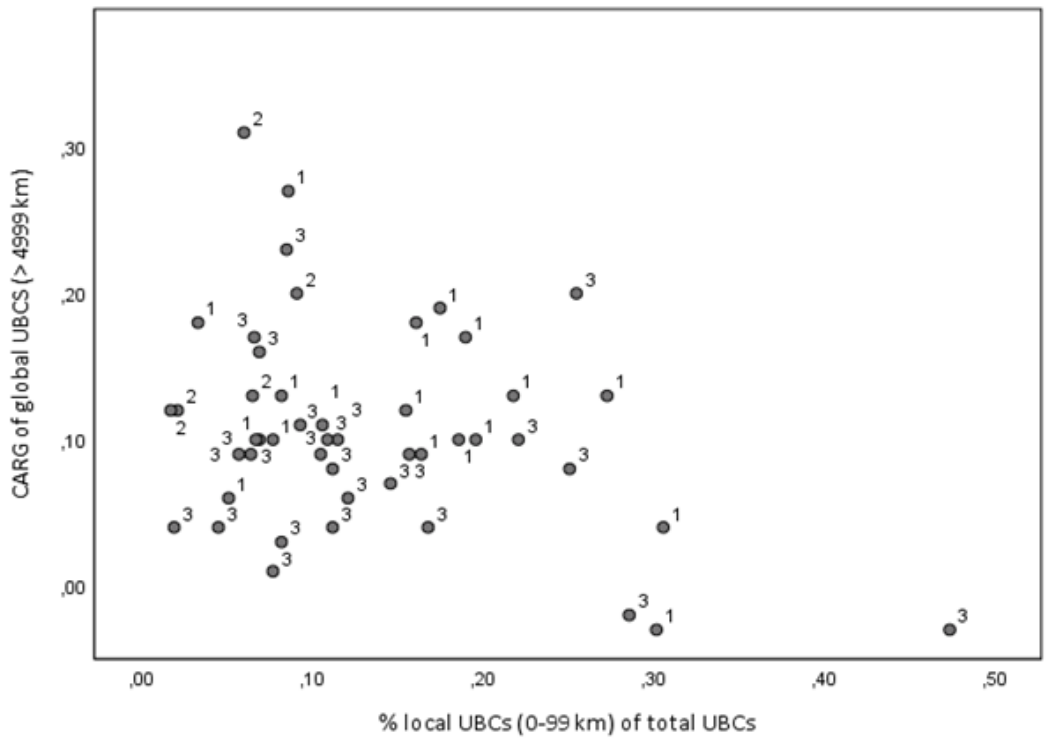
The main results of the discriminant analysis are displayed in **table 6**. The canonical loading of each variable represent the correlation coefficient between the observed variables and the unobserved discriminant function. The canonical correlation coefficients test for the existence of overall relationships between two sets of variables. Wilk's lambda is used as a test of statistical significance of the canonical correlation coefficient. The canonical relation is a correlation between the discriminant scores and two categories levels of the dependent variable.

The correlation coefficient (r=0.79) indicates that collectively the two functions were sufficiently successful in discriminating between the categories 1 ('strongly globalising'; n=5), 2 ('strongly glocalising'; n=18) and 3 ('other CAGR patterns'; n=25) to draw some meaningful inferences about the general patterns. The associated category centroids (group means) present a reference to interpret the canonical loadings of the variables. Those loadings present a complex picture. Focusing on the first function, the variables associated with a university's glocalisation profile (i.e. with positive group centroids and associated positive canonical loadings) are: research specialisation in either medical sciences and/or STEM fields of science; researchers with affiliations in the business sector (UB/MA-Rs); consultancy contracts (with SMEs and larger firms); new patents; IP revenues. *Imperial College London* is one of the glocalising universities. The variables contributing to globalisation profiles (negative canonical loadings on the first function) are: lower citation impact and publication output; less researchers with a history of job mobility (UBM-Rs); less contract research with larger firms and/or new spin-off and start-up firms. *Queen's University Belfast* is an illustrative example of a globalising university. Briefly summarising, the glocalising universities tend to be the more scientifically specialised organisations (especially in the medical/health

sciences), and more industry-oriented, while the globalising universities tend to smaller, less internationalised, and less industry-oriented.

When applying a demand/supply 'marketisation' logic to geographical proximities between universities and their business sector R&D partners, one might expect to see a 'substitution effect' or 'branching out effect' of in those cases where universities face low or declining R&D expenditures and associated diminishing knowledge-demands from universities, by firms in the local area. Or the university's knowledge supply (growth) exceeds the business sector's demand (growth). Such universities are likely to shift academic resources and UBI priorities towards engagement and collaboration with longer-distance business partners. Addressing the issues of how globalisation growth patterns relate to the degree of university's UBC localisation, **figure 3** compares the 2008-2017 CARG of each university's global UBCs (with partners located at 4999 km or more) to the university's current 2016-2017 focus on local UBCs with firm at less than 100 km. We find that glocalising universities (tagged with a '2') are involved in 'catching up' processes, marked by a relatively small share of local UBCs and above average globalisation growth rates. The group of globalising universities (those labelled with an '1') are much more divers; their globalisation rate is independent of the local UBC intensity – the same pattern is found at the other 'no/low UBC growth' universities in the UK.

Figure 3. Long-distance UBC globalisation growth rate versus short-distance UBC activity



General observations and concluding remarks

In this empirical study we applied a quantitative indicator-based mapping of research-related university-business interactions in the United Kingdom. We focused our attention on a selection of 48 research-intensive universities and the dispersion of partner firms across distance-based geographical zones in the UK and abroad. The geographical location and spatial distribution of those firms presents a new perspective on UBI patterns, and addresses an information gap in UK government statistics or university administration data on research cooperation with the (local) business sector.

The results enabled us to track and analyse the gradual changes that have occurred in recent years. We find three common contributing factors, which are significant in most if not all zones, where high UBC levels depend significantly on: (1) business sector R&D-intensity in the local geographical area; (2) the university's research size; (3) the university's high-end international citation impact. So, both supply and demand factors seem to be major drivers UBC activity throughout the UK university system. Further in-depth studies are needed to tease the nature of the interrelations between these forces.

Overall, our findings highlight the multitude of (interacting) determinants that seem to be affecting UBC patterns and trends, where each of our UBC distance zones presents a different set of factors. Local UBCs are more likely to involve boundary-spanning, cross-sectoral researchers. The empirical evidence also suggests that interactions with large firms are relevant across the broader distance range. Universities, especially the industry-oriented ones located in the UK's economically prosperous areas with much higher levels of business sector R&D expenditure, enjoy high growth rates in both local and international collaborative ties with industry. Spatial concentration effects dominate the UBC topography in the UK, where metropolitan cities like London act as hubs of local UBC-intensive ecosystems. These local urban agglomeration effects remain a powerful force.

The numbers of long-distance UBCs have increased very significantly, at a higher rate than short-distance UBCs, hence UBC globalisation is increasing faster than UBC localisation. Globalisation and localisation are interconnected. We observe simultaneous processes 'glocalisation' at several UK universities. Focusing on the subsample of universities with significant growth rates in either glocalisation or globalisation, we find that glocalisation grows faster at the universities with a low levels of local UBCs, i.e. those located in areas with relatively low levels of science-dependent business R&D intensity.

Although the collected data provide interesting new insights into general UBI patterns and trends across the UK university system, the university-level UBI profiles and development trajectories are still insufficiently clear. Our UBI model critically

hinges on the assumption that its three 'key performance indicators' (UBCs, UBM-Rs, and UB/MA-Rs) are sufficiently valid proxies of general patterns and trends in UBI. All three are relate to research publication output, more specifically successful research (otherwise the work would not be published). Moreover, publication output quantities do not necessarily reflect the volume of inputs (such as the amount of industry funding of research) or the effectiveness of knowledge creation processes or productive interactions with the business sector. So relying on only these three KPIs, UBCs in particular, clearly introduces a limited window that overemphasises successful research cooperation and productive interactions. Hence, due caution is required to avoid misinterpretations: our observed patterns and trends do not represent the full research-based spectrum of UBI in the United Kingdom.

There is also insufficient understanding of how knowledge is actually shared or transferred between individuals – either within the same local geographical area or further afield. New analytical frameworks, measurement models and performance indicators are needed to study and manage these transitional processes. Given the growing importance of UBCs for business sector R&D in the UK (witness the emergence of the Knowledge Exchange Framework as policy tool and information platform), there is now an urgent need for new metrics to compare and to track UBC patterns and trends. It is within this UK-specific analytical setting that our approach can add significant value. It taps into a rich source of comparative empirical information on the UK's research-intensive university sector, especially with regards to research cooperation and cross-sectoral mobility of researchers. As such, it not only opens new avenues for further empirical enquiry and represents a valuable supplement to the existing statistical data from the *Higher Education-Business and Community Interaction survey* and possible KEF-relevant indicators on knowledge transfer at UK universities.

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Statistical appendix

Table A1. University-Business Interactions statistics per university (2008-2017)*

	Publ. output UCB (% total output)	Publ. UBM-Rs (% total output)	Publ. UB/MA-Rs (% of total output)
University of Oxford	8.3	0.8	0.4
University College London	7.7	0.8	0.4
University of Cambridge	9.0	1.6	0.6
Imperial College	11.1	1.3	0.6
University of Manchester	10.0	1.1	0.4
King's College London	8.6	1.0	0.3
University of Edinburgh	8.8	0.9	0.3
University of Bristol	7.4	0.8	0.4
University of Southampton	8.0	0.6	0.3
University of Nottingham	7.6	0.7	0.4
University of Birmingham	7.2	0.7	0.4
University of Sheffield	8.9	0.8	0.4
University of Leeds	8.5	0.8	0.4
University of Glasgow	8.6	1.1	0.3
University of Liverpool	7.0	0.4	0.2
Cardiff University	6.9	0.5	0.3
University of Warwick	5.8	0.7	0.4
University of Newcastle-upon-Tyne	7.7	0.6	0.3
Queen Mary University of London	7.9	1.0	0.4
University of Durham	4.7	0.6	0.3
Queen's University Belfast	6.4	0.6	0.3
University of Exeter	4.8	0.4	0.3
University of Aberdeen	7.6	1.1	0.5
University of York	7.1	0.8	0.3
London School of Hygiene & Trop. Med.	6.1	0.6	0.2
University of Leicester	9.2	0.4	0.3
University of St Andrews	4.6	0.5	0.2
University of Lancaster	4.7	0.5	0.3
University of Sussex	3.2	0.3	0.2
University of Strathclyde	7.8	0.9	0.6
University of East Anglia	4.2	0.2	0.2
University of Bath	7.0	0.7	0.5
University of Reading	7.0	0.5	0.3
University of Surrey	8.7	1.4	0.7
Loughborough University	6.9	0.7	0.4
University of Dundee	9.2	1.1	0.5
Swansea University	6.8	0.4	0.2
Brunel University London	5.9	1.3	0.6
London School of Econ. and Pol. Sci.	2.1	0.4	0.2
University of Kent	3.8	0.5	0.3
Heriot-Watt University	7.2	0.8	0.7
University of Plymouth	5.9	0.9	0.3
Open University	5.0	0.3	0.1
University of Hull	6.1	0.8	0.4
Bangor University	4.8	0.4	0.2
Cranfield University	11.3	0.9	0.6
University of Ulster	4.5	0.3	0.3
City University London	4.4	0.8	0.4

* Universities sorted by decreasing 2008-2017 research publication output in the Web of Science.

Table A2. Dispersion of local UBC partners by physical distance (% of total per university; 2008-2017)*

	0-49 km	50-99 km	100-199 km	200-499 km
London School of Econ. and Pol. Sci.	29.6	1.5	3.0	18.2
University of Cambridge	23.6	5.8	8.2	8.7
City University London	23.2	7.0	4.8	9.6
University of Surrey	16.9	7.6	11.8	14.1
London School of Hyg. & Trop. Med.	16.5	5.3	0.6	12.7
Queen Mary University of London	15.8	6.0	3.8	13.1
Imperial College	15.8	6.8	5.2	12.3
University of Reading	15.1	10.5	11.0	15.1
King's College London	15.0	6.1	3.1	10.6
Loughborough University	14.9	11.5	31.3	12.1
University College London	14.8	8.5	2.7	11.3
Brunel University London	12.7	18.4	7.4	15.6
University of Aberdeen	11.5	0.3	3.0	6.4
Heriot-Watt University	11.4	2.6	3.8	15.4
University of Strathclyde	11.2	2.2	1.0	19.4
University of Manchester	11.0	6.2	5.2	20.9
Queen's University Belfast	10.3	0.8	2.4	18.7
University of Nottingham	10.3	9.4	25.3	10.5
University of Durham	9.9	1.9	7.8	30.6
University of Sheffield	9.4	5.7	13.0	18.0
University of Warwick	9.1	7.6	27.7	6.2
University of Bath	8.5	6.9	28.0	14.3
University of Oxford	7.9	12.8	9.2	7.7
University of Bristol	7.9	6.2	19.7	13.6
Cranfield University	7.7	26.0	22.3	12.4
Cardiff University	7.3	1.1	12.8	18.6
University of York	7.1	1.3	6.3	27.5
University of St Andrews	6.9	1.4	2.2	12.3
University of Kent	6.8	5.3	21.7	13.7
University of Edinburgh	6.5	1.2	1.2	12.4
University of Leeds	6.4	6.7	5.7	25.7
University of Ulster	6.0	2.6	1.3	28.3
Swansea University	5.8	4.3	4.4	26.5
University of Liverpool	5.5	5.2	6.1	20.1
University of Glasgow	5.2	1.5	0.9	8.8
University of Plymouth	5.2	0.0	4.5	33.7
University of Birmingham	4.8	10.5	21.0	7.9
University of Southampton	4.7	10.3	15.4	12.0
Open University	4.3	17.1	13.4	6.9
University of Exeter	4.3	1.6	4.4	25.4
Bangor University	4.1	6.6	13.0	29.1
University of Newcastle-upon-Tyne	4.1	0.3	8.8	25.7
University of Leicester	3.5	7.3	14.3	7.2
University of Dundee	3.2	3.2	0.9	4.9
University of Hull	3.1	1.5	11.5	26.3
University of Lancaster	2.4	11.7	5.2	28.4
University of Sussex	2.4	9.7	17.7	15.5
University of East Anglia	1.4	6.1	20.6	19.3

* Universities sorted by decreasing share of UBCs with firms within a range of 50 kilometers.