Value Chains, Systems Thinking and Science, Technology and Innovation Policy: Implications for place-based policy development in the UK A Critical Assessment

A PAPER FOR UK RESEARCH AND INNOVATION

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1 Introduction

There is a growing interest in place-based as opposed to place-neutral policies to enhance innovation and productivity performance in a way that contributes to reducing place-based inequalities. This raises issues for the design of a portfolio of policy instruments to influence the scale and direction of support for research and knowledge exchange. In the case of the UK this includes assessing the role in reducing inequality of emergent place-based funding programmes linking innovation and productivity to the public sector research base. In particular we focus on the Strength in Places Fund (SIPF). Our paper argues for a systems-based approach to these issues and then uses this approach to outlines the case for and potential constraints on a policy such as SIPF.

This paper was commissioned to explore the conceptual and empirical basis for the future operation and development of SIPF as a place-based policy. To anchor the empirical and conceptual discussion in the report we begin with a summary outline of the structure and objectives of the SIPF. We then outline the core elements of a generic system based approach to innovation policy design and emphasise the role of systems failure as opposed to market failure as a framework for place-based policy intervention. We demonstrate how this approach can be used at different domain levels including the sector and technological level and how these *interact* in thinking about regional or other place-based systems. We briefly review the most recent literature bearing on these issues with an emphasis on UK based studies and on the role of universities.

We complement this with an overview of place-based variations in productivity and innovation in the UK; a detailed spatial analysis of the distribution of HEIs and research excellence in the UK; and an analysis of the spatial distribution of the current portfolio of support for research and knowledge exchange. We consider spatial distributions at the level of the region, and within regions the distribution across large cities and smaller urban areas and rural areas.

In developing public research based innovation policy we argue that close attention must be paid the spatial distribution of value chains and of business model innovation in the translation of research into innovative activity. These determine the spatial *generation* and spatial *capture* of value and hence the implications for spatially based inequalities. We also emphasise the need for policy to address the role of systems concepts including networked interactions and the norms and rules, or institutional architecture under which local systems of innovation emerge and operate.

The report is organised as follows. Section 2 sets out the UK policy background to the introduction of the SIPF. Sections 3-5 then develop the conceptual basis for a systems based approach to policy design and an overview of relevant underpinnings for an approach to developing science and innovation-focused place-based policies targeted at reducing spatial inequalities in economic performance. Sections 6 and 7 then provide an empirical assessment of spatial inequalities both in terms of productivity levels and growth performance, as well as in the research, knowledge exchange and innovation capabilities and capacity. Section 8 reflects on both the conceptual and empirical assessments and discusses implications for the design of place-based funding programmes in the UK.

2 The Strength in Places Fund

The SIPF is the first attempt in the UK to allocate funding for the public sector research base for public sector on a specific place-based as opposed to space-blind basis. In proposing this fund the UK Research and Innovation (UKRI) – the primary funding agency in the UK responsible for allocating research and innovation funding – is departing from its historical mode of distributing funding based on excellence in research and knowledge exchange per se. In this section we outline the genesis of this scheme and its essential features.

The UK Government announced the SIPF in the Industrial Strategy White Paper, published in November 2017 (HM Government, 2017). The White Paper highlighted the role that science, research, innovation and skills provision play in driving productivity and economic growth nationally and could play in addressing low productivity in underperforming places.

The SIFP is a place-based policy designed to fund collaborative consortia bids based on research and innovation excellence in particular locations. Bids will need to self-identify the boundaries of the "place" which their activities will be located. They will be required to demonstrate alignment with the relevant Strategic Economic Plan(s) (SEP) for the locality, including Local Industrial Strategies or similar economic strategies in the devolved nations (UKRI, 2018a).

The SIPF is part of the National Productivity Investment Fund (NPIF) that will be contributing to the UK Government's target to reach 2.4% of R&D spending in GDP. The SIPF is designed to complement other UKRI and UK national programmes including the Industrial Strategy Challenge Fund (ISCF) and Future Leaders Fellowship Scheme, and the UK Shared Prosperity Fund (UKSPF) which aims to boost productivity and reduce economic inequality across the country following Brexit.

The overall budget of SIPF is £115million. After inviting expressions of interest seedcorn funding of £50K will be made available for a selected short list group of bids. Out of this group SIPF will select for support between 4 and 8 bids valued between £10 million and exceptionally £50 million spread over 3-5 years per bid. Businesses receiving funding will be expected to provide matching funds.

2.1 Aims and Objectives

The SIPF has two "high level" aims (UKRI, 2018a).

The first of these is to support innovation-led relative regional growth by identifying and supporting "areas of R&D strengths" that are: "driving clusters of businesses across a range of sizes that have potential to innovate, or to adopt new technologies". The aim here is to ensure that those clusters will "become nationally and internationally competitive".

The second high level aim is to "enhance local collaborations involving research and innovation". This aim is to capitalize on the regional economic role of "universities, research institutes, Catapults and other R&D facilities (such as Innovation and Knowledge Centres – IKCs) and the interface with "those businesses at the forefront of delivering economic growth through innovation within the identified economic geography".

These high level aims are combined with specific objectives (UKRI, 2018a).

- That projects funded under the SPIF must have a significant local impact that closes the gap between that region and the best nationally.
- That project activities must focus on supporting those businesses and research organisations at, or near to the frontier of the economy.
- That excellent research and high-quality innovation should be completed, or underway as a result of funded proposals.
- That collaborations between local businesses, research organisations and local leadership are enhanced as a result of the funded proposals.
- That funded proposals are expected to deliver good value for money relative to the area being supported, and in terms of additionality.
- Finally the SIPF programme as a whole is expected to improve the evidence base around the impact of locally targeted R&D spending in the UK.

2.2 Types of activities to be supported

The invitation to submit expressions of interest for support through SIPF provides examples of what might be supported (UKRI, 2018a, 2018b). There is no expressed focus on any particular sector technology or research discipline. Examples can be grouped as follows.

Enhancing existing Clusters

Investment in an existing high-quality local cluster to scale up a critical mass of researchers in an excellent research group. This is widely drawn and can include, for example, investment in networks to draw in venture capital and mentors. The objective of the project must, however, be to deliver business commercialization outcomes through licensing or collaborative partnerships in a specific sector / technology area to develop an existing, high-quality local cluster.

Investing in targeted market assessment activities in an existing cluster so as to increase the number and improve the survival rates of technology driven start-ups and spinout companies within that cluster.

Activities to draw in overseas R&D and or businesses to work with an excellent research group within a cluster to enhance local business supply chains.

Promoting collaboration between universities/research organisations and SME technology-focused companies to drive new market opportunities in specific clusters through a culture of collaborative innovation

Promoting Local System Regeneration and Revival

Reviving an existing industrial and business base through joint business/research base development programmes or transfer of technologies between sectors. This could be through new inward investment and/or support for new start-ups that modernise and transform an existing base or transfer technologies.

The high level and more specific aims of SIPF are thus strongly place specific. Taken together they are designed to enhance place specific interactions between the public and private sectors with the specific objective of reducing gaps between performance in a region and the national best practice. The policy emphasises the exploitation of *existing* excellence in research and commercial exploitation in *existing* excellent "clusters" of frontier businesses.

The policy does not set out a conceptual basis for the policy intervention proposed. The next section sets out and justifies adopting a systems based conceptual approach to a place-based policy design. This then forms the framework around which subsequent sections are organised and the final discussion of SIPF made.

3 Science and innovation policy and innovation systems thinking

The development of science and innovation-focused place-based policies needs to be grounded conceptually. We argue that policy should be grounded conceptually in the innovation systems approach. In this section we review the key elements of this approach and discuss how in principle it might be applied in developing a place-based policy.

An innovation system is usually analysed in terms of three core system elements. The first consists of the agents whose behaviour takes place within the system. Agents include individual consumers, private sector businesses, and public private and third sector organisations. The second element is the institutional framework or institutional architecture within which behaviour occurs. Institutional frameworks encompass "hard" institutional elements such as contract, labour, and intellectual property law, and standards and regulation, as well as "softer" informal norms and rules of the game governing agent interactions. The third element is the set of interactions between agents that take place within the institutional framework. These interactions go beyond arms-length market interactions to include the full set of formal and informal network and collaboration-based interactions. These interactions in turn take place within specific sets of physical (e.g. transport and IT) and science-based infrastructures provided by private and public sector agents.

The emphasis in SIPF on innovation and within that on agent interactions and collaborative arrangements across market and non-market boundaries make it an attractive approach to adopt.

A critical part of understanding and analysing an innovation system is defining its boundaries. The system boundary may be drawn in various ways. It may be defined and analysed at the level of a nation (national innovation systems), a sector or technology (sectoral and technological system of innovation respectively), or in terms of a place (regional or city based innovation system).

Our focus in this paper will ultimately be on place-based systems below the national level (local or regional or city based systems). However, we argue that any place-based approach must address the way in which specific sectoral and technological innovation systems manifest themselves in that place, and the impact on that place of the national innovation system in which it is located.

It is important to note that the concept of innovation system employed in this literature is not mechanistic but organic and is rooted in evolutionary approaches to economics. Innovation systems are constantly evolving. Agents interact and those interactions lead to co-evolved changes in institutional architecture and network structures as individual agents alter network affiliations and enter, leave, grow or shrink in particular sectors.

We return to the important issue of different system boundary types after first outlining the concept of system failure as a guide to policy.

3.1 Systems Failure and Innovation Policy

From a policy perspective the central implication of an innovation systems approach is to expand the basis for policy intervention beyond standard “market failure” reasons to encompass “system failure” (Crafts and Hughes, 2013).

In the case of science and innovation policy market failure approaches emphasise the failure of markets to allow innovators and inventors to capture the full social value of their R&D efforts. Thus, for example, because of R&D externality and spillover benefits not captured by the spender, R&D expenditure is sub-optimal and R&D subsidies are needed to correct the market failure. Additionally high uncertainty in returns and inability of financial markets to price uncertainty may lead to capital market failures in the supply of finance for innovative activity. These arguments can and have been widely used to justify direct and indirect public support for private sector R&D. The evidence in support of a beneficial impact in terms of additionality of this kind of policy is however mixed and the underlying approach is, from a systems point of view, limited (see e.g. Mohnen (2018) for a recent review).

A system failure approach takes a wider view of the functioning of the system as a whole. This wider view is linked to: the inter-related and co-evolving nature of the agents and their capabilities; the physical, and science and knowledge infrastructure in which agents interact; the institutional architecture which governs those interactions; and the network structure of the system (see e.g. Carlsson and Jacobsson, 1997a; Edquist, et al., 1998; Grillitsch and Trippl, 2018; Johnson and Gregersen, 1995; Malerba and Orsenigo, 1997; Smith, 1999; Woolthuis et al., 2005)

Crafts and Hughes in their discussion of industrial policy note *institutional system failures* particularly relevant to the role of the SIPF. Thus they note a failure arising from

> *“ a lack of congruence between formal and informal rules and incentives affecting different parts of the organisation of the system. A particularly prominent case is the alleged difference in norms and incentives between academic scientists and the private sector in conducting research. Here it is argued that the former emphasise open publication and disclosure, whilst the private sector, in its pursuit of research connected to private exploitation, is committed to secrecy and patent protection. This has engendered a major debate in the UK over the extent to which the allocation of public funds should be directed according to the motivations and the incentives of the former as compared to the latter, the nature of UK university-industry links, and the design of intermediary organisations on the boundaries of universities and industry (Deiaco et al., 2012; Hauser, 2010; Hughes, 2012; Hughes and Kitson, 2012; Mina et al., 2009; Royal Society, 2011)”*
>
> Crafts and Hughes (2013) p14

In addition to institutional failures the other components of the system may have associated system failures.

Network failures may arise through sparse or missing linkages between agents. This prevents the development in the system of mutual learning and awareness of complementarities. It limits the system wide diffusion of best practice and its rate of advance (Carlsson and Jacobsson, 1997a; Malerba and Orsenigo, 1997).

Agent capabilities failures may constrain the ability of the system as a whole to adapt or adopt new product and process technologies, new organisational innovations or to respond to new market opportunities (Malerba and Orsenigo, 1997; Smith, 1999). Agents within a system may, moreover vary enormously in their capability to innovate and to access technical and scientific knowledge. Over time a well-functioning system will have selection processes that increase the share of activity in best practice firms. At any particular time (and especially in systems where institutional and interaction elements fail to promote diffusion or prevent exit through subsiding loss making firms) there may be tails of underperforming agents. The resulting spread of efficiency means that at any time considerable gains may be had from policies supporting or developing system features that encourage both the diffusion of best practice across agents and policies ensuring that best practice itself advances.

These failures may be interacting and self-reinforcing. One of the most important outcomes of this may be lock-in failure (Woolthuis et al., 2005). The agents in the system may suffer from "opportunity blindness" and fail to identify new possibilities or fail to move away from a pre-existing system configuration. These lock-in effects arise because of heavy sunk costs in particular sectors and technologies alongside the complementary institutions and networks associated with them. System lock in thus results from the complex interaction of these multiple reinforcing system characteristics. The previous configuration may have been served earlier sectoral specialisations well but now act as an anchor against change and adaptation.

As Smith (1999) puts it in the case of technological systems

> *"Technological regimes or paradigms persist because they are a complex of scientific knowledge, engineering practices, process technologies, infra- structure, product characteristics, skills and procedures which make up the totality of a technology and which are exceptionally difficult to change in their entirety."*
>
> Smith (1999) quoted in Woolthuis et al. (2005) p.44

System lock-in effects in sectors and technological systems are central to many policy issues in place-based innovation policies that are designed to improve lagging productivity regions and localities. We return to their implications in the next section after discussing different system boundaries

3.2 Types of Innovation Systems Boundary

The seminal applications of systems thinking to innovation considered national systems (Nelson, 1993). A national system of innovation considers the agents institutions and interactions within a national boundary and is closely linked to the idea that distinctive national system characteristics can be identified. The idea has subsequently been extensively applied to systems with boundaries defined by sector or technology and boundaries defined at sub-national, typically regional level and more recently at city level.

3.3 Sectoral Systems

The sectoral systems of innovation (SSI) approach emphasizes that each industrial or service sector is an intersection of different networks of producers, suppliers, customers and the public and private knowledge and on which they draw. These sectoral system networks may cut across national and other spatial boundaries (e.g. regions) and are influenced by the national and international system boundaries with which they intersect and may draw on multiple technological and science knowledge bases. Some of these may be more specific to the sector than others and some may be more general purpose and span multiple sectors (e.g. digital or advanced material technologies). SSIs may be characterized by one or more key or anchor firms who act to establish and co-ordinate a specific set of inter firm and knowledge base relations and relevant technologies

More generally,

> *"sectoral analyses should focus on the systemic features of innovation in relation to knowledge and boundaries, the heterogeneity of actors and networks, institutions, and transformation through co-evolutionary processes. As a consequence, the understanding of these dimensions becomes a prerequisite for any policy addressed to a specific sector."*
>
> Malerba (2004) pp. 501-502.

A sectoral system based innovation policy as a result spans a very wide policy domain including (of particular importance from the point of view of this paper) science and technology policy and the role of the public knowledge base in the evolution of the sectoral system. It implies, moreover, a very granular approach to policy formation because of the variation in innovation system characteristics across sectors and the need to root policy in the specific characteristics of each sector.

It follows that the informational requirements in developing policy are substantial. Moreover, it is frequently the case with newly emerging sectors that these requirements are less easily developed using official data based on existing standard industrial classifications.

In this context it has been argued that the agents themselves are key sources of information for policy development and the main actors in developing the evolution of the system.

From this perspective

> *"the principle role of the policy maker is to facilitate the self-organisation of the SSIs within the relative policy domain. An important consequence of this is that the policy-making process is itself the reflection of bounded rationality and learning in the presence of high heterogeneity in technical change and the innovation process. The sectoral system approach is an alternative to the concept of the optimising policy-maker, which characterises the market failure approach to innovation policy ..."*
>
> Malerba (2004) pp500- 501.

In the context of this paper this means understanding the role of the in the specific sectoral context. It requires understanding any system failures which may affect that role and then in turn contextualizing it in a specific spatial context. Empirical attempts at developing sector typologies have suggested that some sectoral systems are more firmly rooted in publicly funded science-based sources of knowledge for innovation as compared to say supplier and customer based sources.

For example Malerba (2018) and Fontana et al (2015) use factor and principal components techniques on a large European firm dataset to identify distinctive sectoral system groupings. This set includes a *distributed science and technology knowledge sectoral system*'. This sectoral system of innovation is of most relevance to the topic of this report. It is one in which:

> "*a wide variety of knowledge sources are relevant and in which networks complement new firms' internal activities in order to create, integrate and distribute knowledge within a context characterized by medium or high R&D intensity. Here the sources of knowledge for business opportunities are universities, public research organizations and external R&D, and the benefits from networking come from accessing complementary assets related to distribution channels, assistance in obtaining funds, advertising and promotion, developing new products and services, managing production and operations, arranging taxation and exploring export opportunities. Formal agreements are quite common and refer to R&D agreements, research contracted out, technical cooperation and licensing. Relatedly, the methods of IP protection cover a wide range of instruments, from tacit to codified and formal (such as patents, trademarks and copyrights), to informal (such as lead time advantages and complexity of design). Many high technology manufacturing sectors such as telecommunications, computers, medical devices and chemicals are part of this group".*
>
> Malerba (2018) p.38

3.4 Technological Systems

A technological system of innovation may be defined as

> *"a network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse and utilise technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks."*
>
> Carlsson and Jacobsson (1997a).

Technological systems may be international in character but may also have strong national, or other place-based characteristics.

Technological systems may also vary in the extent to which they are more or less closely related to developments in particular sectors and are, hence, more or less closely linked to the evolution of sectoral innovation system patterns discussed above (Malerba and Orsenigo, 1997). General Purpose Technologies are characterised by multiple cross-sectoral effects. The application, in particular, of digital technologies and related business models across many sectors can both threaten the viability of existing sectoral systems and provide opportunities for the development of new systems.

3.5 Innovation ecosystems

The systems approach has become associated, especially in the policy and practitioner literature, with a rapid expansion in the concept of innovation *eco*systems where the *eco* is introduced to suggest an evolutionary biological science analogy. This might seem nugatory given the roots of innovation system thinking in evolutionary economic modeling. The additionality and clarity of the concept have, indeed, become highly contested in the academic literature (see e.g. Gomes et al., 2018; Oh et al., 2016; Ritala and Almpanopoulou, 2017). The *eco* component, however, has roots in a separate stream of management literature focusing on the strategic management by anchor or focal firms of their access to external knowledge and their development of frequently vertically linked formal and informal collaboration in pursuit of value creation (Autio and Thomas, 2014; Iansiti and Levien, 2004; Moore, 1997).

The systems and focal firm strategic management roots are synthesized and developed in Fransman (2018). He defines an innovation ecosystem as consisting of

> "*a group of interdependent players and processes who together, through their interactions, make innovation happen. This innovation changes the products and services that are produced by the ecosystem. Over time the innovation ecosystem as a whole evolves, as do its players and processes, as the variety of new products and services produced are subjected to various selection forces, market selection being the ultimate selection mechanism. Those players who produce successful products and services are rewarded with increasing revenue, profit, and growth. …..At the same time, market selection provides players with important feedback that serves as an input into their subsequent rounds of innovation. In this way, over time, the innovation ecosystem further evolves and changes.*"
>
> Fransman (2018) p.62.

Fransman emphasizes the sectoral applications of this concept but emphasises that can as with the systems approach *per se* be applied across various system domains such as city or region or even grand challenge missions (Fransman, 2018). This approach has very close links to the sectoral and technological systems concepts we have discussed above but with a more explicit focus on the organization of the innovation process *per se* across agents and organisations. There is a less explicit assessment of the role of institutions in this definition but they are clearly implicit. As a result specific policy applications of the innovation ecosystems approach emphasise the importance of these institutional aspects, (see e.g. the ICT innovation ecosystems examined at length in Fransman (2010) (esp. Ch.6 pp 86) and Fransman (2014)).

The discussion above of agent interaction and institutional failures therefore apply equally to the ecosystems approach and in particular those mentioned in relation to sectoral systems.

3.6 Regional Innovation Systems

The regional innovation systems approach attempts to integrate the sectoral and technological systems approaches at a level of analysis which is below the national with a corresponding shift in policy emphasis and design.

The approach is predicated upon system boundaries which are identifiable in terms of spatially specific networks of actors and institutions. The sectoral position, capabilities, activities and interactions of these agents generate, import, modify and diffuse new technologies within and outside the region (for a recent review see Grillitsch and Trippl (2018)).

In this approach there is particular emphasis on characterising the regional institutional framework, and the regional processes of generating and diffusing knowledge through regional system linkages.

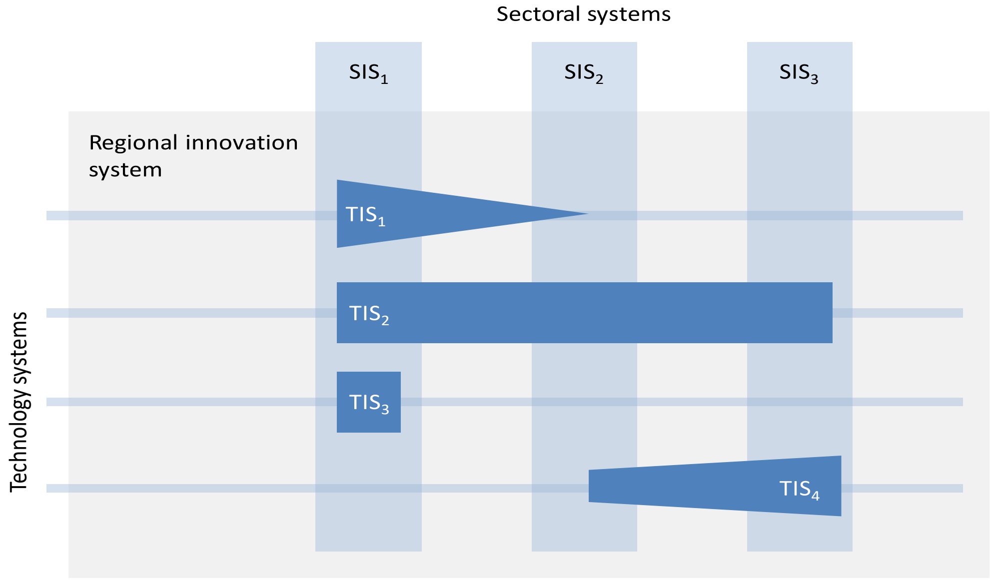
It presupposes that meaningful "regional" system boundaries can be identified. There is a substantial literature on the usefulness of the regional systems concept as opposed to more generic "place" based systems where, for example, boundaries may be drawn in a more scalar place-based fashion. These may locate the appropriate scale of place-based on bottom up quantitative and or qualitative analysis of actual patterns of interaction (see e.g. Uyarra (2010) Uyarra et al. (2010) and in relation to analogous literature on clusters NIESR et al. (2017)).

Assuming that appropriate regional or other boundaries can be drawn the overall capabilities of a place to engage in innovative and organisational processes and to co-evolve appropriate institutional changes may then be analysed. This encompasses: the capacity of a place to implement new technologies; the degree to which the capabilities of a place's actors co-evolve, and are able to adopt and exploit new technologies; and the decline and emergence of new sectors. Since each sector and technology within a place may be part of SSIs and TSIs extending beyond that place some attention must be paid to how they intersect[1].

Figure 1 is an attempt shows how a place (in this case a region) may consist of overlapping sectoral and technological system domains. In this schematic TIS2 may be thought of as general purpose technological system drawn on by each of the three sectors shown. TIS 2 is more specific and in this region is linked only to sector 1. Technology systems 1 and 4 span two sectors to different degrees. Sector 1 overlaps with the general purpose TIS2 plus TIS1 and TIS3 and so on.

[1] This is analogous to the problem for analyzing distinctive national systems of innovation in the face of globalized TSIs and SSIs (see e.g. Fransman, 2014; and Hughes, 2012).

Figure 1 Schematic of interrelationships between different types of innovation systems in a region



It is important to note that as a result of the increasingly global nature of both SSIs and TSIs each may operate across multiple regions and nations and may, and most likely will, operate across several regions and indeed nations.

It follows from this regional level schema that a place-based innovation policy requires deep knowledge of both SSIs and TSIs within and outside a region. It also follows that such policies must not prevent or hamper extra-regional networks and interactions from being created.

A science policy aimed, for example, at reducing inequalities between regions must be based on a clear understanding of the actual and potential role of universities as actors in these overlapping SSIs and TSIs in particular regions and the place of that region in the national and international aspects of those systems[2].

3.7 Sectoral and Technological Maturity, Smart Specialization and Policy Design

The evolution of technological and sectoral systems is frequently a long term process covering decades to maturity. The stage of development of the technological or sectoral system is critically important in relation to the extent and nature of policy interventions. Policy may be particularly important in the early stages of their evolution and in later stages when the objective is to diversify away from an existing mature sectoral base.

In the case of reacting to sectoral decline the prime focus is to develop systemic ability to create diversification into more potentially dynamic sectors and to access related technologies. This is essentially a policy based on creating new options (Carlsson and Jacobsson, 1997b).

Much recent work in this vein has focused on the nature of such transitions and diversification away from declining sectors. This literature has debated, in particular, the claimed benefits of developing

[2] Or in helping to lay the foundations of an SSI or TSI in a region where no effective system currently exists.

sectoral diversity and the relative merits of diversification into sectors and technologies with more or less close links with the pre-existing sectoral and technological structure (Boschma and Iammarino, 2009; Frenken et al., 2007; Grillitsch and Trippl, 2018; Neffke et al., 2011; von Tunzelmann, 2009).

One particularly influential structural diversification approach has been the promotion of "smart specialization" and the requirement to make EU place-based policy support conditional on embedding such restructuring in specified overall regional strategies (Foray, 2014).

Smart specialization has been defined as

> *"a process of priority-setting in national and regional research and innovation strategies in order to build "place-based" competitive advantages and help regions and countries develop an innovation-driven economic transformation agenda"*
>
> Landabaso (2014) p.378. (quoted in Grillitsch, 2016)

At the heart of this approach is the notion that in a regional or place-based context sufficient scale for global competitive advantage requires the identification and development of niche production areas in which to specialize. The selection of areas is seen as drawing on the generation and combinations of private and public sector knowledge sources to identify new innovation opportunities. This must be accompanied by a process of investment to exploit these opportunities and then, through agglomeration effects and firm growth dynamics to develop the system capabilities to sustain competitive advantage in these niches and hence the region as a whole.

The potential role for universities in this approach lies both in the identification of new knowledge based opportunities and in their co-evolution into commercial practice with the local or regional private sector agent base. This "entrepreneurial" bottom up approach is seen as preventing the problems of capture by vested interests associated with old fashioned industrial policy picking winners.

The smart specialisation approach places great reliance on the thickness of the networking and interaction links which exist or can be developed between agents including universities in the system. It also depends on the ability of the existing institutional architecture to support such interactions (see e.g. Grillitsch, 2016; and Grillitsch and Trippl, 2018). There is also an implicit assumption of appropriate regional or other place-based governance structures within which to develop and embed such strategies. It has been argued that the UK is singularly deficient in this particular respect (see McCann, 2016). These are familiar areas of potential system failure that we have outlined earlier.

Technological and sectoral systems failures may inhibit the ability of all agents to be near the best practice frontier as well as for the system as whole to remain innovative. A further issue for system policy is therefore the diffusion of existing best practice. The problems may be especially acute in sectoral systems experiencing rapidly changing scientific and technical change. Systems failure based policies concerned with reducing the dispersion of performance are primarily focused on creating bridging institutions and other activities to strengthen an existing system. The objective is to enhance diffusion of best practice.

The implication of this literature is the diversity of place-based system characteristics and hence the granular nature of place-based policy design. Place-based systems will vary in terms of: the capabilities of agents to engage in innovative processes; the nature and strength of the institutional architecture; the particular combination of sectors and technologies and their degree of maturity; and the overall development path of the place. As a result attempts have been made to identify different types of RIS which exhibit certain combinations of features and types of system failures.

For example, in relation to regions Grillitsch and Trippl (2018) adopt an empirically driven approach to identify three types. The first type is a group of organisationally 'thin' RISs in peripheral regions, characterised by the lack of a critical mass of strong agents in related fields. The second type is a group of organisationally thick and specialised RISs typically characteristic of old industrial regions. These face major challenges to diversify and renew their economic structures and innovation systems. Finally the third type is a group organisationally thick and diversified RISs. These contain a variety of sectors at different points in their industrial lifecycle, and a diversity of system agents. This leads to heterogeneity in locally available competences and resources across sectors. These different RIS types are then argued to exhibit different forms of potential system failures and hence different objectives for policy design. Whatever the merits of this particular typology a crucial insight of this approach for place-based policy development is that there is no 'one-size-fits-all' policy response. Interventions need to be tailored to the specific system challenges and failures faced by a given (type of) region (Grillitsch and Trippl, 2018; Tödtling and Trippl, 2005). This general argument applies also in the specific case of university research-engaged place-based innovation policy and we return to this in more detail in Section 5.

3.8 Systems Policy Design

The systems approach has important implications for policy *implementation and design* as much as for the choice policy instruments *per se*. The bureaucratic and informational constraints on the exercise of system based innovation policy are substantial and are the same as those required in developing system based industrial policy more generally.

Crafts and Hughes following Rodrick (2008) identify three key elements to systems based policy design. The first of these is "embeddedness". Policy development needs to be embedded in private sector networks in order to draw upon and connect with and between information sources in that sector and the public sector.

> *"the government has only a vague idea at the outset about whether a set of activities is deserving of support or not, what instruments to use, and what kind of private sector behaviour to condition these instruments on. The information that needs to flow from the private sector to the government in order to make the appropriate decisions on these are multidimensional and cannot be communicated transparently through firms' actions alone. A thicker bandwidth is needed."*
>
> Rodrik (2008) p.26

This approach entails "strategic collaboration and coordination between the private sector and the government" (Rodrik, 2008, p. 2). This needs to be designed to uncover significant system failures and to learn from mistakes as the policy evolves. Policy is thus a process of learning and discovery.

The second feature of policy design is to ensure the weeding out of investments that fail or activities that become "honourable dead-ends" (Rodrik, 2008). Policy makers and the political system must accept a failure rate consistent with the underlying riskiness of the activity being supported.

Thirdly policy design must include full public accountability for any resources committed and an integrated system of evaluation to ensure both staged weeding out future policy development.

In essence policy is based on a real options approach.

4 Capturing Value Added in Place-based Systems Policy

A further essential factor for place-based policy analysis is how to identify sectoral and technological systems whose development in a nation or region will yield value added for that place as opposed to its appropriation by agents outside of it. Although a central part of understanding the distribution of system outcomes across agents, and hence places, this aspect is rarely explicitly discussed in regional policy discussions or industrial policy more generally (Hughes, 2012; Hughes and Spring, 2017).

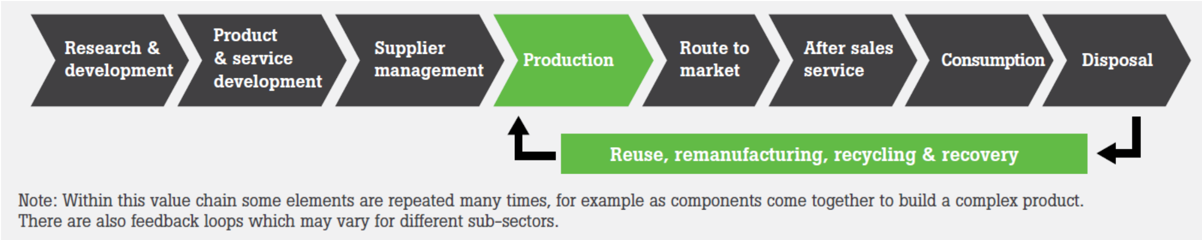
Value is added at each stage of the process by which economic activity converts factors of production, raw materials and energy in to the final value of output. The sum of value added captured by a particular region relative to its input determines it productivity. A place-based science policy designed to reduce inequalities between regions must therefore take account of the spatial pattern of value appropriation arising from any intervention.

As Crafts and Hughes put it in their discussion of industrial policy

> "*Globalization entails reductions in trade costs and increased international mobility of capital. A major implication is that the relative attractiveness of locations that business chooses for different stages of production in the value chain including manufacturing may change over time. Indeed, a notable feature of the past quarter century has been the rapid expansion of 'vertically-specialized' trade where value added to the final product sold to the consumer has been built-up in a series of different locations perhaps in several countries (Yi, 2003). Linked to this has been the so-called '2nd Unbundling' in which technological change, especially in terms of ICT, has made it possible to disperse production stages that previously had to be performed in close proximity (Baldwin, 2006).*
>
> *These developments have implications that change the optimal composition of industrial policies compared with the less globalized world in the earlier technological era of the 1970s (Baldwin and Evenett, 2012). First, with regard to selective industrial policies, it may be necessary to re-think the notion of giving support to particular manufacturing sectors and think instead in terms of interventions targeted at stages of production in a value chain. Second, the increased mobility of some factors of production means that it may be important not only to consider externalities but how far these will be internalized to the UK. This means that compared with earlier times, the weight of subsidy should tilt towards 'high-spillover, low-mobility' factors – for example, horizontal policies should emphasize human capital rather than transferable technology."*
>
> Crafts and Hughes (2013) p.33

The argument can be illustrated in relation to manufacturing. Figure 2 shows a simplified manufacturing value chain.

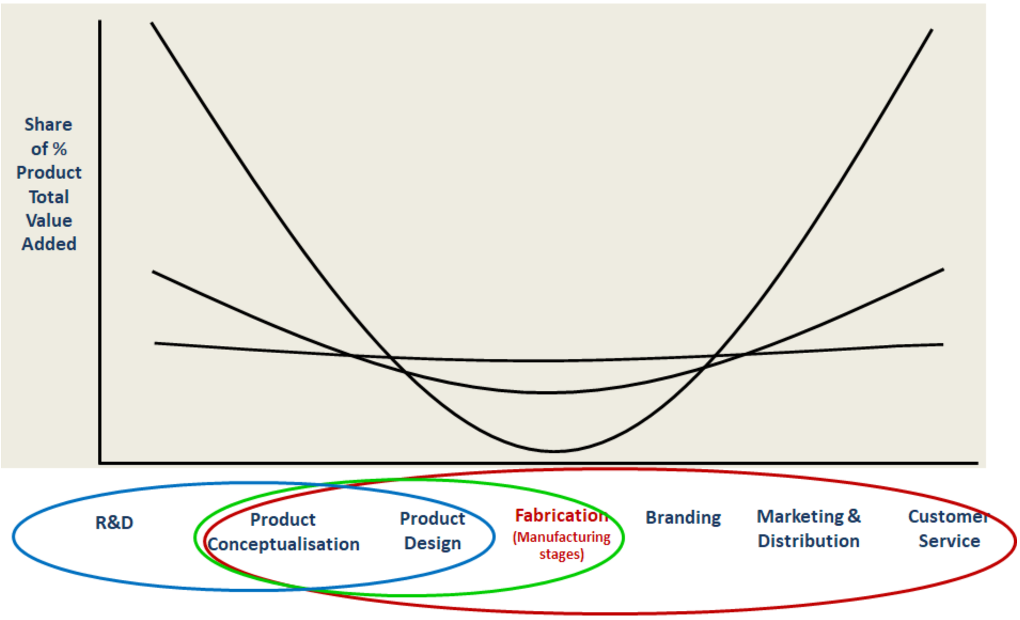
Figure 2 Simplified model of a manufacturing value chain



Source: UK Government Office for Science (2013) The Future of Manufacturing: A New Era of Opportunity and Challenge for the UK. UK Government Office for Science, London, UK.

Figure 3 plots the distribution of total value added across various value chain stages. The flattest curve shows a case where value is added more or less evenly across all stages. The more U-shaped curves show cases where higher shares of value are added at the early R&D and later customer sales and service stages. The ellipses at the foot of the table show possible business model combinations. Adding and capturing value at the extremes in these cases is more valuable than production *per se* in the middle of the chain.

Figure 3 Value chains and business models



Source: Crafts and Hughes (2013)

The geographical dispersion of these stages, and the identity and location of those creating and appropriating value at each stage, must be key features for policy development in relation to any SSI with a footprint in a specific place or where a new SSI is to be developed in that place.

This raises a number of important questions. First, can high value added share stages with local value appropriation be attracted to and remain "sticky" within a Regional Innovation System. Second, are there stages where co-location generates superior innovation and business performance (whether or not they need to be owned by the same business). Third, is it possible to maintain innovative activities and system performance in a given place if for example production is extra-regional or offshored.

In relation to the first point broad spectrum policies are needed. As Crafts and Hughes (2013) put it

> *“Perhaps most important of all is to recognize the value of increasing the ‘stickiness’ of economic activity by making alternative locations less good substitutes. This results from advantages that cannot easily be replicated elsewhere. In particular, this suggests that policies to nurture successful agglomerations deserve a high priority. It may be appropriate for the British government to follow the lead of the Dutch (CPB, 2010) and consider what a successful portfolio of British cities would look like in future and how this can be underpinned. This calls for an approach different from that of traditional industrial policy with its emphasis on subsidies to physical investment or promoting particular manufacturing industries. Instead, it will be important to develop well-designed transport infrastructure and land-use planning policies. Unfortunately, these are areas in which British policies leave a lot to be desired”.*
>
> Crafts and Hughes (2013) p.33

On the second and third issues it is possible to indicate which forces may be most important in predisposing stages to be co-located and the need to keep production physically close to the other stages. An important question here is: are there value chains where businesses can remain innovative even if the production process is located overseas or extra regionally? In other words are “innovate here produce there” business models sustainable and what are the implications for policy in a regional innovation system if in some SSIs they are not. (Bonvillian, 2017; Pisano and Shih, 2012). There is, for example, some evidence for the USA that corporate patenting (as a proxy for innovation) has fallen where manufacturing employment has been relocated overseas (Autor et al., 2016).

Identifying the factors which determine more generally where it is necessary to co-locate stages is therefore an important task for a regional systems policy. Hughes and Spring (2017) have provided a concise review of these factors and their summary may be reproduced here.

> *“A number of factors have been identified which may help in this identification process. They centre on the interplay between product and process innovation and the degree to which the former can be physically separated from the latter without reducing overall innovation capacity. When design is closely integrated into the production process then co- location of research and production will be required for effective innovation. This is the case for example in a range of biological and advanced materials production processes. Where it is difficult to predict the relationship between new product development and process innovation then co-location may be essential because of the need to have “intense iteration between product and process development and feedback during actual production” (Pisano and Shih, 2012, p. 65). The desire to combine close-to-market customization and mass production by designing plants and plant scheduling may also make high wage cost locations feasible (Ketokivi et al., 2017).*
>
> *Where the stages in the value chain are closely coupled in these ways and when there is a close connection between specific customer requirements and production characteristics*

(e.g. customised production), then co-location will be at a premium. This will be reinforced when coordinating relationships between different business entities along the value chain cannot be easily captured or formalised by simple pre-established rules (de Treville et al., 2017; Ketokivi et al., 2017). In these cases, offshoring production may lead to R&D and design also moving abroad to maintain innovative capacity. This could lead to high-wage, high-skill jobs following the low-wage, low-skill jobs offshore, and the capacity for future domestic innovation being irreversibly lost."

Hughes and Spring (2017) pp. 9-10.

The coupling, specificity and customising characteristics of value chains are therefore key ingredients in defining both SSIs and their regional footprints and hence the basis for policy intervention generally and for science policy to influence or develop the role of HEIs in a specific place-based context.

5 Universities in local innovation systems

5.1 Capturing the roles and contributions of universities in local innovation systems

Our discussion of types of system and system failure has included drawing out some general policy principles and the implications for a place-based science policy aimed at reducing regional inequality. In this section we focus on the system role and contribution of Universities in more detail at a conceptual level and summarise relevant UK empirical evidence. In doing so it is important to bear in mind that, in general terms, universities are far less frequent and important as sources of information for innovation than other innovation system agents such as customers and suppliers. (e.g for the UK and the US see Cosh, Hughes and Lester (2006) and for the UK Hughes and Kitson (2012)). This not to say that in some sectors they may be more important than in others. Rather it is to keep in mind that relationships between universities and industry must always be seen as part of a wider system of interactions. Moreover in thinking about the pull of universities in business location decisions, or as part of perceived benefit of being in a particular region, they frequently lag behind other factors such as the availability of skilled labour or the presence customers suppliers and other firms in the same line of business (Hughes, 2011).

Given these caveats there are a number of reasons for thinking universities may have a potentially distinctive role within a local innovation.

As major employers of highly skilled labour and owners of major physical and cultural assets they are quantitatively significant agents in a local system and are often the main knowledge producing organisation in a local economy.

Universities as *agents* in local systems have some other particular characteristics. They are typically stable, and (once we move beyond commercialisation *per se*) relatively neutral environments for agent interaction. These characteristics of universities may provide a conducive environment for catalysing *interactions* within the innovation system, including between academics and innovators as well as between innovators in different parts of the value chain. These often informal, non-transactional and people-based system interactions may help to bridge disconnected or weakly connected actors in the innovation system and develop common interests, and may lead to more formal activities (Hughes, 2011).

Through deploying their knowledge and physical assets in *interactions* with other local agents they have the potential to make important contributions to the local innovation system, both in addressing specific technical and business needs, and in helping to strengthen the underpinning systemic pattern of innovation (Gunasekara, 2006; Lester, 2005; Power and Malmberg, 2008; Ulrichsen, 2015).

The extent and "thickness" nature of these interactions will influence the extent to which the contributions of universities stretch well beyond those enabled through increasing the stock of knowledge through publications and educating the labour force of the future. Through more direct linkages with universities, firms may be able to develop and enhance technologies and capabilities that feed into their innovation processes at different stages of the value chain, from early stage technology development to scale-up, production, logistics, marketing and sales (Bercovitz and Feldman, 2007; Cohen et al., 2002; Hughes and Kitson, 2014; Lee, 2000). These linkages touch many sectors of the economy, stretching well beyond manufacturing and product driven sectors to include service-based and public sectors (Cohen et al., 2002; Hughes and Kitson, 2014; Laursen and Salter, 2004; Salter and Martin, 2001).

Universities may also have a role to play in strengthening wider *system and agent capabilities* (Breznitz and Feldman, 2012; Gunasekara, 2006; Ulrichsen, 2015; Uyarra, 2010; Youtie and Shapira, 2008). Examples include: working locally to develop the underpinning skills and physical innovation infrastructure critical to the functioning of the system; informing the development of local economic and innovation strategies; working alongside key stakeholders to provide local leadership. This in turn may be closely linked to the co-evolution of *institutional architectures* designed to shape people's innovation-related behaviours and activities. This may include altering the norms associated with career progression in universities to incorporate knowledge exchange activities or altering HEI research quality assessment or strategic focus to include local "impact".

There is a large literature examining these roles. Of particular relevance to this report, is research analysing the role of university-industry proximity in relation to locally clustered science and technology based sectors and firms.

One stream of this literature has stressed the importance of geographical proximity for "local" knowledge spillovers. This has led to an emphasis on science-based cluster analysis and policy design (Acs et al., 1992; Adams, 2002; Ponds et al., 2007). The significance of spillover effects *per se* may however be overestimated (Breschi and Lissoni, 2001) and alternative explanations of clustering independent of spillovers have been advanced. These have, for example, emphasised agglomerations based on an intra sector pattern of spin offs and learning from originating or pioneer firms as the sector evolves and matures rather than spillovers (see e.g. Golman and Klepper, 2018).

Other factors may also mitigate against the importance of spillovers based on geographic proximity. For example, proximity in other terms (e.g. technological, scientific, or organisational) between firms and universities may lead to the sourcing of knowledge outside a university's or firm's "home" region (e.g. D'Este et al., 2013). The importance of geographical proximity to a knowledge source may also vary with the type of research knowledge sought by the firm. Thus a survey of Swedish firms showed that geographical proximity mattered when research collaborations were focussed on short-term incremental outcomes, but that collaboration of a longer term more exploratory nature were more frequently undertaken with overseas universities (Broström, 2010).In general terms geographical proximity is thus neither a necessary nor a sufficient condition for spillovers to occur (Boschma, 2005).

The contributions enabled through KE interactions are also dependent on the underpinning knowledge base available within the institution. The knowledge base varies between universities along a number of dimensions (e.g. discipline, quality, distance from application). Where and how universities make system contributions through KE will vary accordingly. In addition, KE interactions will be affected by the social capital (networks) of academics and the physical assets of the university (lab-space and other facilities, equipment, innovation spaces etc.).

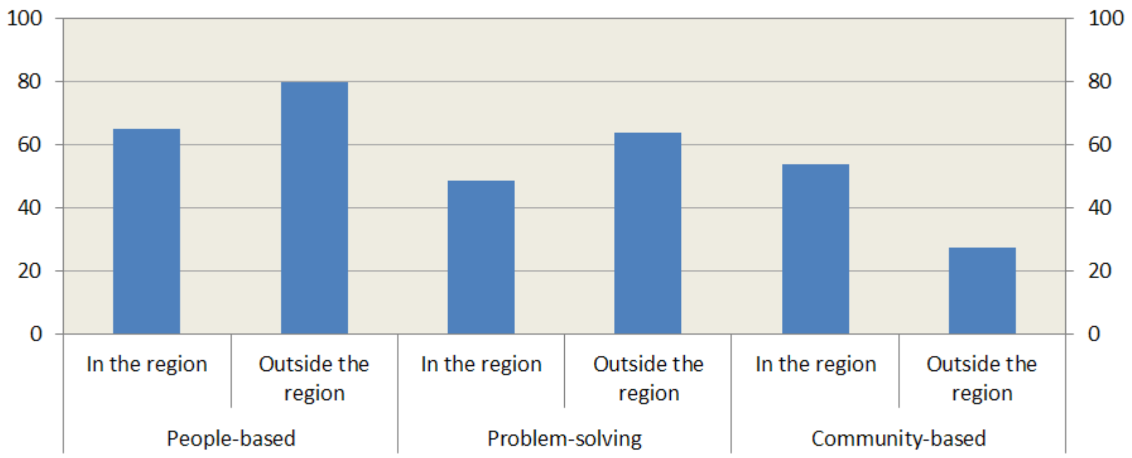
In the light of these considerations it is perhaps not surprising that the link between research excellence and industry clustering based on proximity effects in the UK is mixed. Abramovsky and Simpson (2011) show that in bio-science firms are liable to locate close to universities with departments, especially high quality departments, in related areas of science. For that sector proximity in a geographical sense maps into scientific proximity. They also found, however, that in many other industries there was little evidence that geographic proximity was a key factor in determining patterns of university industry collaboration.

This kind of variation in pattern is revealed in other UK research. Thus in a study of EPSRC funded university-industry collaborations D'Este et al. (2013) found that university industry geographical proximity was less important where a collaborating firm was part of a cluster with strong technological inter-firm collaborative structures and where the firms themselves had strong technological complementarities. In these circumstances university links were more often sought *outside* the geographical cluster. In a related study using the same type of data and sample, Laursen et al. (2011) found that UK firms, more generally, prefer collaborations with distant (including international) high quality universities over collaborations with low quality universities located nearby. Thus quality mattered more than geographical proximity.

There is ample evidence to illustrate the diversity and specificity of roles across places and types of university in the UK.

Although the abolition of the binary divide between technical colleges and universities the UK has had a relatively undifferentiated HEI sector in terms of functional category considerable differences between universities remain. These in turn may be associated with the potential to fulfil different roles in a regional or local system.(Howells et al., 2008; Hughes and Kitson, 2012; Ulrichsen, 2015; Uyarra, 2010). These differences may be based on the specifics of their knowledge base, physical assets and social capital available, the strategic priorities and ambitions of the university leadership, and the viable engagement opportunities in their locality which they may undertake.

Figure 4 **Universities and Place-based focus: People-based, problem solving, and community based activities by academics within and outside the region of their HEI (% of respondents)**



Source: Hughes, A., Lawson, C ., Kitson, M. and Salter, A. (2016)

Ulrichsen (2015), for example, showed that different universities vary in the extent to which they strategically prioritise their region in their KE activities, with less research intensive institutions more likely to be regionally focused than their research intensive counterparts. Figure 4, drawn from Hughes et al. (2016) and using their 2015 large-scale survey of over 18,000 UK-based academics, shows that more academics engage outside their region than within it for both people-based and problem-solving interactions. That said, over 60 percent of academic respondents to their survey had people-based interactions within their region and just under 50 percent had intra-regional problem-solving interactions.

Figure 5 **Universities and Place-based focus: People-based, problem solving, and community based activities by academics at different types of HEIs within and outside the region of their institution (% of respondents)**

Regional engagement activities by academics by type of institution (% of respondents)

	People-based		Problem-solving		Community-based		Total
Institution Type	In the region	Outside region	In the region	Outside region	In the region	Outside region	(N)
Top-decile research institutions	58.9	81.8	44.1	67.3	50.4	28.4	6504
Other older universities (est pre-1992)	62.0	80.2	45.7	64.6	51.8	28.4	6086
Younger universities (est post-1992)	75.7	76.8	57.5	57.3	59.6	24.2	5004
Specialist institutions	67.6	82.8	55.6	68.4	58.8	36.5	583

Source: Hughes, A., Lawson, C ., Kitson, M. and Salter, A. (2016)

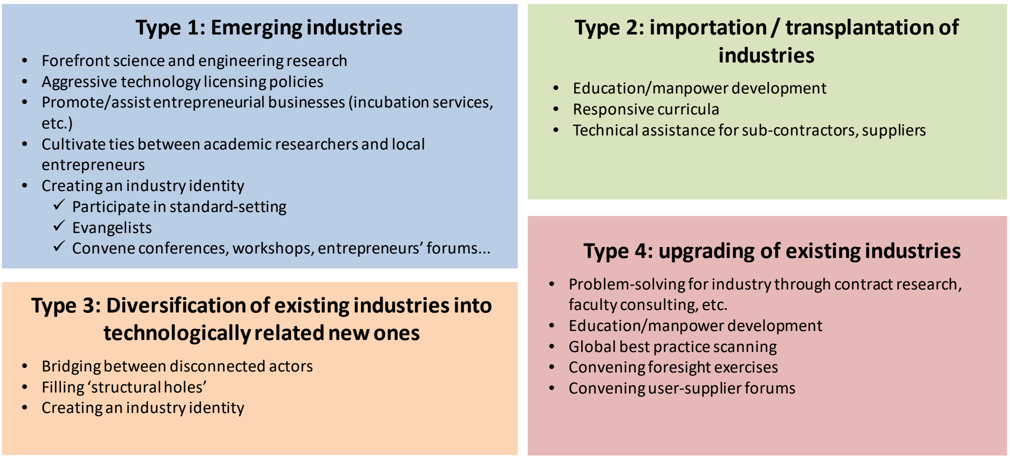
Comparing different types of universities (Figure 5) – also drawn from Hughes et al. (2016) – shows that academics at younger universities are much more likely to interact within their regions (across all KE categories) than those at top-decile research institutions and other older universities. It also shows that people-based activities tend to be more regionally focused than problem-solving interactions across all types of institutions.

These cross institution patterns are important in thinking through place-based policies linked for example to research excellence such as the emergent SIPF. This is not least because the share of total science policy based research funding is heavily skewed towards the top decile of UK HEIs (Table 6 in section 6).

In the face of this diversity one way forward in the context of this report is to see if a "ideal type" pattern of university industry collaborative patterns may be identified linked and linked to specific local industrial development contexts. Using an inductive case based approach one study in the USA has led to the identification of such a typology. In this research the role which universities may play and the interaction pathways used are seen to depend critically on the nature of industrial transformation within a local system (Lester, 2005).

Four 'idealized' types of industrial transformation are identified: *local creation* of a new industry (e.g. based on major technological advances in the local economy); the *importation and transplantation* of industries into a local economy from elsewhere (i.e. not based primarily on technology generated locally); the *diversification of existing* local industries in decline into technology related areas; and the upgrading of industries for example through the introduction of new production technologies or new product or service enhancements (Lester, 2005). These types of system strategies have obvious links to and implications for our earlier discussion of regional system change and diversification and the debate for example on smart specialization.

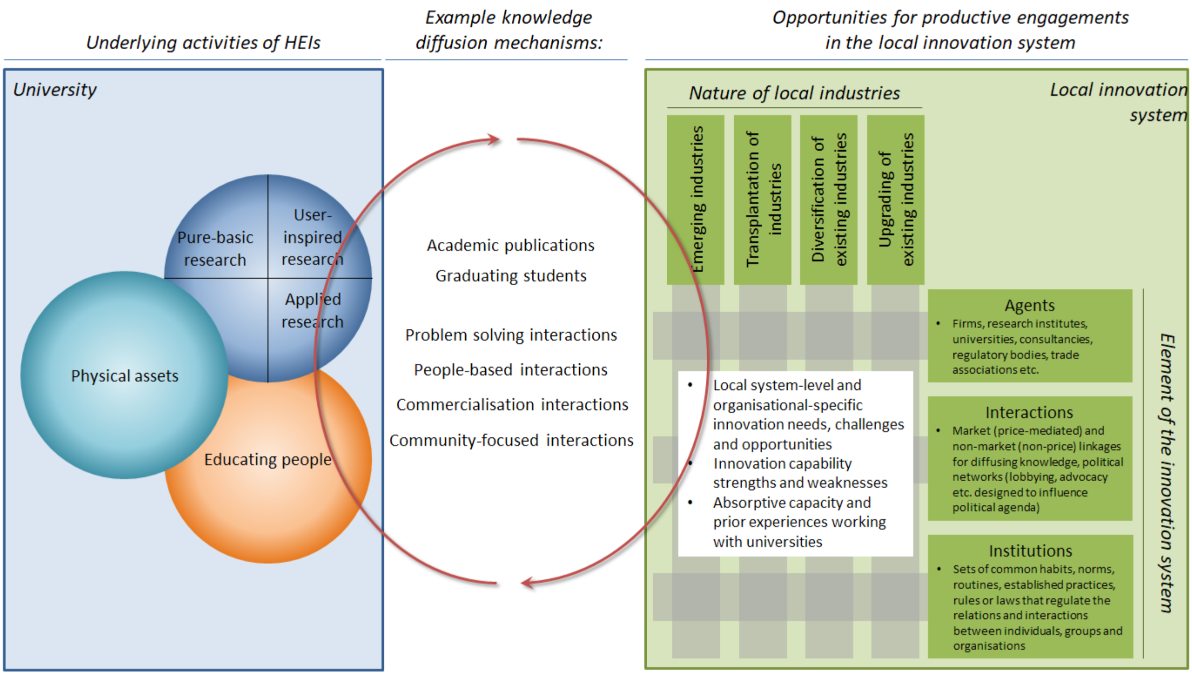
Figure 6 Contributions by universities to local industry



Source: Lester (2005)

The detailed cases reveal significant differences in how universities contribute as agents in themselves; their patterns of interaction with other agents; and the institutional architectures which hinder and help the innovation process. For example, universities are seen as more likely to contribute to emerging industries through the application and commercialisation of the latest scientific and technological developments (e.g. through technology licensing, spin-outs or collaborative research), working with partners to develop industry identity and legitimacy, and developing standards. By contrast, universities in areas with industries that are seeking to upgrade are more likely to contribute through problem solving activities, provision of training, and helping firms identify global best practice. Figure 6 provides a summary overview of the 4 ideal types. From the point of view of this report Type 1 and 2 and especially Type 1 seem most relevant in thinking though policy development.

Figure 7 Positioning universities in a systems context



Source: developed by the authors

Given the links between local strategy and interaction pathway it is useful to try and map out the more general positioning of universities in a local innovation system and industrial development context. Figure 7 attempts to do this. It highlights the importance of different types of research in generating new knowledge to add to the stock available for exploitation through KE; the role of HEIs in educating labour; and the physical assets developed by the HEI. It also highlights some key characteristics of a local innovation system –in terms of the actors, linkages and institutions, and the nature of industrial transformation at play in the local system. Each of which we have seen can shape the nature of the opportunities for productive engagements.

6 Spatial Disparities in Productivity and Innovation across the UK

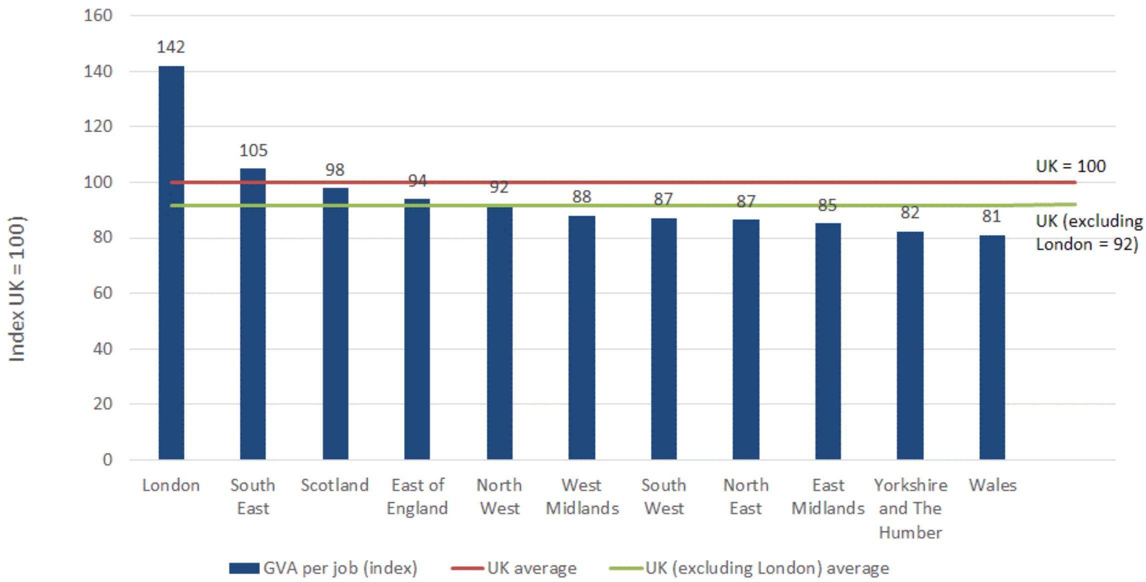
We now turn to an empirical assessment of the key motivator for developing place-based research and innovation funding in the UK as part of the emerging industrial strategy, namely an ambition to reduce the significant spatial disparities that exist in productivity and economic performance across the UK (HM Government, 2017). This provides important context for our discussion around the development of place-based funding for research and innovation in the UK. We review the evidence on UK regional productivity disparities and innovation performance. We further examine how productivity varies at the sub-regional level. This disaggregation recognises that regions comprise of many cities and other urban and rural areas, and a region-level analysis may mask important intra-regional disparities. Recognising the importance of cities in innovation and economic development, we focus distinguish in our analysis large cities from smaller urban areas and rural communities.

This analysis serves as the backdrop against which we map the distribution of the UK stock of HEIs and their funding flows against the same spatial dimensions (section 6), and consider the implications for the development of place-based research and innovation funding that seeks explicitly to reduce spatial economic performance disparities (section 7).

6.1 Productivity and innovation variations across the regions and nations of the UK

Figure 8 presents the nominal gross value added (GVA) per job – a proxy for labour productivity - in 2016 by region. It highlights the particular strength of the Greater South East GSE (London, the South East and the East of England) and Scotland in terms of the level of productivity. It also highlights the singular outlying nature of London. Productivity exhibits relatively less variation in the aggregate across the remaining regions but even so the North East for example is 13% below the UK average and Wales 19%.

Figure 8 Nominal gross value added per filled job by region, 2016

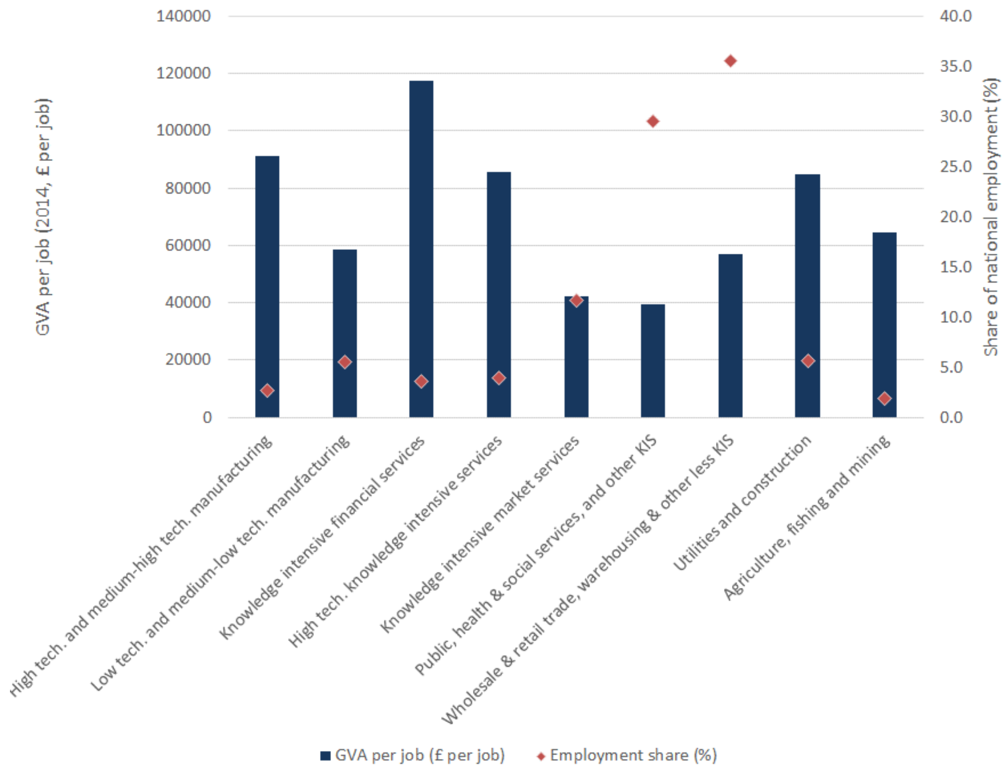


Note: unsmoothed series
Source: Subregional Productivity: Labour Productivity (GVA per hour worked and GVA per filled job) indices by UK NUTS2 and NUTS3 subregions, UK Office for National Statistics

One possible explanation for these productivity variations could lie in the differences in the sectoral composition across regions. Figure 9 shows that productivity does vary significantly by broad sector. Higher technology manufacturing sectors, knowledge intensive financial services and high tech knowledge intensive services generate much higher GVA per job than other types of sectors[3].

[3] We use here for consistency the categorisation developed by Eurostat and used in recent ONS studies to distinguish the manufacturing industries and service sectors based on their technology and knowledge intensities.

Figure 9 Gross value added per job and share of national employment by sectoral grouping, 2014



Source: UK input-output analytical tables available from the Office for National Statistics at https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

Table 1 presents the industrial composition of the regions and nations of the UK using the same broad groupings. Some important sectoral differences across the regions emerge which could have implications for aggregate regional productivity. For example, it shows the particular concentration of manufacturing (both higher and lower technology) outside the GSE; the concentration of high-technology knowledge intensive services in the GSE; and the particular dominance of the high GVA-per-job knowledge intensive financial services in London. It is also revealed that outside London most regions have a similar share of jobs in less knowledge intensive services. This table also highlights that the GSE employs more people in the private sector compared with other regions. These sectoral differences imply quite different SSIs and TSIs between GSE and other regions. This in turn implies potentially very different value chain structures as an object of policy analysis.

The relative importance outside the GSE of lower technology manufacturing, and the other and less knowledge intensive service sectors (which are relatively low productivity sectors), may be a factor in differences in productivity levels across regions. Estimating the quantitative impact of these differences, however, involves going beyond inspection of these tables. A recent 2018 study by the UK Office for National Statistics (ONS) (Office for National Statistics, 2018) attempts to do this using an albeit different level of disaggregation.

Table 1 Industrial structure by UK region, 2016

Local economy		Region											Total
		North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland	
Total jobs (000s)		1,071	3,346	2,421	2,132	2,588	2,803	5,144	4,277	2,550	1,330	2,585	30,251
Breakdown by (%):													
Manufacturing	High tech. and medium-high tech. manufacturing	4.4	3.2	2.1	3.2	4.4	2.6	0.4	2.5	3.5	3.2	1.9	2.5
	Low tech. and medium-low tech. manufacturing	6.2	6.5	8.0	9.3	7.2	5.1	1.8	3.7	5.2	7.6	5.0	5.3
Knowledge intensive services (KIS)	Knowledge intensive financial services	2.1	2.9	2.8	1.4	2.3	2.3	7.6	2.8	3.4	2.1	3.2	3.5
	High tech. knowledge intensive services	2.7	2.6	2.7	2.2	2.6	4.1	7.3	6.2	3.3	2.3	3.0	4.1
	Knowledge intensive market services	8.1	12.1	10.4	12.1	10.2	12.9	20.4	11.6	8.9	6.5	8.8	12.3
	Public, health & social services, and other KIS	34.8	29.6	30.8	27.3	28.9	27.2	24.7	28.0	29.6	33.8	32.8	28.8
Less knowledge intensive services	Wholesale & retail trade, warehousing & other less KIS	35.3	36.6	35.4	36.2	37.5	37.5	33.5	37.7	36.7	33.2	34.3	35.9
Other	Utilities and construction	5.1	5.3	6.0	6.3	5.1	6.6	4.2	6.3	6.6	6.7	6.8	5.8
	Agriculture, fishing and mining	1.3	1.2	1.8	1.9	1.8	1.7	0.1	1.2	2.8	4.6	4.1	1.7
Breakdown by (%):													
Public / private sector	Employment in the public sector	24.0	22.9	23.4	20.9	21.1	20.6	19.4	19.9	22.1	27.1	26.2	21.9
	Employment in the private sector	76.0	77.1	76.6	79.1	78.9	79.4	80.6	80.1	77.9	72.9	73.8	78.1

Sources: Sources: ONS Business Register and Employment Survey 2016, extracted from Nomisweb on 31 July 2018 (open access)

The ONS study attempts to estimate the proportion of productivity differences across regions which may be accounted for by differences in sectoral composition. It also explores variations in productivity at the plant level within and across regions. The analysis does not cover the whole economy and only considers sectors and plants in the non-financial business economy. This unfortunately excludes the financial sector which is a major component of the economy of GSE. The results are nonetheless of some interest bearing that caveat in mind.

The authors of the ONS study conclude that differences in the non-financial industrial structure between regions have only a small effect on regional differences in productivity. In other words a low regional aggregate productivity level is not much due to having a preponderance of sectors which have relatively low UK productivity (they term this the industry composition effect). Rather, they find that there is a downward effect on productivity levels across all sectors within lower productivity regions. This is calculated to be due to having a preponderance of low productivity plants within each sector (they label this the firm productivity effect) (Table 2)

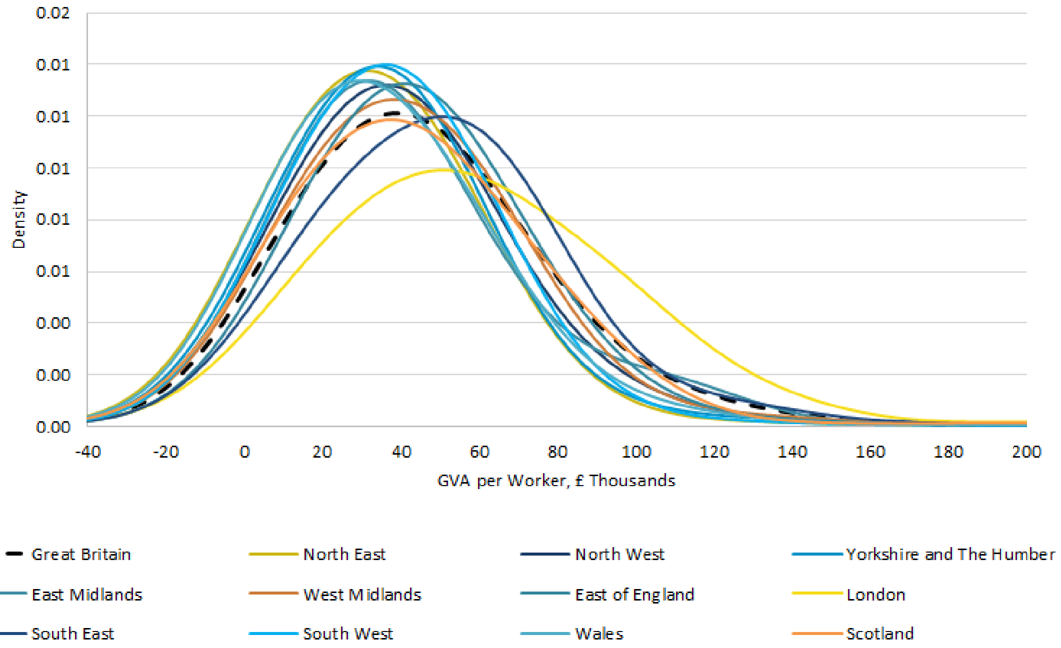
In exploring this issue further the study analyses the frequency distributions of plant-level productivity for each of the regions and nations of the UK (Figure 10). These distributions are skewed to the left reflecting the fact that relatively fewer firms are to be found at the high productivity end of the spectrum. It shows that London – and the North West to a lesser degree – exhibits a particularly large number of higher productivity plants in the non-financial business sector compared to other regions. In the other regions the distributions of plant-level productivity are more alike. This suggests that in those cases each has a roughly similar proportion of productivity 'leaders' and 'laggards'.

Table 2 Sources of aggregate labour productivity (gross value added (GVA) per worker)

	Aggregate Average Labour Productivity Index	Firm Productivity Index	Industry Composition Index	Aggregate Average Labour Productivity, Great Britain	Residual Covariance
North East	85	85	99	100	1
North West	91	91	99	100	1
Yorkshire and The Humber	84	85	97	100	1
East Midlands	78	80	100	100	-1
West Midlands	91	89	99	100	3
East of England	91	91	100	100	0
London	143	136	102	100	5
South East	107	105	101	100	1
South West	82	83	98	100	1
Wales	74	75	98	100	2
Scotland	99	93	103	100	3

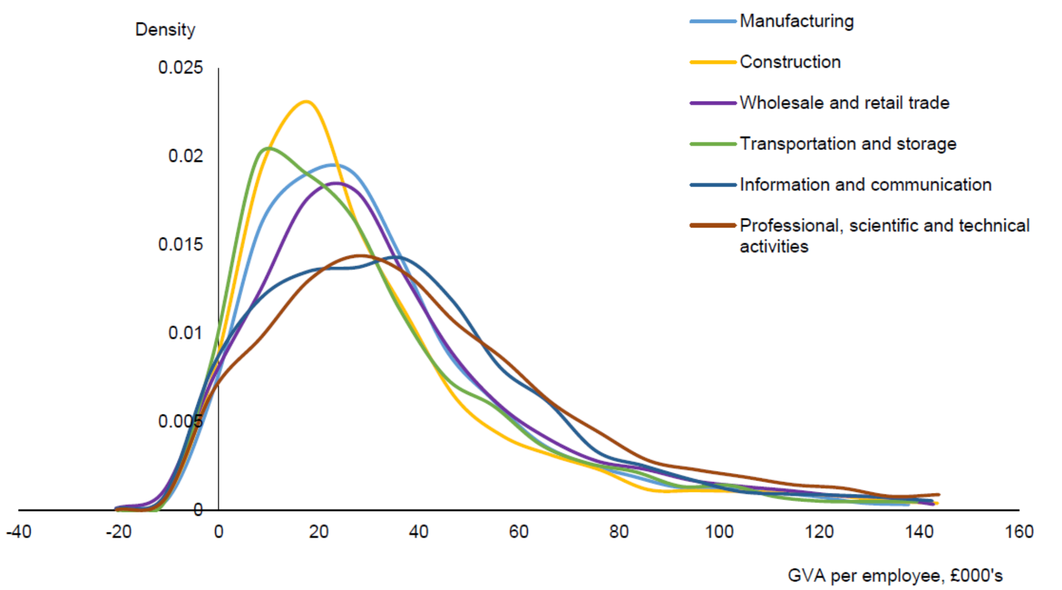
Source: Annual Business Survey, Office for National Statistics, reproduced from ONS (2018) Regional firm-level productivity analysis for the non-financial business economy, Great Britain: April 2018

Figure 10 Distribution of firm-level (local plant) productivity (gross value added (GVA) per worker), Great Britain regions and countries, 2015



Source: Annual Business Survey, Office for National Statistics, reproduced from ONS (2018) Regional firm-level productivity analysis for the non-financial business economy, Great Britain: April 2018

Figure 11 Distribution of firm-level productivity across sectors in 2013/14



Source: ONS; Bank calculations. Notes: This chart plots the kernel density distribution of labour productivity (real GVA per employee) across Great Britain. This work contains statistical data from ONS which is Crown Copyright. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

Source: reproduced from Haldane (2016)

Figure 11 shows similar frequency distributions by sector. The distribution is even more heavily skewed to the left with a small handful of plants at the higher levels of GVA. This set of decompositions is consistent with an earlier study that found much larger within-sector and within-region differences in productivity compared with across-sector and across-region differences – i.e. every region and every sector has a range of both high and low productivity firms, with large overlaps across regions and sectors (Haldane, 2016).

Reflecting on Haldane's finding, Kierzenkowski et al. (2018) suggest that this could be due to barriers in the diffusion of innovation *within* regions and sectors, for example around the uptake of digital technologies by smaller firms. In terms of our earlier policy discussions this suggest that diffusion of best practice within systems may be a more significant policy target than moving the best practice frontier itself.

It is important to note a number of important caveats to these findings as a guide for policy. The first is that the level of aggregation is high so that within each of these sectors there will be distinctive subsectors the weight and pattern of which may vary across sectors. Equally plants may be located within high and low productivity sub sectors and may not be part of the same sub sector systems or value chains. Secondly the regional boundaries are administrative and may cut across sectoral, sub sectoral and technological systems which have cross regional interactions and institutional architectures. Finally within a given region there may be substantial spatial variations in productivity performance. These may be revealed by analysis at different spatial scales such as at city level or in terms of urban rural splits. This will have implications for the identification of the appropriate spatial scale for policy intervention.

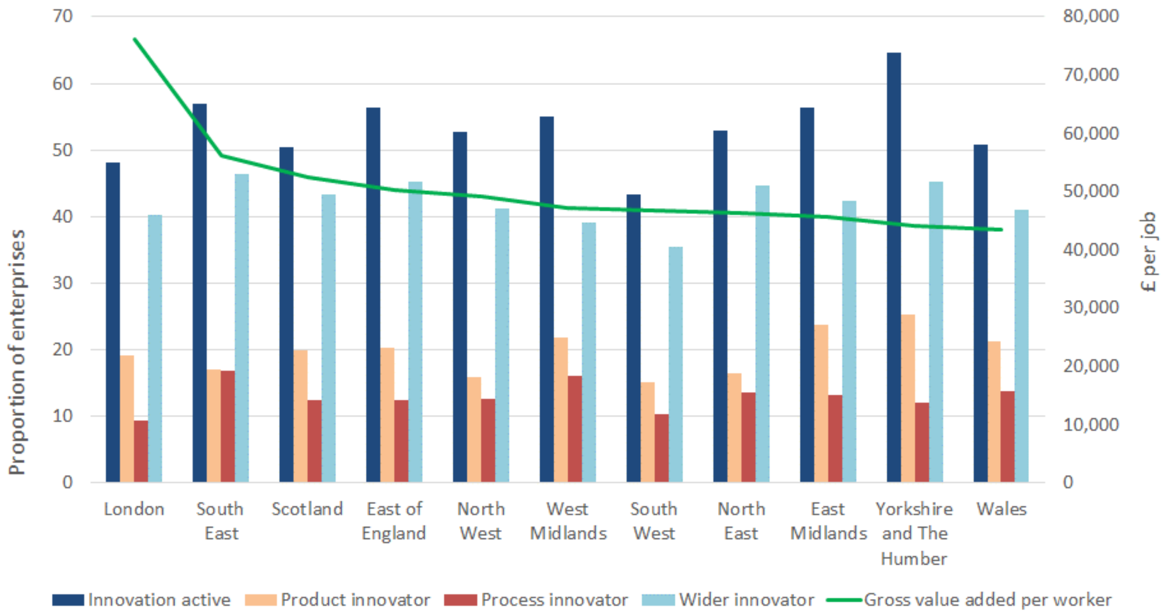
6.2 Innovation performance across regions

Innovation is known to be an important driver of long-term productivity growth (see e.g. Hall, 2011). To complement the productivity analysis we therefore examine spatial patterns if innovation performance. This analysis draws on the most recent data available at the time of writing from the UK innovation survey (covering the period 2012-2014). All the figures presented have been ordered from left-to-right in terms of decreasing levels of GVA per job (London with the highest level of GVA per job on the left, and Wales with the lowest level on the right) to help provide a link with the productivity analysis. In interpreting these figures it is important to bear in mind that differences in sectoral composition across the regions and hence in their patterns of sectoral systems of innovation may affect the type and extent of innovation carried out in their firms.

Figure 12 presents the incidence of different types of innovation activities across the regions and nations of the UK. It distinguishes between product, process and wider forms of innovation (such as in business practices, organisation of work responsibilities, or marketing strategies). It shows that innovation active firms exist across all the regions and nations of the UK. Paradoxically, areas with lower GVA per job exhibit similar, if not higher, proportions of enterprises engaged in innovation than those areas with higher productivity. Even when broken down by type of innovation, this pattern is still observed, with the proportion of enterprises engaged in product innovation – known to be an important driver of productivity growth (Hall, 2011) highest in the East and West Midlands, and Yorkshire and the Humber;

areas with lower levels of productivity. The proportions of enterprises engaged in process innovation does not vary much across the nations; Enterprises in the South East and West Midlands are more likely than those in other regions to engage in this type of innovation.

Figure 12 Innovation activity by type of innovation across regions, proportion of enterprises between 2012-2014

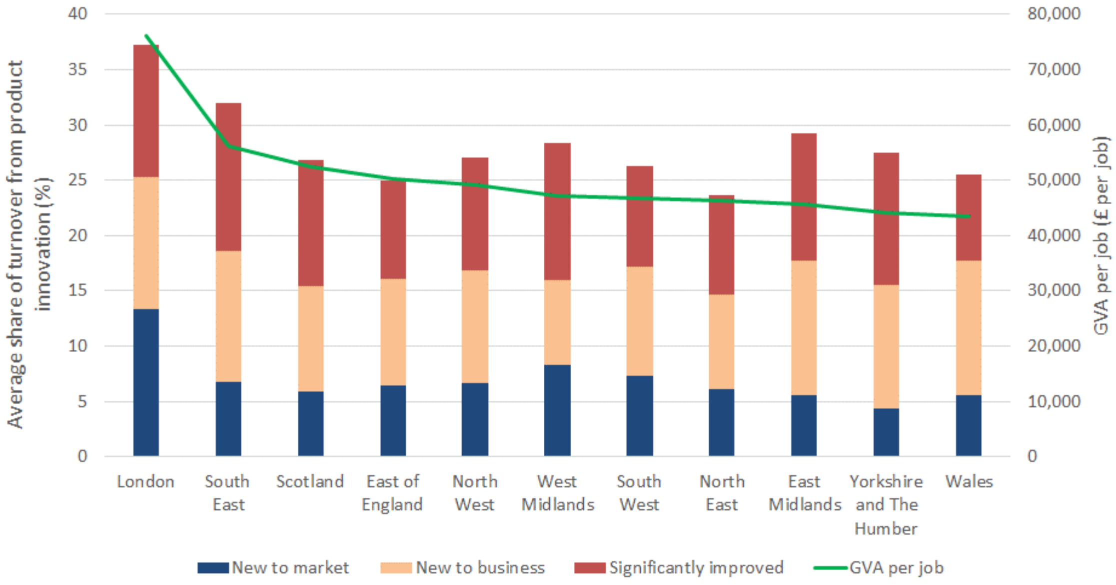


Source: UK innovation survey 2012 to 2014: statistical annex, available at https://www.gov.uk/government/statistics/uk-innovation-survey-2015-statistical-annex-and-interactive-report (accessed on 12th September 2018)

The data presented in Figure 12 focuses on whether an enterprise engages in any way in different forms of innovation. It says little about the scale of effort, nor about the importance of different types of innovation to their operations. Through the UK Innovation Survey it is possible to examine the importance of product innovation to enterprises using the contribution such innovations make to its turnover. The survey helpfully distinguishes between the degree of novelty of the product innovation, separating 'new to the market', 'new to the business', and 'significantly improved' (incremental) innovations.

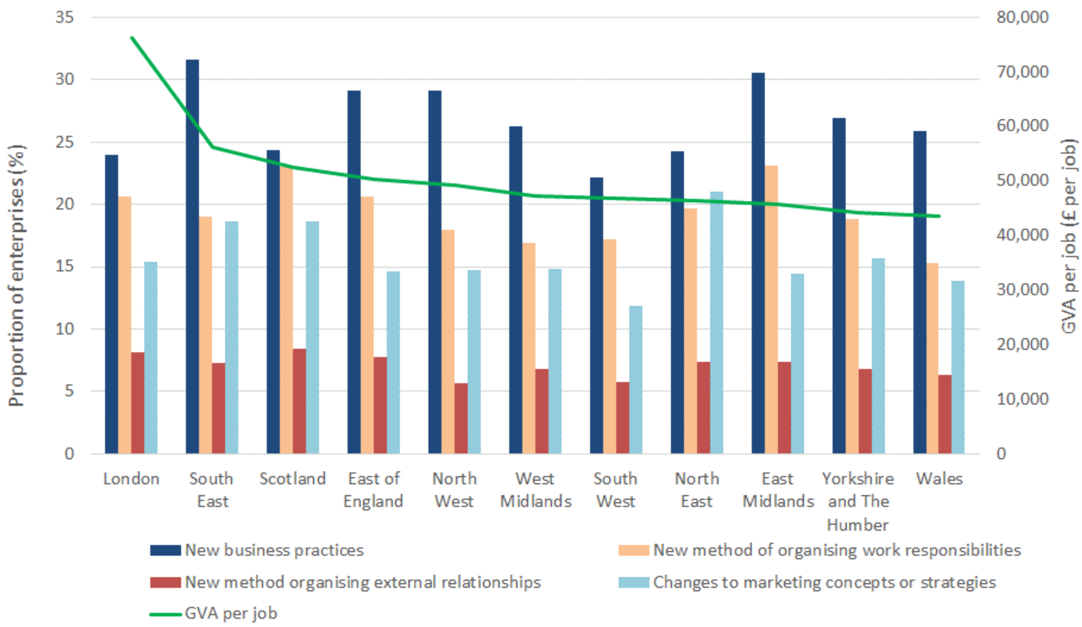
While the incidence of product innovation exhibits little relationship with productivity levels, Figure 13 reveals that the extent to which firms rely on it to drive turnover does show some (albeit limited) relationship. The correlation coefficient between the proportion of turnover derived from any form of product innovation and productivity is 0.86; a result strongly influenced by London as an outlier (0.53 excluding London). When broken down by type, excluding London, this correlation appears to be driven by the importance of 'significantly improved' innovations (correlation of 0.52) and to a lesser extent 'new to market' innovations (0.32). The importance of 'new to business' product innovations is relatively constant across the regions. This suggest that incremental and diffusion based innovation is more important in these cases than frontier moving new-to-market-changes. This again links to the relevance and importance of knowledge and technology diffusion policies.

Figure 13 Average share of turnover from product innovation in 2012, by degree of innovativeness, by region (percent)[4]



Source: UK innovation survey 2010 to 2012: statistical annex, available at https://www.gov.uk/government/statistics/uk-innovation-survey-2013-statistical-annex (accessed on 12th September 2018)

Figure 14 Proportion of enterprises engaging in wider innovation activities, by type of activity, by region (proportion of enterprises between 2012-2014)



Source: UK innovation survey 2012 to 2014: statistical annex, available at https://www.gov.uk/government/statistics/uk-innovation-survey-2015-statistical-annex-and-interactive-report (accessed on 12th September 2018)

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[4] Note that the data for this figure was drawn from the 2010-2012 UK innovation survey due to issues with the reporting of the data in the statistical annex for the 2012-2014 survey.

The analysis of wider forms of innovation (Figure 14) – which cover new business practices, work organisations, methods for organising external relationships, and changes to marketing strategies and concepts – shows a weak relationship between the proportion of enterprises engaging in such activity and productivity levels, particularly when London is excluded. The correlation coefficient between the proportions of firms innovating in new business practices and productivity levels is 0.43, for those innovating in new methods of organising work responsibilities it is 0.37; for those innovating in new methods for organising external relationships it is 0.44, and for those innovating in marketing strategies and concepts it is 0.43. The prevalence of these types of innovation is important since in terms of university industry interactions they frequently draw on disciplines outside STEM and the extent of these non-STEM interactions is known to be substantial from surveys of UK academics and businesses (Hughes and Kitson 2012)

6.3 Productivity disparities at the sub-regional level: cities, smaller urban and rural areas

We have emphasised earlier that regional based disaggregation may conceal significant intra-regional variations across cities, towns and rural areas. We therefore turn in this section to examining how productivity and productivity growth since 2009 vary at this level. This provides the context for going on to examine how the current distribution of science and innovation funding varies at the city level. We exploit data produced by the Centre for Cities which has collated data on the 63 largest cities in the UK (using aggregations of local authorities). Outside these cities, we identify the remaining local authorities and distinguish those that are predominantly urban from those that are rural using information available from the Office for National Statistics. The distribution of these types of areas by regions is show in Table 3.

Table 3 Number of types of areas across regions and nations of the UK

Regional group	Region	Large city	Smaller urban local authorities	Rural areas	Total
Greater South East	South East	11	38	4	53
	East of England	7	21	11	39
	London	1	0	0	1
South West	South West	6	12	14	32
Midlands	East Midlands	5	17	12	34
	West Midlands	4	14	6	24
North	North West	9	12	5	26
	North East	3	4	0	7
	Yorkshire and The Humber	9	6	5	20
Scotland		4	22	3	29
Wales		3	10	7	20
UK		62	156	67	285

Source: Authors' analysis based on data available from the Centre for Cities and the Office for National Statistics

The focus of place-based research and innovation funding as set out in the UK Industrial Strategy is to address the disparities in productivity across the UK. We therefore further sub-divide the large cities and smaller urban areas into those with higher-than-average productivity, and those with lower-than-average levels. Doing so reveals significant disparities in the distribution of jobs across these types of areas across the regions of the UK (Table 4). It reveals a stark contrast between the Greater South East – in which many of the jobs are located in higher productivity areas – and the Midlands and North – in which many of the jobs are located in lower-productivity areas

Table 4 Proportion of workplace jobs by type of area, distinguishing higher and lower productivity areas

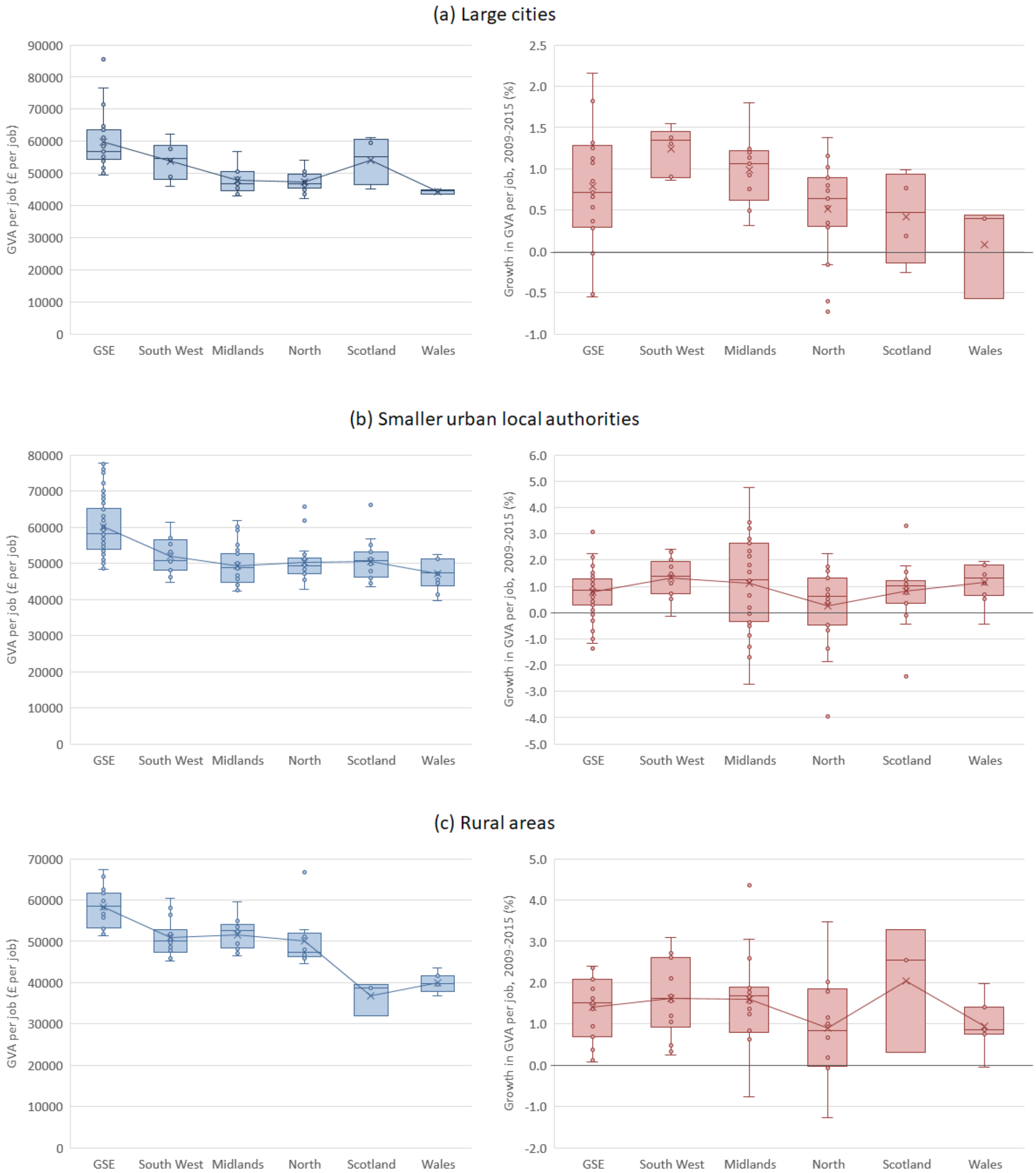
Regional group	Region	Large cities		Smaller urban areas		Rural areas	Total
		Higher productivity	Lower productivity	Higher productivity	Lower productivity		
Greater South East	South East	38	0	48	9	5	100
	East of England	16	13	41	9	21	100
	London	100	n/a	n/a	n/a	n/a	100
South West	South West	33	8	19	13	26	100
Midlands	East Midlands	6	39	10	24	21	100
	West Midlands	0	59	3	22	15	100
North	North West	4	65	13	13	5	100
	North East	0	66	0	34	0	100
	Yorkshire and The Humber	0	73	0	21	6	100
Scotland		20	25	12	41	1	100
Wales		0	38	0	38	24	100
UK		31	29	15	16	10	100

Source: Authors' analysis based on data available from the Centre for Cities and the Office for National Statistics

Figure 15 presents the distribution of productivity and productivity growth since the onset of the global economic crisis across the large cities, smaller urban areas and rural areas by region. This analysis includes the financial services sectors of the economy in contrast to the ONS compositional study discussed earlier. The figure reveals higher levels of productivity in many large cities and smaller urban areas of the Greater South East compared with the Midlands and North of the UK. However, it also reveals how regional aggregates can mask some higher performing areas – particularly smaller urban areas – in these latter regions.

The figure also presents the distributions of productivity growth for the large cities and smaller urban areas in the regional groupings. Compared with the levels of productivity, there is a much greater variability in productivity growth in all regions of the UK. And while the *average* level of productivity growth is slightly above zero across the regions of the UK, the regional aggregates again hide significant variability within regions, with some areas experiencing positive productivity growth over the period 2009-2015, while others experiencing declines.

Figure 15 GVA per job, and real-terms growth in GVA per job over period 2009-2015 in large cities, smaller urban areas and rural areas



Sources: Office for National Statistics: Regional GVA(I) by local authority in the UK, release date 31 March 2017; Annual Population Survey, extracted from Nomisweb on 31 July 2018 (open access)

Table 5 presents the industrial composition of the different types of large cities, smaller urban areas and rural areas. It shows that higher productivity locations tend to have a greater proportion of jobs in knowledge intensive financial and market services and in high tech knowledge intensive services compared to lower productivity locations; these are all sectors that generate relatively high GVA per job (Figure 9). Similarly, they have a lower proportion of jobs in those sectors that generate lower GVA per job. These locations also tend to have a higher proportion of employment in the private sector.

Table 5 Industrial structure for different types of UK cities, smaller urban areas and rural communities.

Local economy		GVA per job (£ per job)	Large cities		Smaller urban areas		Rural areas	Total
			Higher productivity	Lower productivity	Higher productivity	Lower productivity		
Average number of jobs		n/a	385,500	224,900	63,800	57,100	44,800	105,700
Breakdown by (%):								
Manufacturing	High tech. and medium-high tech. manufacturing	91,300	3.2	3.1	3.1	3.5	3.0	3.2
	Low tech. and medium-low tech. manufacturing	58,500	3.4	6.8	5.9	7.7	7.9	6.8
Knowledge intensive services (KIS)	Knowledge intensive financial services	117,600	3.8	2.9	2.3	1.5	1.1	2.0
	High tech. knowledge intensive services	85,800	5.2	2.6	4.6	2.1	2.3	3.1
	Knowledge intensive market services	42,400	13.2	10.3	10.7	7.9	7.1	9.2
	Public, health & social services, and other KIS	39,300	29.8	33.2	26.3	31.0	26.0	28.9
Less knowledge intensive services	Wholesale & retail trade, warehousing & other less KIS	56,900	35.4	34.9	37.8	37.2	37.9	37.0
Other	Utilities and construction	84,900	5.2	5.7	6.9	6.3	7.0	6.4
	Agriculture, fishing and mining	64,600	0.7	0.5	2.3	2.8	7.7	3.3
Breakdown by (%):								
Public / private sector	Employment in the public sector	n/a	21.3	23.9	19.7	23.1	21.1	21.7
	Employment in the private sector	n/a	78.7	76.1	80.3	76.9	78.9	78.3

Sources: ONS Business Register and Employment Survey 2016, extracted from Nomisweb on 31 July 2018 (open access)

Overall, this sections points to significant disparities across the UK in both productivity and productivity growth performance since the onset of the global financial crisis in 2008. We highlight in particular how region-level analyses can mask many of the important disparities that exist at the level of the cities, towns and rural communities across the UK suggesting that place-based funding to address these issues must pay close attention to the spatial scale at which funding is targeted. This analysis also showed that, while the average level of productivity at the regional level across the Greater South East is higher than that of the UK, there are still many areas within this region that perform poorly. This reinforces the need to go beyond the region in targeting any place-based funding. Lastly, we presented evidence in this section that each region of the UK has high-performing and low-performing firms, as well as innovating firms across product, process and wider forms of innovation. This suggests that a key challenge in reducing disparities is – at least in part – around strengthening knowledge diffusion to raise the performance of the 'laggards' in each region.

7 Spatial Distribution of Research and Knowledge Exchange Funding in the UK

It is important in moving forward to place-based policy design to complement our understanding of the conceptual issues (sections 2 and 3), our understanding of the diverse roles of the university system in addressing local innovation and economic development needs (section 4), and our understanding of the scale and nature of the spatial disparities in productivity that need to be addressed (section 5), with an account of how *existing* UK public sector resources are committed across the HEI sector and, by implication, the UK. This helps to provide an understanding of whether there are significant gaps in provision and where additional funding programmes may usefully be targeted.

In this section we first look at the nature and scale of funding flows from the public sector to support research via the UK dual support system along with direct public sector funding for knowledge exchange and innovation. We also look at the income secured by HEIs through external engagements ranging from collaborative research and continuing professional development through to commercialisation. We then turn to how these funding and income streams are distributed across the regions, cities, towns and rural communities of the UK, using the same spatial disaggregation as in the previous section.

7.1 The nature and scale of UK public research and innovation funding

The UK government has historically distributed much of its funding and support for research and innovation without explicit consideration of local socio-economic and innovation need, rather focusing on funding excellence wherever located nationally. The breadth of support for research and innovation includes, among other things, funding for projects and capability development in the public research base and the private sector; procurement programmes to provide incentives for small firms to innovate; and tax incentives for R&D. Much of the more direct public funding for research and innovation is now channelled through the new UK Research and Innovation (UKRI) agency. This agency was established in 2018 and brought together the seven Research Councils, Innovate UK and Research England (previously part of the Higher Education Funding Council for England).

The range of funding provided by UKRI can usefully be distinguished in terms of the phase of the innovation journey targeted (from research to development to deployment in the real world). From a systems policy perspective it may also be grouped by the innovation system features to developed or strengthened. For example funding programmes help to:

- Develop knowledge and insights at specific points along the innovation journey from idea to concept development to commercial deployment
- Enable the transition of knowledge and technologies towards application
- Build individual-level skills and capabilities to undertake research and innovation, and to work across organisational boundaries
- Build resources and capabilities within organisations to enable and facilitate the creation of effective knowledge-based linkages, and networks between research performing organisations and those in the private, charitable and public sectors
- Stimulate demand for innovation e.g. by creating demand for innovative products and services through dedicated government procurement programmes

Funding also targets different agents in the innovation system and in different ways. For example, the Research Councils and Research England provide funding to universities and other public sector research organisations (often in collaboration with industrial partners). The Research Councils typically fund specific projects and major research-specific infrastructure, while Research England typically provides funding to universities at the organisation-level, for example through its formula-driven quality assessment based funding for research, funding for research capital, and for knowledge exchange. These are the two sides of the Dual Funding System.

Innovate UK typically funds business-led research and innovation-related projects, alongside projects and infrastructure spending that seeks to bridge the gap between early research phases of the innovation process and the later, more commercial phases typically undertaken by the private sector. Figure 16 attempts to capture key differences in focus between the funding programmes of these different funders in the UK innovation system. This is the broader context within which the SIPF must operate.

Figure 16 Focus of public and private sector funds across the innovation journey

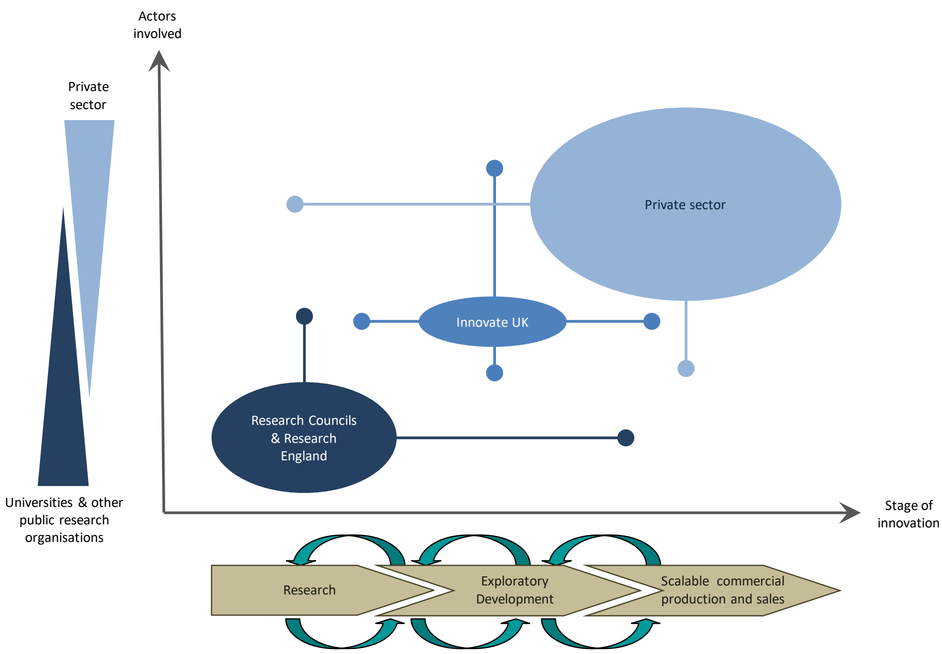
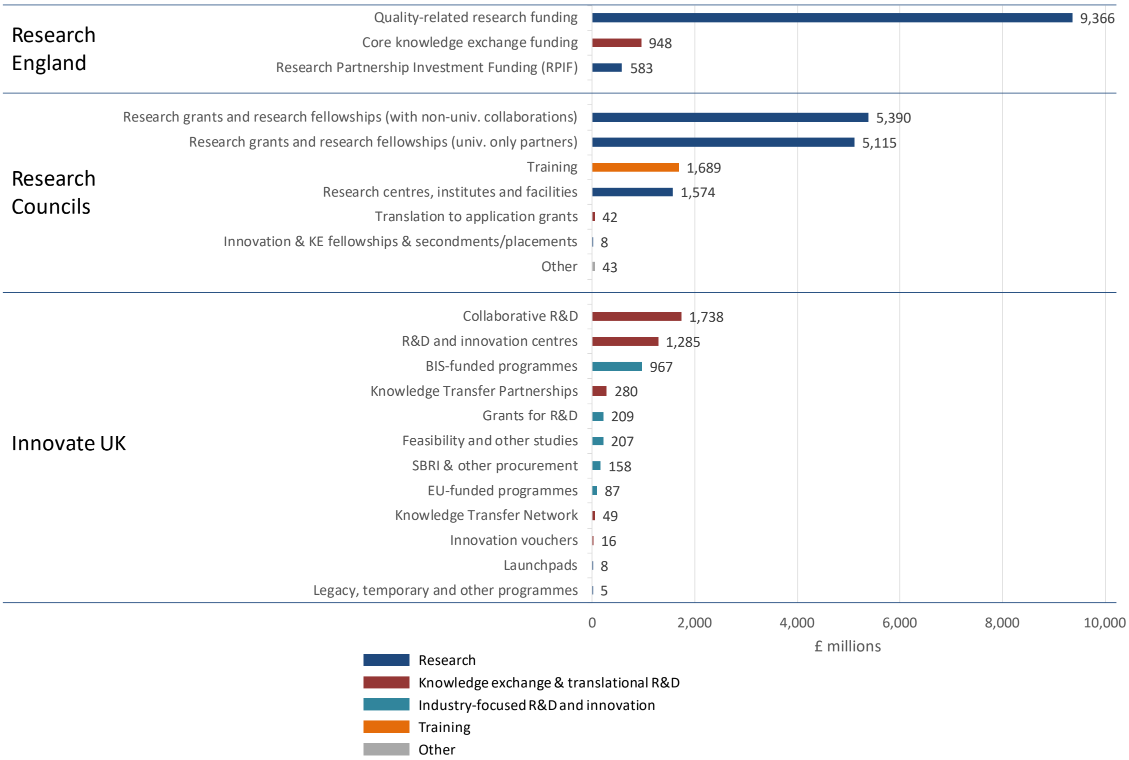


Figure 17 presents available data on the current scale of public funding provided by the Research Councils, Research England and Innovate UK over the period 2012 – 2017[5]. The first two are the dominant funders. In the case of Research England the bulk of the funding is not overtly linked to the later stages of the innovation process. However the REF assessment exercise which drives the allocations across HEIs now explicitly includes a significant element (25%) based on demonstrating socio-economic impact. In the case of the Research Councils, over half of research grant funding already supports collaborative research with non-HEI partners. A significant amount of Council funding is also being allocated to research and innovation-focused centres and institutes. The Innovate UK portfolio is more explicitly

[5] Data for the Research Councils is developed from the UK government's Gateway to Research web-database of grants distributed by the seven councils. However, the web portal does not capture all grants distributed.

focussed on the later stages of the innovation process. It also has a substantial investment in centres (e.g. Catapult Centres) and a wide variety of smaller KE linked innovation process programmes.

Figure 17 Scale of public research and innovation-related funding 2012-2017



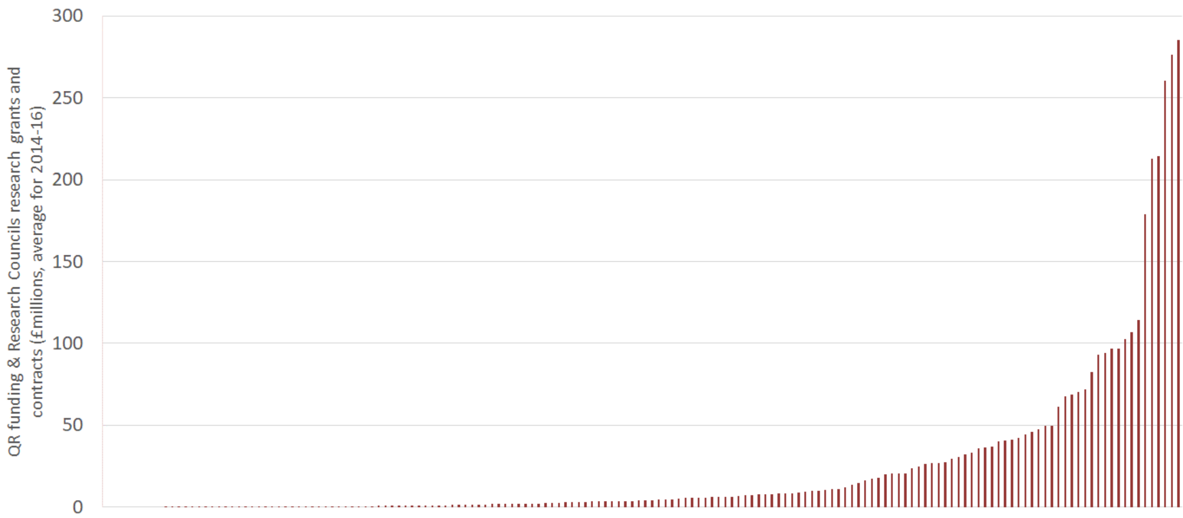
Note: Data on the Research Councils' Impact Acceleration Accounts (IAAs) were not available. IAAs provide a funding to selected universities to enable them to progress council funded research towards impact.
Sources: Gateway to Research, Innovate UK project data, HEFCE publications

7.2 Concentration of research and knowledge exchange activity

It is important to recognise that research and knowledge exchange effort is heavily concentrated in a handful of institutions. This clear from Figure 18 which arrays the individual members of the population of 162 UK HEIs by combined dual support funding from QR and Research Councils.

This dual support skewness is mirrored in all sources of income for research. This is shown in Table 6 which presents data for the top decile based on total QR and Research Council grants and contracts income. It also shows the inverse Herfindahl index, which can be interpreted as the number of equally sized universities that would account for the total amount of funding being considered. The lower the number, the more concentrated the distribution of funding (Hughes et al., 2013). By contrast, core KE funding distributed by Research England is much more broadly distributed. This is driven by the specifics of the formula which allocates the resources (not least the funding cap on individual institutions).

Figure 18 Amount of funding received by universities through QR and Research Council grants and contracts, by university, average 2014 - 2016



Source: Higher Education Statistics Agency (HESA)

Table 6 Concentration of different types of research and knowledge exchange funding in the UK higher education system

Funding type		Total (£000s)	Top 10% of HEIs ranked by QR and Research Council research funding *	Inverse Herfindahl
Recurrent research funding (QR)		1,990,014	57	35
Research grants and contracts	Research councils	1,831,316	67	26
	Charities	1,197,099	72	15
	Government bodies	1,671,079	59	34
	Industry	561,279	63	24
	Other	447,058	60	24
Research capital funding		429,651	43	52
Core knowledge exchange funding (England only)**		160,328	27	69
Number of HEIs		162	16	162

Notes:
* Ranked by the amount of funding received by universities through Quality-Related research funding and Research Council grants and contracts
** Core knowledge exchange funding only collected for England (132 HEIs)
Sources: Higher Education Statistics Agency (HESA), HEFCE circulars

Sixteen out of the 162 UK HEIs account for 57% of REF related QR funding and 67% of Research Council funding. This handful of institutions are similarly dominant in research grants from Charities Government Departments and Industry. They also dominate external revenue streams from commercialisation and from interaction pathways based on collaborative and contract research (Table 7). They also account for around half by value of all public sector and large firm based partnerships and 29% by value of SME partnerships. They are less dominant in Continuing Professional Development (CPD) and in relation to regeneration and development based funding streams. The latter might be thought to be of particular interest from the point of view of a commitment to addressing regional inequalities.

Table 7 Concentration of different types of knowledge exchange activity in the UK higher education system (based on knowledge exchange income)

KE type		Total (£000s)	Top 10% of HEIs ranked by QR and Research Council research funding *	Inverse Herfindahl
KE mechanism	Collaborative research	1,248,711	51	34
	Contract research	1,234,229	66	22
	Intellectual property	156,243	48	9
	Consultancy	453,112	33	44
	Facilities & equipment services	193,172	38	39
	Continuing professional development	706,360	24	58
	Regeneration & development programmes	185,430	19	25
KE partner type	Large companies	830,880	55	28
	Small and medium sized companies	222,691	29	47
	Public and third sectors	1,372,556	48	42

Notes:
* Ranked by the amount of funding received by universities through Quality-Related research funding and Research Council grants and contracts
Sources: Higher Education Statistics Agency (HESA), HEFCE circulars

This degree of concentration means that the potential for place-based science policy based on "excellence" depends critically on the spatial distribution of these research intensive universities and on the extent of their interactions as agents in local and regional innovation systems. This not to argue that non-research intensive universities are unimportant in local or regional systems. Indeed, as the earlier survey data showed, they may be relatively more engaged in KE activity at regional and local level. However, to the extent that the SIPF wishes to build on excellent research to address regional dipartites in performance and property, the existing spatial distribution of the handful of intensive HEIs may be an important structural imperative.

7.3 Regional distribution of higher education capabilities and public funding for research and innovation

In this section we analyse the distribution of higher education capabilities, and public funding for research, knowledge exchange and innovation, across the regions and nations of the UK. This provides evidence on the spatial foundation on which the SIPF will be based.

7.3.1 Distribution of higher education capabilities by region

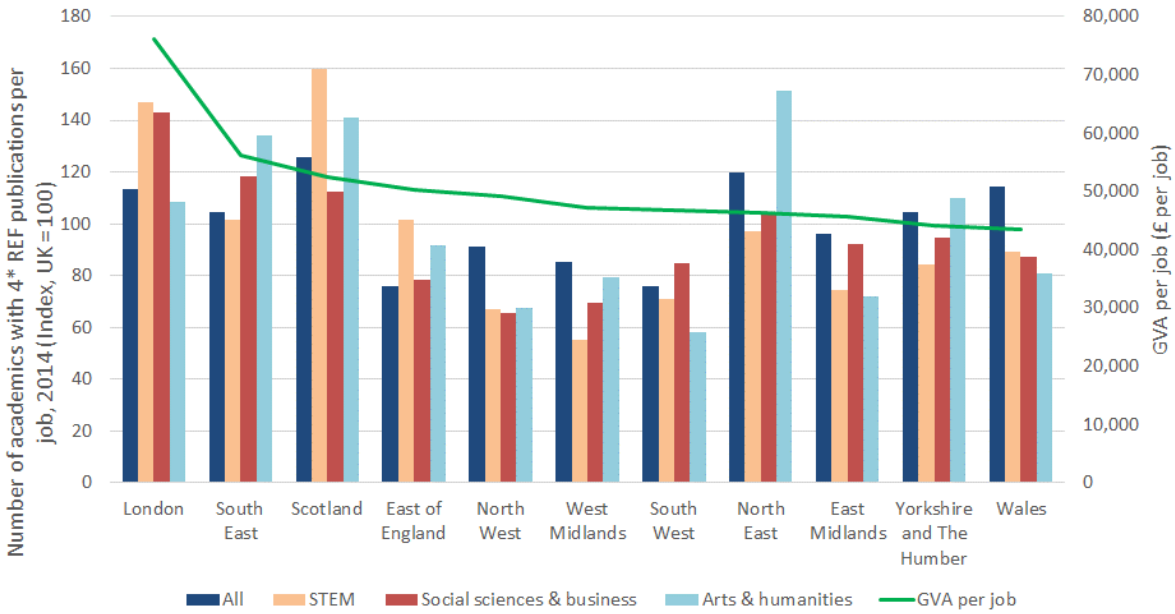
The regional distribution of key indicators of higher education capabilities in presented in Table 8. The dominance of London and the South East – in terms of the aggregate scale of academic activity – is clear. The table also shows that these regions are home to a significant proportion of the total number of academics across STEM, social sciences and business, and arts and humanities disciplines that generated world-leading (4*) ratings in the most recent 2014 Research Excellence Framework (REF) assessment.

Table 8 Selected higher education system characteristics by UK region

Higher Education System	Region											Total
	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland	
Number of academic FTEs	6,465	15,222	12,650	10,204	10,964	10,654	29,636	22,366	9,556	7,368	16,034	151,117
Number of HEIs	5	15	11	9	12	10	38	19	13	8	18	158
Number of Russell Group HEIs	2	2	3	1	2	1	5	2	2	1	2	23
STEM academic FTEs gaining 4* in REF	299	638	583	448	407	811	2,187	1,240	508	329	1,161	8,611
Social science & business academic FTEs gaining 4* in REF	148	287	302	258	235	289	981	668	280	148	376	3,973
Arts & humanities academics FTEs gaining 4* in REF	146	203	239	137	184	231	507	516	131	94	323	2,709

Sources: Higher Education Statistics Agency (HESA), Research Excellence Framework 2014, ONS Business Register and Employment Survey 2016, extracted from Nomisweb on 31 July 2018 (open access)

Figure 19 Number of academics with 4* (world-leading) publications in REF 2014 per job (index, UK = 100)



Sources: REF 2014, Subregional Productivity: Labour Productivity (GVA per hour worked and GVA per filled job) indices by UK NUTS2 and NUTS3 subregions, UK Office for National Statistics

The regions themselves however vary in terms of employment and output size. It is useful therefore to normalise results by expressing them per job in the region. This also gives a better sense of their significance as regional system agents. Figure 19 shows the number of academics with 4* world leading publications per job for all disciplines and three disciplinary subgroups. Variations remain especially when disciplinary subgroups are considered. The North West, West Midlands and South West – and surprisingly perhaps the East of England which is home to leading universities including the University of Cambridge, the University of

East Anglia, and the University of Essex – exhibit lower levels of world-leading expertise *when normalised per job* compared with other regions.

The correlation of all staff numbers with productivity is however low (correlation coefficient 0.25). By contrast, the per job number of academics in STEM and social sciences and business disciplines generating world leading publications exhibits a much higher correlation with productivity (coefficients of 0.65 and 0.77 respectively).

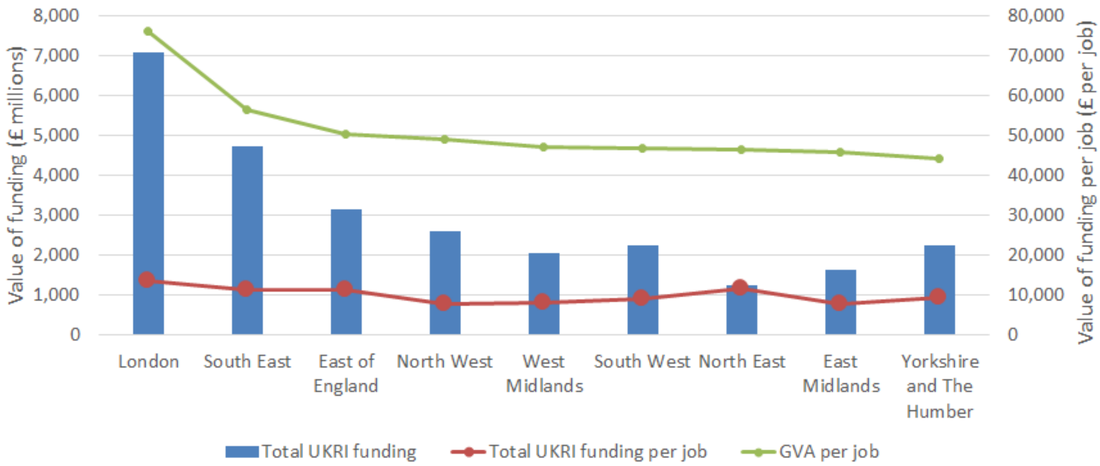
It is important not to read too much into these correlations in a *causal* sense. They are presented for essentially summary descriptive purposes. The subject distributions in particular may reflect the longer term historical evolution of HEIs in particular places. From a place-based policy perspective the important finding is that there is an uneven spread of research excellence across regions.

7.3.2 Distribution of research, knowledge exchange and innovation funding by region

In principle it might be argued that the current allocation model for public funding for research, innovation and knowledge exchange is place-blind. However it may be that the spatial distribution of HEIs across the UK means that the allocation of these resources in absolute terms is inevitably unevenly spread across locations.

Figure 20 thus presents the distribution of aggregated UKRI funding across the English regions, both in terms of the total value of funding as well as funding normalised by the number of jobs. The absolute data is consistent with a perception that public funding of research and innovation is concentrated in the Greater South East. However, when normalised by the number of jobs – accounting for the scale of economic activity in each region – the picture is of a much more even distribution with North East and Yorkshire and the Humber receiving levels similar to those in the Greater South East.

Figure 20 Spatial distribution of public research and innovation-related funding over the period 2012-2017



Sources: Gateway to Research, Innovate UK project data, HEFCE publications

Figure 21 further explores the spatial distribution of different types of UKRI funding, distinguishing between that focused on research (either involving universities alone or in collaboration with non-academic partners); knowledge exchange and translational R&D funding; industry-focused R&D and innovation funding (largely distributed by Innovate UK); and training-related funding. When normalised by jobs the West Midlands and North East do particularly well in terms of KE and translational R&D funding, while the South West secures significantly more per job of industry-focused R&D and innovation-related funding. It appears therefore that there is already some weighting of this kind of support away from the high productivity GSE when job normalised numbers are considered.

Figure 21 Spatial distribution of different types of public research and innovation-related funding, over the period 2012-2017

Note: bars are the total value of funding (left axis); lines are funding per job (right axis)
Sources: Gateway to Research, Innovate UK project data, HEFCE publications

7.4 Sub-regional distribution of higher education capabilities and public funding for research and innovation

It is clear from the above that regional variations in funding are not as severe as we might expect once the scale of economic activity is taken into account. However, as discussed earlier, the region-level masks significant heterogeneity in types of areas within each; often including a mix of large cities, smaller towns and rural communities with different levels and growth performance in productivity. Importantly, section 5 highlighted that each region of the UK has locations with productivity levels and growth performance above the national average as well as (often many) areas below it.

We therefore turn to an examination of how the higher education capabilities and public funding for research, innovation and knowledge exchange are distributed across these different types of sub-regional locations, distinguishing cities and smaller urban areas into those with higher productivity and lower productivity levels.

7.4.1 Distribution of higher education capabilities by sub-regional location type

Table 9 Selected higher education system characteristics for different types of UK cities

Higher Education System	Large cities		Smaller urban areas		Rural areas	Total
	Higher productivity	Lower productivity	Higher productivity	Lower productivity		
Number of academic FTEs	65,400	64,000	7,150	12,300	2,400	151,100
Number of HEIs	61	60	14	17	6	158
Number of Russell Group HEIs	10	12	0	1	0	23
STEM academic FTEs gaining 4* REF	4,921	3,002	222	407	60	8,611
Social science & business academic FTEs gaining 4* in REF	2,020	1,338	108	466	41	3,973
Arts & humanities academics FTEs gaining 4* in REF	1,306	1,009	47	301	45	2,709
Number of academic FTEs per million jobs	7,062	7,505	1,629	2,554	821	5,065
4* STEM academic FTEs per million jobs	531	352	50	85	21	289
4* social science & business academic FTEs per million jobs	218	157	25	97	14	133
4* arts & humanities academic FTEs per million jobs	141	118	11	63	16	91

Note: number of academic FTEs has been rounded to the nearest 50 and the sum of academics across the types of areas may therefore differ slightly from the total

Sources: Higher Education Statistics Agency (HESA), Research Excellence Framework 2014, ONS Business Register and Employment Survey 2016, extracted from Nomisweb on 31 July 2018 (open access)

The distribution of higher education capabilities across the different sub-regional location types is shown in Table 9. It shows that these capabilities are concentrated in the larger cities of the UK. In addition, while the numbers of academics per million jobs is similar between the more and less productive large cities, academics generating world-leading research, particularly in STEM and the social sciences and business disciplines are more heavily concentrated in more productive large cities. This pattern is reversed at the smaller urban area level of analysis. Thus less productive smaller urban areas are home to more academics, and more world-leading researchers across the disciplines, than higher productive smaller urban areas.

Table 10 Knowledge exchange portfolios for different types of UK cities

Higher Education System	Large cities		Smaller urban areas		Rural areas	Total
	Higher productivity	Lower productivity	Higher productivity	Lower productivity		
Total (£ per job)	202	197	47	56	18	137
Of which through (% of total KE income)						
Research-related KE (including contract and collaborative research)	60	64	36	48	48	60
Consultancy	11	10	16	14	4	11
Intellectual Property	6	2	1	1	0	3
Facilities & equipment services	4	5	9	8	1	5
CPD	18	14	30	17	30	17
Regeneration & development	1	5	8	13	18	4
Of which with (% of total KE income)						
Large-firms	25	15	28	12	3	20
SMEs	5	5	12	7	4	5
Public & third sectors	32	34	26	37	22	33
Collaborative research	27	35	20	25	27	30

Note: Based on average income between 2012 – 2016

Sources: Higher Education Business and Community Interaction Surveys 2012 – 2016, ONS Business Register and Employment Survey 2016, extracted from Nomisweb on 31 July 2018 (open access)

Table 10 explores the level of knowledge exchange activity of universities based in different types of cities, once again normalised by the number of jobs. It also looks at how the portfolio of knowledge exchange activities varies between different city types. This is important in the context of place-based funding as it provides an indication of the available knowledge diffusion capabilities in a local area that could be drawn upon to address local economic objectives.

The table reveals that, as with the distribution of academic research expertise, knowledge exchange activity is much higher (per job) in the larger cities of the UK. This reflects not least the location of many large, research intensive HEIs in these larger cities of the UK. The table also reveals some differences in the portfolio of KE activities across area types. Reflecting the distribution of HEIs in terms of their research expertise, research-related KE dominates the KE portfolios of larger cities; both those that are more *and* less productive. By contrast, training and consultancy, as well as regeneration and development activities form a much greater part of the portfolio in smaller urban areas.

Table 10 also reveals some interesting variations in the partner types of HEIs based in different types of cities. Those based in more productive smaller urban areas see SMEs form a greater percentage of their KE portfolio. Large company engagements (excluding those through collaborative research) form a larger part of KE portfolios of HEIs in higher productivity locations, for both large cities and smaller urban areas alike.

These variations, across different intra-regional location scales, in productivity and in the scale and intensity of both research quality and quantity have policy implications.

First, it is apparent that inequality may be measured at different locational scales. Where a policy target is to reduce spatial inequality the scale chosen for analysis therefore matters.

Second, there is an uneven distribution of research excellence and KE capacity across different locational scales. This is heavily influenced by the location of the small number of research intensive institutions. These, as we have seen, account for the bulk of UK research which in turn is heavily dependent on the 4* quality of their academic staff. That measure of quality is also frequently linked to superior productivity performance. If the SIPF is to be linked to research excellence then its locational spread will not necessarily or easily map into the least productive locations.

7.4.2 Distribution of research, knowledge exchange and innovation funding by sub-regional location type

Table 11 presents how public research and innovation funding varies by sub-region location type, normalised by the number of jobs in that area. It shows that much of the UKRI funding is concentrated in the larger cities of the UK. This is perhaps not surprising as much of it has to be led by universities which are themselves concentrated in these types of areas. Industry-led funding (much of it distributed by Innovate UK) is more evenly distributed between larger cities and smaller towns, although it is concentrated as might be expected in those that are more, rather than less, productive.

Table 11 Distribution of UKRI funding across different types of cities in the UK, value per job

	Large cities		Smaller urban areas		Rural areas	Total
	Higher productivity	Lower productivity	Higher productivity	Lower productivity		
Research funding	1,251	900	216	247	117	710
KE & translational research funding	161	191	113	91	54	144
Industry-focused funding	84	36	53	36	32	54
Training	95	72	14	18	8	51
Other	4	2	1	0	0	2

Sources: Gateway to Research, Innovate UK project data, HEFCE publications

Overall, this section provides an assessment of the empirical evidence on how public funding for research, innovation and knowledge exchange distributed by UKRI is distributed across the locations of the UK. As with our analysis of productivity and innovation across the English regions, public funding for research, knowledge exchange and innovation – when normalised for the scale of economic activity in the region – is relatively evenly distributed. However, when we dive below the regional level to explore variations by large cities, smaller urban areas and rural communities, we find much bigger differences, with large cities host to much of the research and knowledge exchange activity.

Perhaps most important to recognise is that universities are strongly anchored in place, with many established many decades and even centuries ago. Given the strong path dependency in the development of research and KE capacity and capability, the spatial distribution of these activities will be driven by the historical location of universities. We also show the significant concentration of research excellence and KE capacity in a handful of HEIs. That is not to say that other HEIs do not perform important KE functions in their local economies, but rather that, in terms of the scale of supply of research at the technological frontier and related KE, this is driven by a handful of HEIs mostly located in the nation's large cities.

8 Discussion and conclusions

8.1 Principles of place-based science policy design

In this report we have argued that a place-based science policy to enhance innovation should be based on addressing system failures. These may emerge in terms of agent capabilities, interaction patterns, and the norms rules and institutional architecture in which the interactions occur.

We have also argued that policy design should be developed in a way that is embedded in the specifics of the local institutional architecture. It should be informed by granular bottom up information about the intersection, in a given place, of particular sectoral and technological systems. It should also recognise that the boundaries defining the system being analysed may not fit into existing administrative boundary definitions, and be part of wider national and international sectoral and technological system systems.

In addition, we argued that a central feature of place-based policy design should be an explicit analysis of the value chain associated with the activities to be supported. This must be combined with a clear identification of how value would be *generated* and *captured* locally. This is not the same as a process of identifying the location of supply chain links which says nothing per se about value distribution and capture. The role of key anchor or focal firms in value chains may be a key feature at local as at wider geographically based systems.

This approach to policy design is information intensive. It requires the development, as an integral part of policy, of: the location and nature of research excellence; the existence of agent capacity and of value chains in multiple sectors; and the range of applications of multiple, often general purpose, technologies (CST, 2007).

This cannot readily be achieved in a top down way at national, or even local, level. At a local level as much as national. Policy design depends on the development of institutional architectures which embed information generation and collation in the local business and research communities themselves and enhances their capacity to access relevant information outside the locality. In an uncertain and complex innovation landscape this should be seen as a long term commitment. Selection of projects to support should be seen as series of placing bets (not picking winners) and policy should be iterative and focus altered as circumstances change (Hughes, 2012). Finally in many areas the route to commercialisation is long. Policy will require an evaluation and impact time scale commensurate with the path to scalable and sustainable competitive production.

We reviewed literature which outlined ways of identifying the characteristics of interactions within the innovation system which may enhance the value of co-location and hence proximity in successive value added stages. These include: close coupling based on interaction across stages; a close connection between specific customer requirements and production characteristics; and interactions which cannot easily be captured in formal written contract structures.

The evidence that we reviewed of sources of knowledge for innovation showed that the role of universities as a source of business knowledge for innovation must be kept in perspective when compared with customer and supplier source which, in general, are far more frequent and important. Given that sense of perspective we reviewed and identified a wide variety of ways in which universities may contribute to local innovation systems. We emphasised that the evidence shows that not all of these are linked to research excellence per se, but rather to other – potentially linked – capabilities and resources of HEIs as knowledge generating and diffusing organisations. We also reviewed literature that showed that cluster-based innovation systems may depend upon significant non-local HEI research base connections. The evidence also showed that the role and type of interactions with the research base should be seen as rooted in the wider development strategy being pursued in the place concerned and in its particular sectoral and technological base.

Our review of the distribution of research excellence, research funding and knowledge exchange capacity in the UK showed high levels of concentration across universities and hence on the location and system role of those particular universities. This evidence showed that research excellence may not necessarily map into locations with significantly lagging productivity performance.

Our review of the evidence on productivity performance revealed the massive imbalance between London and the South East on the one hand and the rest of the UK on the other. It also revealed wide variations in productivity performance within all regions when other location scales such as city or urban/rural splits were analysed. A UK science-focused place-based innovation policy aimed at reducing spatial inequality must therefore be clear about the location scale at which the inequality is being measured and about the magnitude of the gap to be closed in setting policy objectives.

Against that background we now comment on implications of our review for the SIPF as a science-focused, place-based innovation policy to reduce place-based productivity inequality across the UK.

8.1.1 Implications of our review for SIPF-like funding programmes

The emergent SIPF being developed by UKRI aims to take a place-based approach to research and innovation funding in order to support significant regional growth. The fund does not specify the location scale. Bidders can define it as they see fit in the context of their bid. There is no requirement that bids must come from localities with underperforming productivity.

In relation to our discussion of effective policy design there is an appropriate strong commitment to bottom up embedded information flows. There are also exhortations to develop appropriate local databases and institutional architecture as part of bids. Finally there is an element of an options approach in having two rounds to bid selection. The first round provides seedcorn funding for the development of substantive bids from which a second round final shortlist is to be drawn.

There are, however, some problematic aspects of the policy which need to be addressed.

Bids are required to have a high level aim to close a "gap" with the national frontier in the chosen location. The participants are, however, all supposed to be at, or near, the frontier already and in existing excellent clusters. This implies the existence of best practice clusters in low productivity performing places. It also implies that the cluster activity to be supported is sufficiently scalable over a 3-5 years to have a significant impact on the performance of the region as a whole. And that this can be accomplished with modest funding amounting to £2-5 million per project per annum. Given the existing scale of cross regional performance differences is it realistic to expect effects of the orders of magnitude required to close those regional gaps? Would it be more realistic and useful to require monitoring and evaluation against a bespoke set of project specific and time sensitive outcome targets?

Where selected bids are based on cluster excellence in already high performing regions it is not clear how the high level aim of narrowing regional inequalities will be met.

More generally it is apparent that in project selection the precise definition of excellence used in research and cluster analysis will have a significant bearing on the spatial distribution and hence inequality impact of the policy. This implies that award selection process may therefore involve some trading off of excellence in research and cluster quality against inequality reducing outcomes

The focus on the frontier poses another challenge. The evidence we have reviewed on productivity suggests that inequalities between regions are driven by low productivity across multiple sectors within regions. The productivity problem from this point of view is much more about reducing the dispersion of productivity within a range of sectors in a region rather than moving their respective frontiers. This need not link to collaboration with "excellent" research and points to other criteria *for value enhancing collaboration* with universities. This may as we have suggested involve a rather different conception of excellence to that used to that in UK REF research output assessment (e.g. defined in relation to a specific regional need as opposed to being measured in absolute international or national terms).

The requirement to build upon existing "excellent research" raises a further important issue. This research requirement presupposes that there are localities with "excellent" research that are lagging in overall productivity performance. Moreover it presupposes that in such cases there may be a conjunction between the excellence of universities and a region's technological and science base needs. The evidence we have reviewed, for example, suggests that in some cases extra-regional knowledge sources may be the most relevant, particularly for firms at or near the technology frontier (the focus of the SIPF). Moreover, research excellence in the UK, as we have shown, is heavily concentrated in a handful of universities and in relatively high productivity places. Place-based funding programmes – while focused on delivering place-specific objectives – must therefore not prevent or hamper the development of extra-regional interactions between innovating agents in the relevant sectoral and technological systems.

Finally, appropriate regional or other place-based governance structures with which to develop and embed place-based policies and programmes are known to be important. This poses another challenge for SIPF since the UK is thought to be particularly deficient in this area compared to other nations with strong place-based policies. A key consideration for SIPF in the near term in selecting bids must therefore be around assessing the capabilities of the local consortia to deliver place-based projects. In the longer term, if the UK chooses to pursue place-based approaches, appropriate governance structures and capabilities need to be developed and nurtured.

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