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Examining the Requirement for Public Funding for University Knowledge Exchange to Deliver the 2.4% R&D Target

A Technical Report for Research England

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Contents

1 Introduction

This technical report examines the funding requirements for supporting knowledge exchange and commercialisation (KE/C) within English Higher Education Institutions (HEIs) to ensure they can contribute actively and fully to the delivery of the UK government's target of achieving 2.4% R&D spending as a share of GDP (hereafter referred to as the 2.4% R&D target). The report seeks to both explore how achieving a 2.4% R&D target will affect KE/C opportunities and as a result the resourcing of this activity within HEIs, as well as produce an estimate the scale of funding required under some different scenarios.

The UK's emergent industrial strategy set an ambitious target of raising total R&D investment in the UK to 2.4% of GDP by 2027 and to 3% in the longer term (HM Government, 2017). This increase would close the significant gap in the level of R&D investment in the UK compared to other OECD countries and, if other countries do not increase their levels further, eventually place the UK in the top quartile of this group.

Delivering this will require significant increases in investment in R&D by both the public and private sectors. HEIs, firms and other organisations involved in the innovation process will have to significantly increase the level of R&D activity they undertake. This substantial increase in activity will likely have significant effects on both the scale and nature of KE/C interactions that form between HEIs and non-academic organisations to co-develop, exchange, diffuse and deploy knowledge in the innovation system.

My focus in this report is on this specific topic: on how the delivery of a 2.4% R&D target will affect the nature and scale of KE/C and the implications on public funding to enable and facilitate these interactions. In terms of funding, the report will focus its attention on the Higher Education Innovation Fund (HEIF).

The report is structured as follows. It first considers the nature and scale of the 2.4% R&D target and how the increased spending will feed through to activity in different types of HEIs. It then sets out the nature of KE/C in the context of the R&D activities of HEIs in order to develop a conceptual model capturing how substantial increases in R&D spending may affect the opportunities for KE/C. This model is then used to estimate the nature and scale of KE/C opportunities in a 2.4% R&D spending world. The report then turns to developing a conceptual model for the funding requirements for KE/C, focusing on the need for institution-focused funding programmes such as the Higher Education Innovation Fund (HEIF). This model is used to develop estimates for KE/C funding requirements in a 2.4% R&D world. The final section explores potential factors that could see the funding requirements deviate from the base-case.

2 The 2.4% R&D target and implications for knowledge exchange and commercialisation

2.1 The nature of the 2.4% R&D target

The UK's industrial strategy set a target of raising total R&D investment in the UK to 2.4% of GDP by 2027 and to 3% in the longer term (HM Government, 2017). The vision set envisages:

> "*a knowledge-led economy is underpinned by world-leading research, world-class facilities and international collaborations that push scientific frontiers and attract the brightest talents, from Nobel Prize winners to ambitious graduate students. 'Innovation clusters' will form and grow around our universities and research organisations, bringing together world-class research, business expertise and entrepreneurial drive.*" (HM Government, 2017, p. 67)

To achieve this target, the industrial strategy set an ambition to significantly grow public sector investment in R&D to £12.5 billion per year in 2021/22 from approximately £9.5 billion in 2016/17. This includes investing strategically in technologies and ideas closer to market while maintaining investments in curiosity-driven research. As one of the primary organisations undertaking publicly funded research in the UK national innovation system, universities will inevitably play a significant role in delivering this additional public sector investment in R&D.

Meeting this target also requires the private sector to engage and substantially increase their levels of R&D investments in the UK not least to invest in, and drive the development of, next generation of technologies in different areas of the economy and drive productivity growth. To facilitate this increase in private sector R&D, the government's industrial strategy sets out an ambition to improve the underpinning conditions for locating and undertaking R&D in the UK, such as improving the business environment, access to finance, regulatory frameworks, and intellectual property. With R&D intensive businesses increasingly seeing HEIs as key partners in innovation, it is highly likely that additional private sector spending on R&D will result in additional opportunities for KE/C.

2.2 Estimating the scale and composition of R&D spending and activity

Given the likely impact of substantial increases in R&D spending on the HE system and on KE/C in particular, it is important that we understand the potential scale of increases expected if the 2.4% target is delivered in 2027. To understand how it will affect the opportunities for KE/C, it is also important to understand the likely composition of this increased spending between the public and private sector, as they typically focus on funding different parts of the innovation process[1].

A simple schematic to guide my approach to predict both the scale and composition of R&D spending is shown in Figure 1. This crucially distinguishes between spending on R&D by the public and private sector, and the organisations that are funded to undertake the activity, recognising that private sector firms receive funding from public sources, and that organisations such as HEIs receive funding from private sector firms.

[1] This definition of public and private sector funded R&D is adapted from that used by Economic Insight (2015) who develop estimates of the interdependencies between public and private R&D spending. Public R&D spending includes that by the UK government, Research Councils, Higher Education Funding Councils and overseas funding from the EU government funding in to HEIs. The latter was obtained from the Higher Education Statistics Agency (HESA) and used to adjust the GERD data. Private sector R&D spending includes that from business enterprises, private non-profit organisations and overseas sources excluding funding from the EU government into HEIs.

Figure 1 Public and private sector R&D spending and activity increases to deliver the 2.4% target

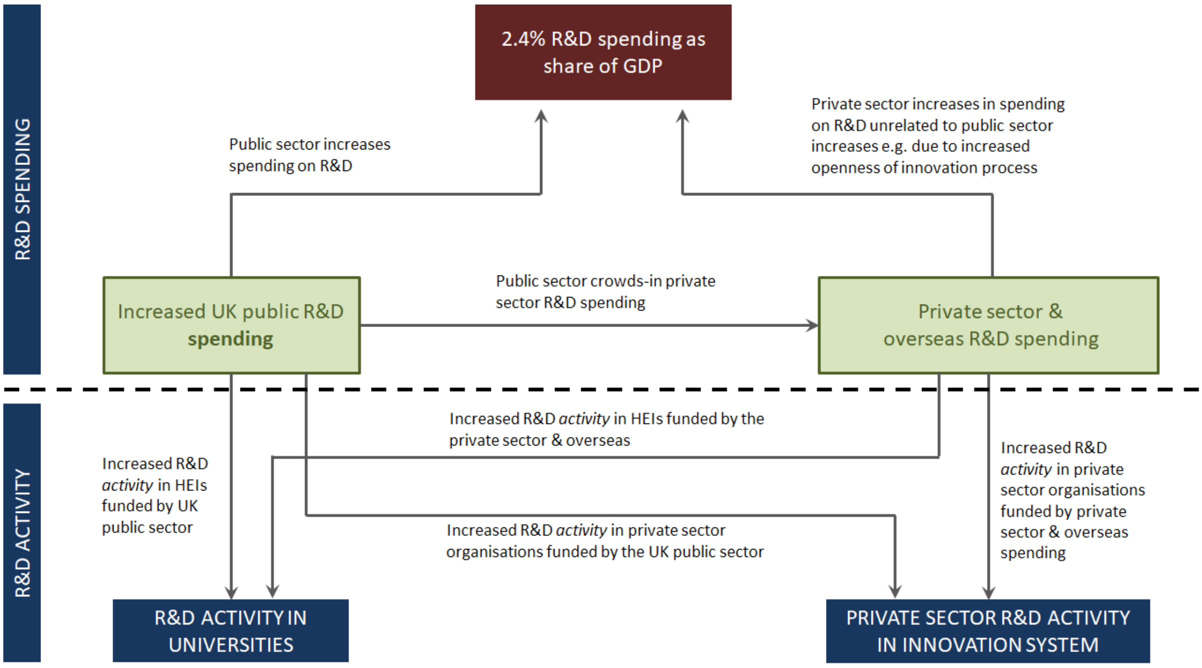
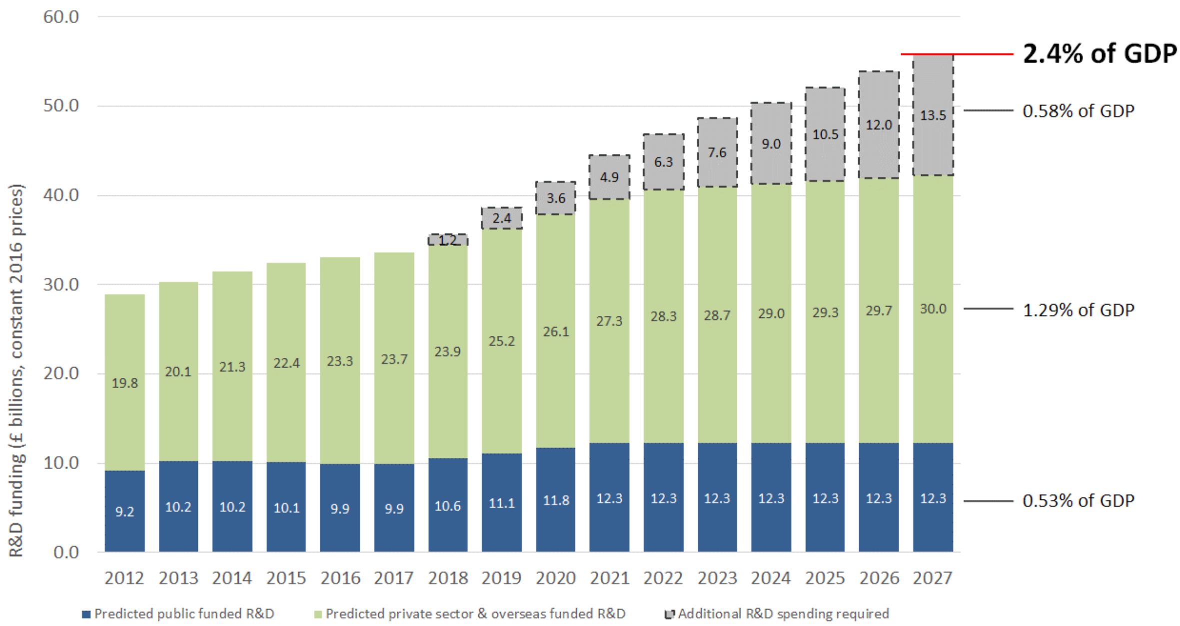


Figure 2 Estimates of the scale of R&D investments, 2012 - 2027



Spending on R&D (from all sources) in real terms (2016 prices) stood at £33 billion in 2016 (Office for National Statistics, 2018). Figure 2 presents my estimation of the scale of public and private sector R&D increases required to deliver the target. The predicted public sector funding for R&D includes the planned uplift in spending to 2020/21 announced by the government through the National Productivity Investment Fund (NPIF) and the reallocation of Official Development Assistance (ODA) to fund R&D[2]. After this period of uplift I assume that public spending remains flat in *real* terms. I

[2] See Table 9 in Appendix A

have also assumed that the UK government maintains in real terms EU spending on research into UK HEIs post-Brexit.

In terms of R&D spending by the private sector and overseas organisations, I assume it grows based on its previous trend with GDP growth and use this relationship to predict future levels of spending (Figure 13, Appendix A). Forecasts of GDP growth to 2023 were obtained from the Office for Budget Responsibility (Office for Budget Responsibility, 2018) (Figure 12, Appendix A), with growth beyond that assumed to be the average of 2021-2023. I also assume that additional public funding for R&D will crowd in *additional* private sector and overseas spending based on a leverage ratio of an additional £1 in public spending leads to £1.36 in additional private sector spending (Economic Insight, 2015). This is added to the total predicted business enterprise spending on R&D.

I have also assumed that the R&D-to-GDP *target* grows linearly from its current position now to 2.4% in 2027. Given this, my estimations suggest that meeting the 2.4% R&D target will require additional spending increases beyond what is planned already amounting to an additional £13.5 billion in 2027. This would have to be met through additional public and/or private sector spending.

Table 1 Sources of funding for R&D and sector of R&D, 2016

	Sector performing the R&D, 2016						
	UK						Overseas
	Government	Research Councils	Higher Education	Business Enterprise	Private Non-Profit	Total	
Sector funding the R&D							
Government	1,136	137	483	1,730	98	3,584	542
Research Councils	47	554	2,107	5	197	2,909	292
Higher Education Funding Councils	-	-	2,207	-	-	2,207	-
Higher Education	2	17	299	-	131	449	-
Business Enterprise	15	25	350	16,742	18	17,151	6,658
Private Non-Profit	13	42	1,242	188	170	1,655	-
Overseas	122	60	1,346	3,560	85	5,174	-
Of which							
EU government to HEIs	-	-	715	-	-	715	-
Other overseas	122	60	631	3,560	85	4,459	-
TOTAL	1,335	837	8,035	22,224	699	33,130	-
Of which:							
Total public sector	1,185	708	5,811	1,735	426	9,864	834
Total private sector and overseas	150	127	2,223	20,490	273	23,265	6,658

Note: All monetary values are in constant 2016 prices

Source: Office for National Statistics (2018)

From national data on R&D we also know *who* performs the funded activity (Table 1). Assuming a similar mapping between the sources of R&D funds and sectors of performance in 2027 as in 2016, Table 2 estimates the scale of R&D activity likely in each sector of the UK innovation system. It suggests that the scale of R&D activity in the HE sector will grow from approximately £8 billion today to approximately £14.2 billion in 2027, while activity in business enterprises will grow from £22 billion to approximately £36.5 billion over the time period.

Table 2 Sources of funding for R&D and sector of R&D, 2027

	Sector performing the R&D in UK					
	Government	Research Councils	Higher Education	Business Enterprise	Private Non-Profit	Total
Sector funding the R&D						
Public sector R&D	2,166	1,294	10,621	3,171	779	18,028
Private sector and overseas	244	206	3,609	33,268	443	37,774
Total	2,409	1,500	14,230	36,439	1,222	55,802

Note: All monetary values are in constant 2016 prices

2.3 Estimating the distribution of R&D activity in different types of HEIs

The next important question is which types of HEIs will undertake the increased public and private sector spending on R&D. A diverse range of HEIs operate in the UK's national innovation system, playing different roles in addressing local, sectoral, technological and socio-economic challenges. This diversity is seen as important for a healthy national innovation system (Howells et al., 2008; Sainsbury, 2007; Ulrichsen, 2015a; Uyarra, 2010). Given the nature of the 2.4% R&D target focusing on increased R&D activity, and the different capabilities and resources of HEIs to undertake this type of activity, it is likely that some HEIs will benefit from increased opportunities than others.

Estimating how any increases in R&D spending will feed through to different types of HEIs is challenging without good information about investment plans for these institutions in developing their research-related capabilities and assets. However, the reality is that the rank order of HEIs in terms of the scale of their research activity does not change much over time (Hughes et al., 2013). An analysis of the correlation of ranking of public and private sector research income by HEI across years from 2008 to 2017 reveals a correlation of above 0.93. Therefore, as a first approximation, one could assume that the increase in public and private sector funded R&D undertaken at HEIs is distributed across HEIs in a similar pattern as it is today. This assumption, and possible alternative scenarios, discussed further in section 6.4.

Table 3 Predicted distribution of public and private R&D spending across different types of HEIs

HEI Cluster	Number of HEIs	Share of total (%)		Research income (£ billions)					
		2016		2016		2027			
						Baseline		2.4% R&D target	
		Public R&D	Private R&D	Public R&D	Private R&D	Public R&D	Private R&D	Public R&D	Private R&D
Cluster V	16	56.4	64.2	3,276	1,428	3,276	1,637	5,987	2,319
Cluster X	20	14.0	7.8	812	173	812	198	1,484	280
Cluster E	29	5.3	3.1	306	69	306	79	559	112
Cluster M	17	0.2	0.1	11	3	11	3	19	5
Cluster J	17	0.7	0.5	43	12	43	14	78	20
STEM Specialists	10	3.0	7.9	174	175	174	200	319	284
Other Specialists	24	0.4	0.2	23	3	23	4	42	5
Scottish, Welsh and Northern Irish HEIs	30	20.1	16.2	1,166	360	1,166	413	2,132	585
Total	163	100	100	5,811	2,223	5,811	2,548	10,621	3,609

Note: All monetary values are in constant 2016 prices

Table 3 presents the predicted distribution of public and private R&D spending in 2027 across different types of HEIs. I exploit the groups of HEIs proposed in the Knowledge Exchange Framework (KEF) which attempts to identify groups of HEIs based on their quasi-fixed capabilities and assets which shape their opportunities and challenges for KE/C (Research England, 2019a; Ulrichsen, 2018a). The use of these groupings (rather than more research-focused groupings) is deliberate given the focus in this report in estimating how additional R&D spending may shape the scale and portfolio of KE/C activity in the system in 2027 and hence the need for additional resources to support this increased activity.

3 Knowledge exchange and commercialisation activity in the innovation system

What does a substantial increase in public and private sector spending on R&D mean for KE/C opportunities between HEIs and non-academic organisations in the innovation system?

3.1 Innovation systems and the role and contributions of universities

To examine this it is important to ground the discussion in a conceptual framework of how HEIs operate and contribute within the national innovation system. Given our particular focus on R&D and innovation in the context of the UK's industrial strategy, I suggest that adopting an innovation system lens provides valuable insights that would be hard to reveal through other lenses.

At the core of the innovation systems approach are processes of knowledge generation, diffusion and deployment. This process is shaped by the systems 'structure', which typically distinguishes three core elements. The first element 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* within which activities occur and which shapes agent behaviour. This encompasses '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 such as culture. 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.

Returning now to the innovation process at the core of the innovation system, this can be thought of as progressing through a number of value adding stages. These typically include: understanding the potential market (including needs, technical and economic feasibility, idea generation and selection etc.); research and development; design and prototype; demonstration and testing; production; and commercialisation and deployment in practice (Caraça et al., 2009; Kline and Rosenberg, 1986). Critically, these stages do not occur in isolation from each other, nor do they necessarily occur sequentially. Rather they are strongly iterative and coupled (Caraça et al., 2009; Kline and Rosenberg, 1986). Further, the different stages may be undertaken by different agents in the innovation system and are shaped by the system's institutional framework and the strength of the system functions. Evidence suggests increasing levels of in collaboration and partnership as part of the innovation process.

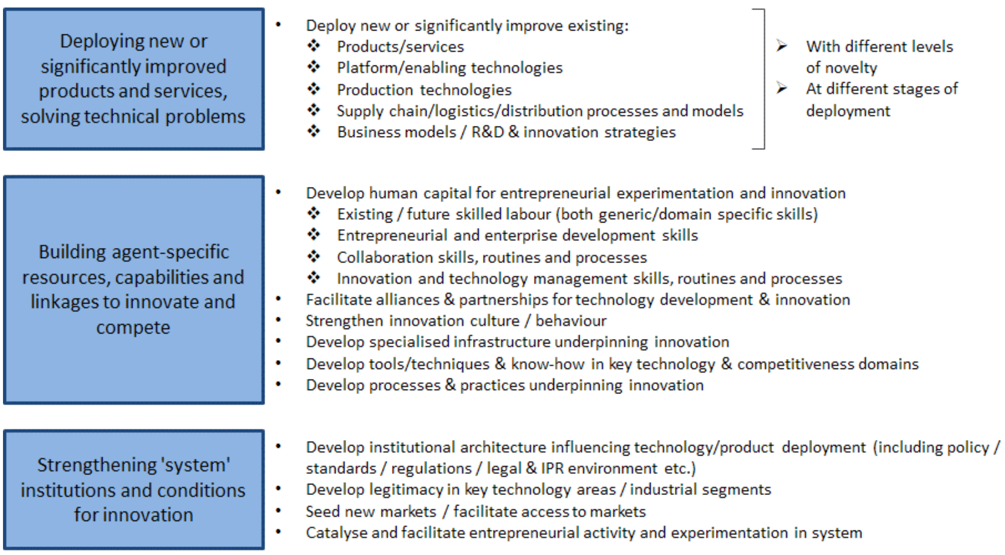
Within this broad innovation systems framework, and in the UK context, HEIs form a core part of the scientific infrastructure. They are one of the primary agents in the system creating the variety of underpinning knowledge and technological alternatives from which agents operating in competitive markets can select and further develop. As *agents* in innovation systems they are typically stable, and (once we move beyond commercialisation *per se*) relatively neutral environments for agent interaction. This helps to create a conducive environment for *catalysing* interactions within the innovation system, including between academics and innovators as well as between innovators involved in different parts of the innovation process. These often informal, non-transactional 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).

Academic and practitioner studies examining how universities contribute to innovation have identified a variety of areas where they impact. Through deploying their knowledge and physical assets in *interactions* with other innovating agents they have the potential to make important contributions to the innovation system, both in addressing specific technical and business needs, and in helping to strengthen the conditions underpinning innovation in the system (Gunasekara, 2006; Lester, 2005; Power and Malmberg, 2008; Ulrichsen, 2015a).

Through more direct linkages with HEIs, 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).

HEIs may also have a role to play in strengthening wider *system and agent capabilities* (Breznitz and Feldman, 2012; Gunasekara, 2006; Ulrichsen, 2015a; Uyarra, 2010; Youtie and Shapira, 2008). Examples include: working to develop the underpinning skills and physical innovation infrastructure critical to the functioning of the particular innovation system; informing the development of economic, innovation and sector strategies (locally or nationally); working alongside key stakeholders in the system to provide leadership. This in turn may be closely linked to the co-evolution of *institutional frameworks* designed to shape people's innovation-related behaviours and activities. The variety of areas where HEIs contribute to innovation systems is captured in Figure 3.

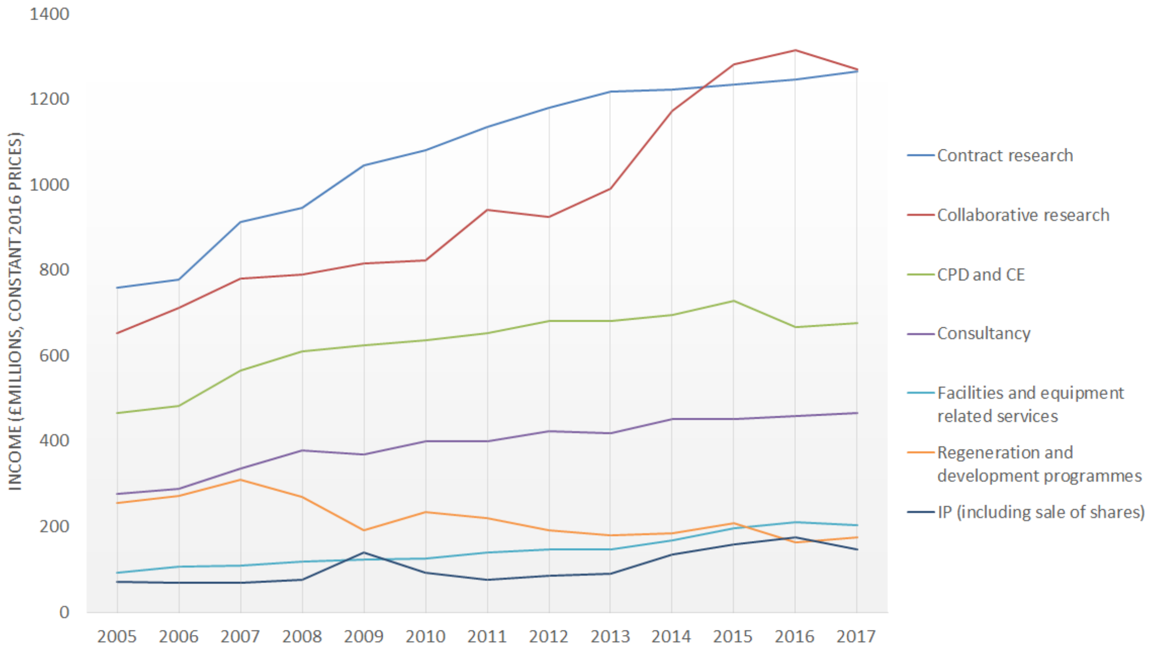
Figure 3 Areas of contributions of HEIs to industrial innovation



The past twenty years or so have seen HEIs become more strategically active in enabling knowledge to be exchanged, diffused and deployed in practice to enable these types of contributions to be realised by innovating agents. This has been facilitated by a significant increase in policy focus on, and public resources devoted to, strengthening the contributions of HEIs to address important economic and social challenges and the innovation needs of industry. These developments have seen HEIs move well beyond their traditional knowledge diffusion mechanisms through scholarly publication and the movement of students into the labour market and dramatically expand more *direct* knowledge exchange and commercialisation focused interactions with innovating organisations. Importantly, these KE/C interactions are fundamentally shaped by the type of knowledge generated and held by HEIs, or accessible through them (e.g. through collaborations).

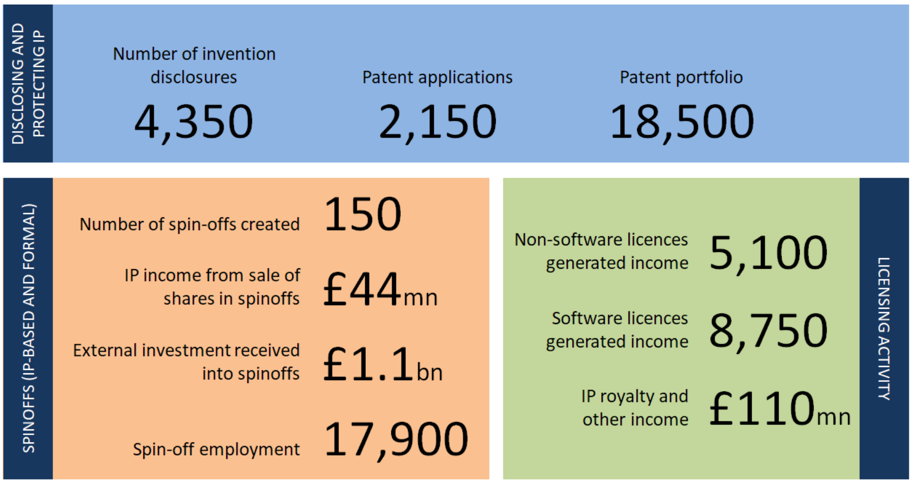
Studies have also frequently highlighted the many *types* of KE/C interaction mechanisms that form between HEIs and non-academic organisations. The nature and scale of key mechanisms are captured annually for all UK HEIs in the Higher Education Business and Community Interaction (HEBCI) survey and are shown in Figure 4 and Figure 5. These form a subset of the full set of KE/C mechanisms that have been identified in surveys of academics and non-academic organisations and other studies on KE/C (see e.g. Hughes et al., 2016; Hughes and Kitson, 2012; Philpott et al., 2011).

Figure 4 Knowledge exchange income by mechanism, 2004/5 – 2016/17



Source: HEBCI surveys 2004/05 – 2016/17

Figure 5 Selected measures of IP commercialisation (average for 2014-2017)



Source: HEBCI surveys 2013/14 – 2016/17

3.2 'Push', 'pull', and 'co-developed' KE/C opportunities

Some KE/C opportunities arise through what one might term *'KE/C-push'* engagements: opportunities that emerge as a result of the research activity undertaken within the HEI. For example, new knowledge and novel technologies developed through research may lead to new commercialisation opportunities (e.g. through spin-outs and licensing).

Other opportunities are driven more by decisions in the private sector (and indeed government departments, public organisations such as the NHS, and charities) to engage externally to acquire knowledge to feed into their innovation and wider business activities. This creates a *pull* for KE/C engagements. Examples might be include firms looking to commission research, testing or consultancy services from academics, or take part in training courses to build new capabilities to innovate and compete. There are also *co-developed* and collaborative KE/C opportunities that emerge through the interactions of HEIs and non-academic organisations, for example co-investing in collaborative research projects.

Figure 6 Framework for exploring university contributions to innovation system through KE/C

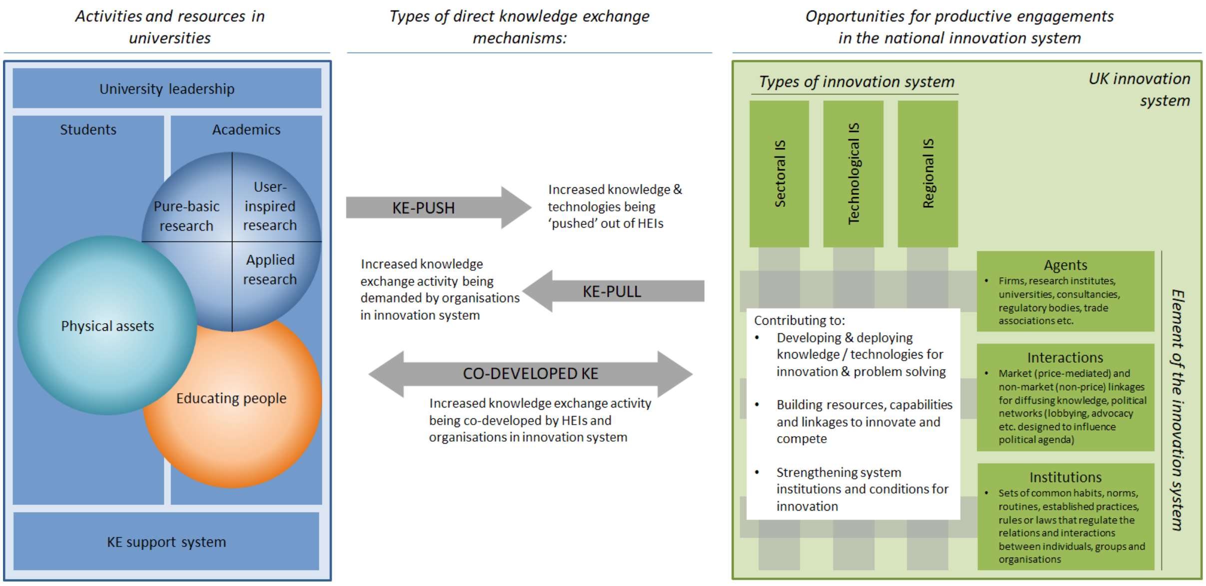


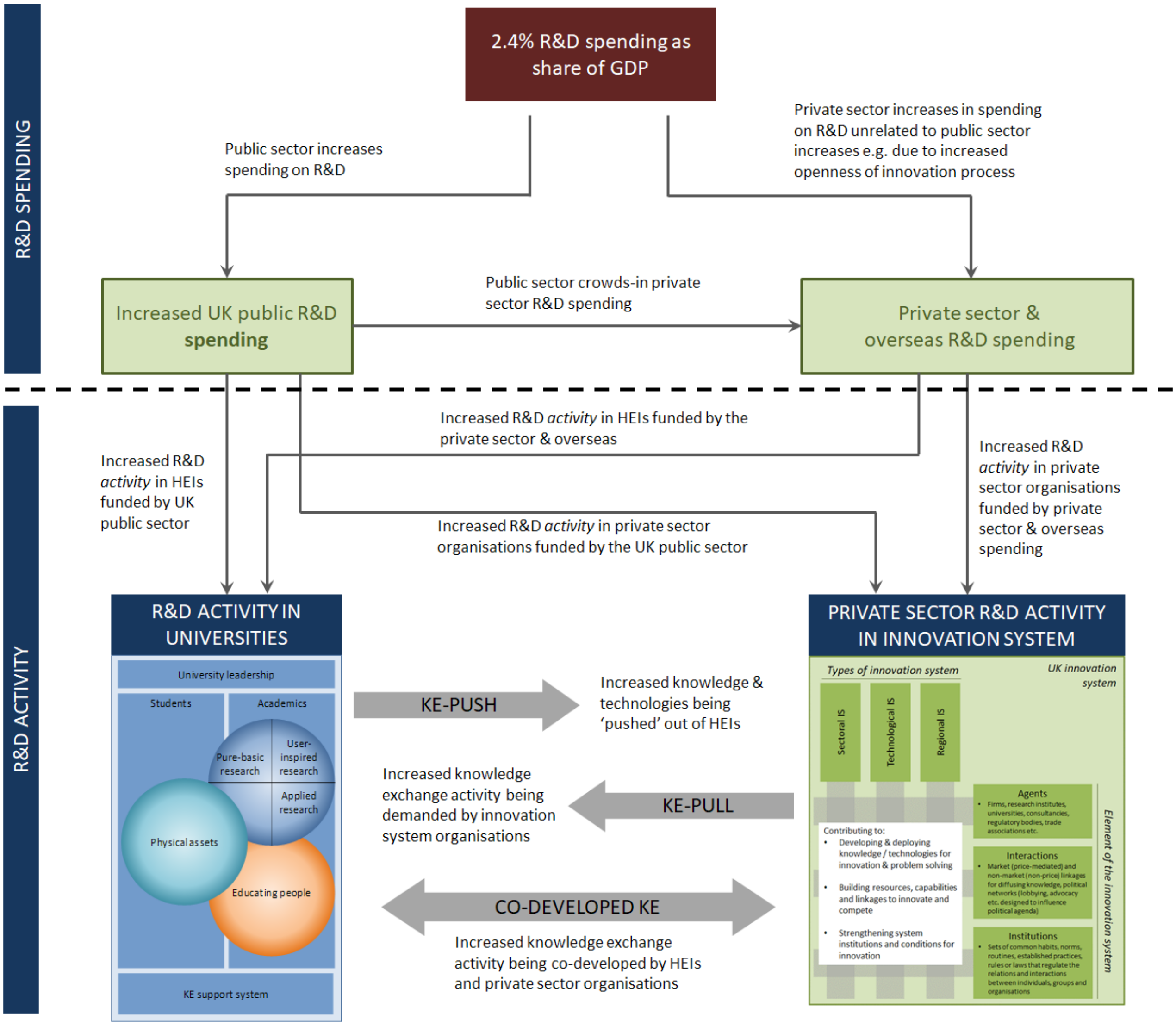
Figure 6 brings together this discussion and attempts to capture how HEIs work with, and contribute to the UK's national innovation system. It deliberately distinguishes the assets and resources of HEIs, the different types of KE/C mechanisms, and the types of contributions they make to different types of sectoral, regional and technological innovation systems.

4 Effects of R&D spending increases on KE/C activity

This section now turns to how increased spending on R&D by organisations in the public and private realms of the innovation system feed might affect the scale and portfolio of KE/C opportunities for HEIs. Figure 7 brings together the working model developed.

Estimating how public and private R&D spending increases feed through into KE/C opportunities requires plausible assumptions to be made about how public and private sector R&D spending will influence different types of KE/C mechanisms. Broadly I assume that increases in research activity resulting from public-sector R&D spending made *directly* in HEIs (e.g. through Research England and the Research Councils) increases the stock of knowledge and results in increased opportunities for *push*-related KE/C. By contrast, increases in private sector spending on R&D results in increased demand for R&D related KE/C engagements – i.e. KE/C-*pull* – as organisations seek to engage externally to acquire knowledge to support their internal R&D efforts and priorities. This could include services such as contract research, testing services, technical and business consulting, facilities and equipment services etc. Demand could also increase for KE/C engagements such as training that help organisations raise their technical and generic capabilities related to their R&D and innovation efforts, and exploit the knowledge and technologies generated outside their organisations. In addition, the increase in overall R&D activity in HEIs and the private sector is assumed to lead to increased demand for *co-developed* KE/C opportunities. Details of the assumptions along with scaling factors are set out in Table 4.

Figure 7 Framework capturing how increases in R&D spending influence KE/C opportunities



Increased R&D activity in HEIs:

- Requires expansion of academic base to undertake R&D with implications for capacity of HEIs to engage in KE more broadly
- Increases number of inventions being disclosed with commercial potential
- Increases stock of knowledge with exploitable potential

Increased R&D activity in private sector organisations:

- Increases demand for R&D focused KE services
- Increases demand for related KE services focused on building capabilities to undertake R&D and exploit HEI knowledge, such as training, technology testing services, and consultancy

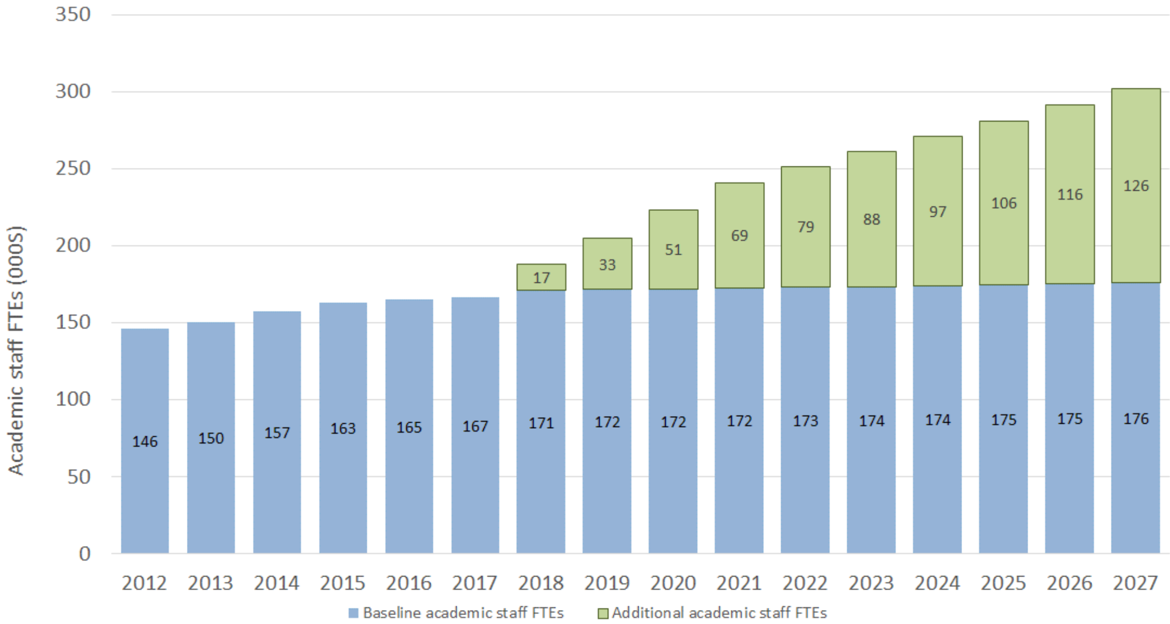
Table 4 Assumed effects of R&D spending increases on KE/C and scaling factors

Type of R&D spending increase	Effect on KE/C opportunities	Scaling factors
Increased public sector R&D spending in HEIs leads to…	- Increased commercialisable outputs being disclosed and patented resulting in increased number of IP-based spinouts being set up and raising external investment	- Spinouts per £million public sector R&D spending - External investment raised per spinout
	- Increased public sector contributions to collaborative research - This generates leverage of private sector spending on collaborative research	- Public sector contributions to collaborative research per £ public sector R&D spending - Leverage ratio of cash & in-kind contributions to collaborative research per £ public sector contribution to collaborative research
Increased public and private sector funded R&D spending in HEIs leads to…	- Increased number of academics to undertake this R&D. This increases the overall capacity to undertake KE of all types (not just R&D-related KE/C)	- R&D spending in HEIs per academic FTE
	- Increased licensing activity emerging from public and private funded R&D in HEIs	- Licensing income per £R&D spending
Increased private sector R&D spending in HEIs leads to…	- Increased demand for contract research - Increased demand for consultancy, CPD and facilities and equipment services related to research exploitation, technology transfer and exploitation of HEI physical assets	- Contract research income per £ private sector R&D spending - Consultancy income associated with R&D-related HEIF categories per £ private sector R&D spending - CPD income associated with R&D-related HEIF categories per £ private sector R&D spending - Facilities and equipment services income associated with R&D-related HEIF categories per £ private sector R&D spending
Increased number of academics resulting from increased R&D spending leads to…	- Increased KE/C activity in non-R&D related HEIF categories including CPD, consultancy, and provision of facilities and equipment services - Increased non-formal staff start-ups	- Consultancy income per academic in non-R&D-related HEIF categories - CPD income per academic in non-R&D-related HEIF categories - Facilities and equipment services income per academic in non-R&D-related HEIF categories

The scale of increases in R&D activity in HEIs required to deliver the 2.4% R&D target will likely not be able to be met by the capacity of the existing academic community. As such I assume that the additional R&D spending in HEIs will lead to expansion of academic capacity to undertake the research. The estimates of this increased capacity are shown in Figure 8 and assume a similar capacity to deliver research per academic in 2027 as now (i.e. the ratio of research income to academic FTEs remains constant).

The previous assumptions have all focused on the effects of increased spending on R&D-related KE/C-engagements. However, the expansion of the scale of the academic community to undertake the increased research activity would also create a significant larger capacity to undertake KE/C in other areas not related to R&D. This effect is built into the model exploiting information available through the HEIF strategies on how different types of KE/C mechanisms are associated with different types of support (distinguishing not least those associated with research exploitation and commercialisation from skills and workforce development and community-focused activities)[3].

Figure 8 Estimates of the academic capacity to deliver the 2.4% R&D target, 2012 – 2027



4.1.1 Estimates of the nature and scale of the KE/C portfolio in a 2.4% world

Given the geographic focus of HEIF funding, the analysis that follows focuses on England only.

The conceptual model in Figure 7 and assumptions set out in Table 4 were used to estimate both growth in the scale and nature of KE/C in 2027 resulting from a baseline increase in public and private sector R&D spending, as well as from the additional spending required to achieve the 2.4% R&D target[4]. In addition, recognising that the changes to R&D spending will affect different types of HEIs in different ways (e.g. due to their research intensities and their propensity to engage in different types of KE/C), the model estimates changes for each HEI cluster (using the clusters proposed for the KEF). The resulting model estimates that English HEIs will generate approximately £5.9 billion in KE/C income in 2027. Full details are shown in Table 5.

[3] Details of this split can be found in the Appendix B.

[4] The scaling factors for the different HEI clusters are provided in Appendix B.

Table 5 Estimated scale and portfolio of KE/C in 2.4% R&D world

	KE/C activity	2017	2027		
		Baseline	Baseline	Additional	**Total**
Income (£millions)	Collaborative research	1,014	1,073	865	**1,939**
	Contract research	1,111	1,156	512	**1,669**
	Consultancy	373	392	208	**600**
	Facilities and equipment services	181	189	88	**278**
	CPD	569	617	436	**1,054**
	Regeneration & development	135	147	0	**147**
	IP income (excluding sale of shares)	27	24	19	**43**
	IP income (sale of shares)	89	106	71	**177**
	KE/C income (total)	3,499	3,705	2,201	**5,906**
New venture creation	Spinoffs (HEI IP-based): Number	102	113	91	**205**
	Spinoffs (HEI IP-based): External investment raised (£millions)	819	770	620	**1,390**
	Staff start-ups: Number	42	47	16	**63**
	Staff start-ups: External investment raised (£millions)	11	16	5	**21**

Note: All monetary values are in constant 2016 prices

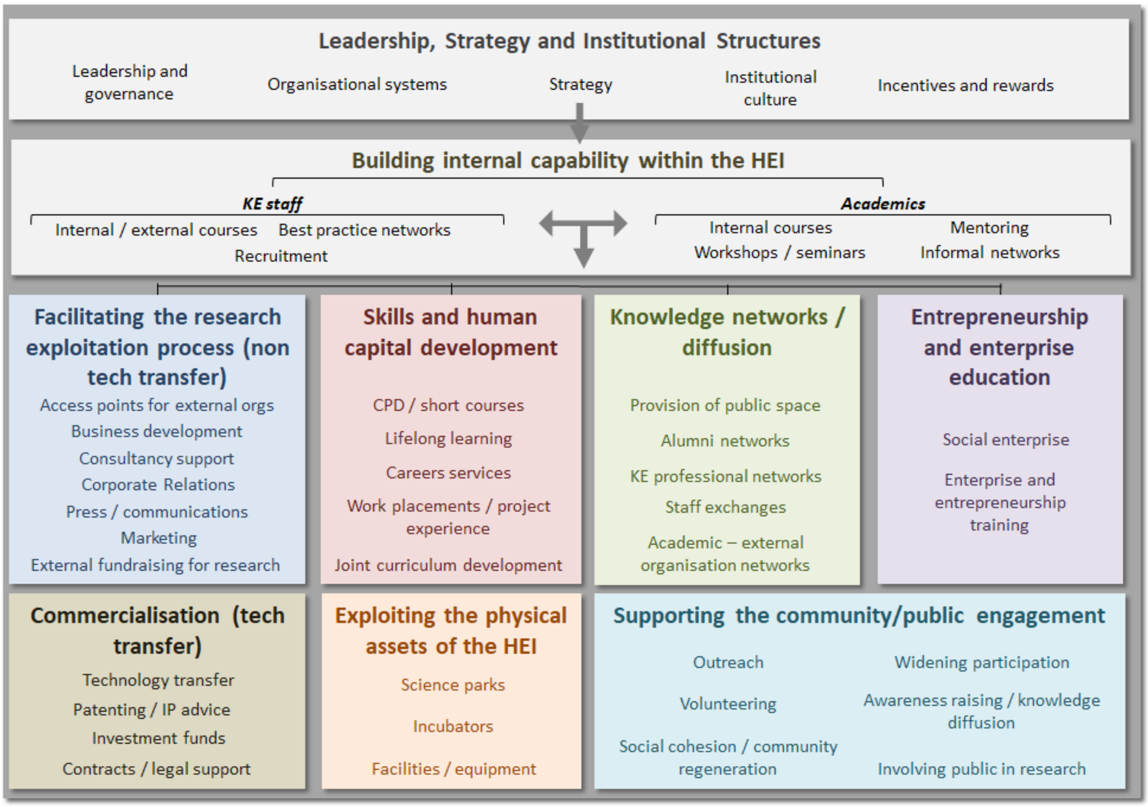
5 The effects of increased KE/C on the need for public funding for KE/C support

5.1 The nature of public support for KE/C

KE/C activities – not just IP commercialisation but also many other types – benefit from investments by HEIs in the building of capabilities and capacity to facilitate engagement (see e.g. Galán-Muros et al., 2017; Galan-Muros and Davey, 2017; PACEC/CBR, 2009; Perkmann et al., 2013; Ulrichsen, 2015b). This includes developing an *institution-wide professional KE/C support system*, including: new or strengthened leadership roles for KE/C; policies and incentives; support units; innovation-focused centres and institutes; processes and approaches to KE/C; and strengthening the internal capabilities of support staff as well as individual academics to engage. This type of institution-focused funding has been shown in evaluations of HEIF to be important in enabling HEIs to develop the long-term capabilities and capacity to engage, respond flexibly to opportunities, invest in strategically important areas of KE/C, experiment with novel approaches to engagements, and leverage additional, project-specific funds for KE/C (PACEC/CBR, 2009; Ulrichsen, 2014).

Work by PACEC/CBR (PACEC/CBR, 2011) and subsequently by Ulrichsen (in an internal publication for HEFCE) developed a framework to capture the variety of support being put into place by HEIs to support different forms of KE/C. This is shown in Figure 9.

Figure 9 Focal areas for knowledge exchange support



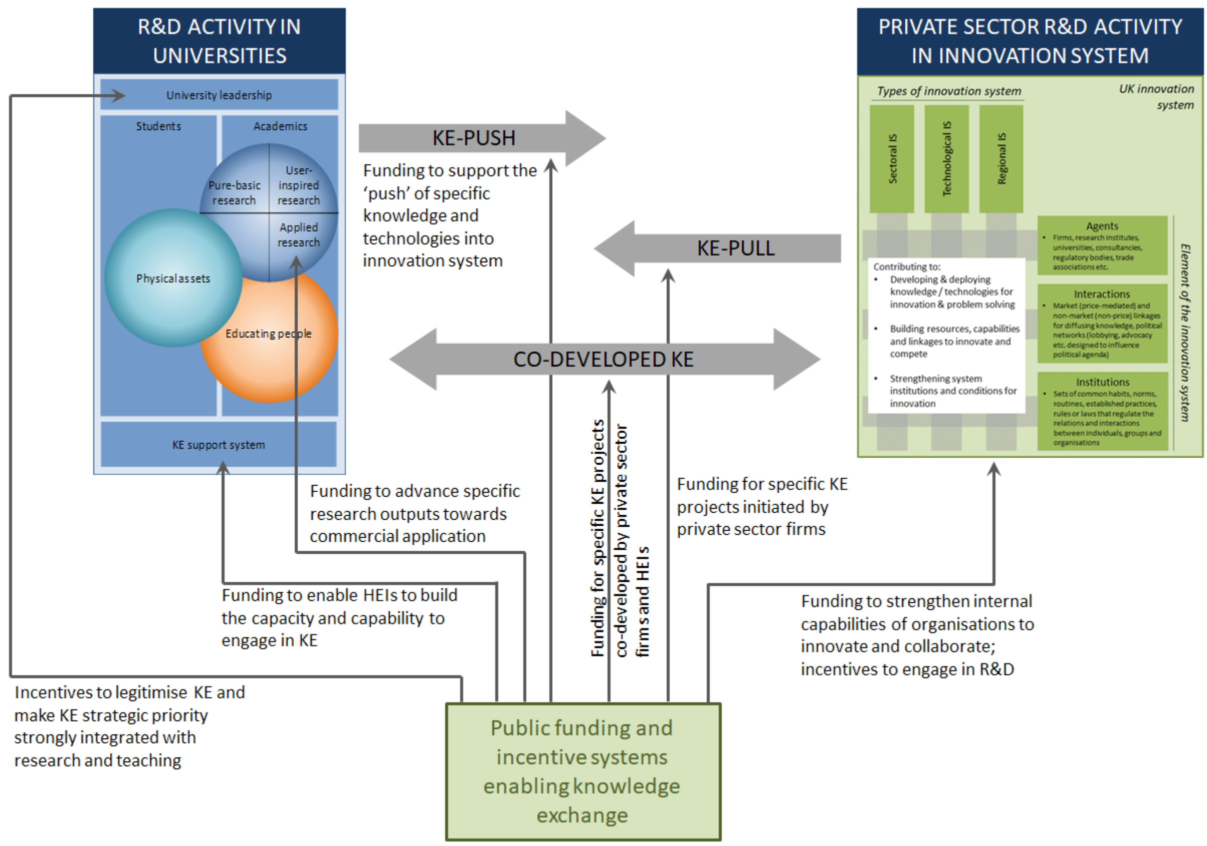
In addition to this 'institution-wide' support system for KE/C, specific research outputs or other knowledge held by academics may require further development towards application in a practical setting and de-risking to make them conducive to investment, absorption and exploitation by external partners. These highly project-specific KE/C *activities* may require the investment of specifically targeted KE/C funds.

Critically, HEIs will inevitably require a balance of funding that enables them to develop the necessary long-term, institution-wide capabilities and capacity to engage in KE/C, and invest in project-specific KE/C activities to make their knowledge outputs more easily absorbed by external partners.

Previous evaluations of HEIF suggest that some HEIs use part of their HEIF allocation to support these types of transactional activity (PACEC, 2012; PACEC/CBR, 2009). Other public sources of funding for specific KE/C transactions include from the Research Councils providing translational and proof-of-concept funding to further develop research outputs into commercial or socially valuable propositions, funding from Innovate UK such as its Knowledge Transfer Partnership scheme, and from specific government departments and agencies to develop practical solutions to particular needs. Some charities, particularly in the field of biomedical research, provide funding to support the translation of research into commercial application.

Figure 10 builds on the KE/C conceptual framework set out earlier to capture how governments can support KE/C between HEIs and non-academic organisations in the innovation system. In addition to direct grants, the framework captures other incentives governments can put into place to change behaviours. For example, the changes to the periodic assessment of research excellence to include impact considerations, and by funders to include requirements of consideration of pathways to impact by grant applicants, help to alter the culture towards greater engagement in KE/C.

Figure 10 Different types of public support for KE/C



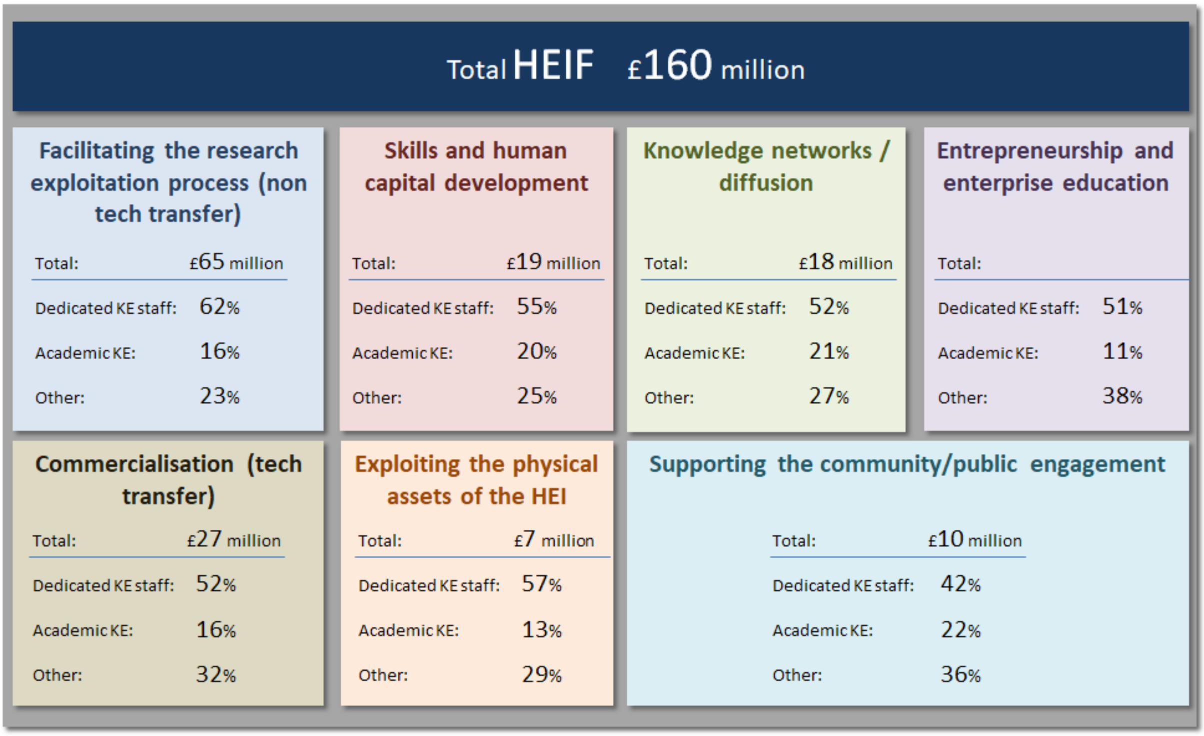
The central focus of this paper is exploring the scale of KE/C funding programmes focused on building institution-wide capability and capacity required to deliver the 2.4% R&D target. I do not consider the demand for project-specific funding of the type typically allocated by the Research Councils and Innovate UK.

5.2 The English Higher Education Innovation Fund

The primary public funding programme in England for developing institution-wide capability and capacity for KE/C is HEIF. It is managed as part of the dual funding system through Research England with other funds for KE/C distributed through the Research Councils and Innovate UK.

HEIF has allowed HEIs to develop a system of KE/C support facilitating a wide range of KE/C activity (PACEC, 2012; Research England, 2019b; Ulrichsen, 2014). As part of the HEIF allocation process, data is collected on how the £160 million funding distributed in 2016/17 is invested across the different support areas identified in Figure 9. It also provides a breakdown between investment in dedicated KE/C staff, academic KE/C activity, and other costs and initiatives. Academic staff KE/C activity includes the buying out of academic time to develop KE/C practice, as well as academic leadership and development activities. Other costs and initiatives include all forms of projects (such as proof of concept, seed-corn funding and pump-priming) as well as the costs of managing KE/C activities (such as marketing or evaluation) (HEFCE, 2011a). These breakdowns are captured in Figure 11.

Figure 11 Allocation of HEIF funding by KE/C focus and type of support in 2016/17



5.2.1 Evidence on the effects of HEIF funding on KE/C outcomes

To what extent does this funding lead to additional KE/C outcomes? Mounting evidence over the past decade points to the success of HEIF funding in enabling HEIs to engage in KE/C with partners in the wider economy and society and increase the socio-economic benefits achieved (PACEC/CBR, 2009; Ulrichsen, 2015b, 2014). The success and importance of the funding programme has also been well articulated by practitioners and experts in response to government reviews of university-business collaborations and knowledge exchange (see e.g. Dowling, 2015; Witty, 2013) and select committee inquiries on the topic (UK Science and Technology Committee, 2017, 2013).

The most recent quantitative assessment of the economic impact of HEIF funding was presented in Ulrichsen (2015b) who estimated the additionality of HEIF funding using both subjective methods (based on the expert views of practitioners gathered through their HEIF strategies), and objective methods (using econometric modelling techniques). These estimates are presented in Table 6. These methods focus on using income generated through different forms of knowledge exchange mechanisms as a *proxy* for the economic value generated. This assumes that the income received by the HEI reflects the user's willingness to pay for the KE/C 'service'; their perception of its value to their organisation. A discussion on this topic and some important caveats to be borne in mind from Ulrichsen (2015b) is reproduced here[5]:

> "…the best alternative proxy indicator currently available [for KE/C impact] is the amount of income received by HEIs through their KE/C activities. The primary assumption made here is that reasonably well governed and accountable organisations in the private, public and third sectors willing to pay for a service (here KE/C-related) must believe that they are deriving value from it in some way. At minimum, KE/C income represents implied demand for the capabilities and expertise available within universities. Standard economic theories of the

[5] A think-piece by the author from 2016 on the use of income as a proxy for impact in KE/C is reproduced in Appendix C.

firm would go further and suggest that the price paid for the service reflects the marginal contribution of that service to their organisation. Alternative theories of the firm reveal other pricing approaches which weaken this assumption somewhat. Given the complexities of spillovers, multiplier effects, supply chain effects, unexpected benefits being realised and other reasons, it is likely that KE/C income represents a *minimum bound* on the monetary value of the KE/C activity on the organisation. Importantly, assuming that the extent to which the price paid for different types of KE/C is at least proportional to its economic value (if not reflective of it), KE/C income can be aggregated across different mechanisms and, importantly, compared across institutions."

(Ulrichsen, 2015b)

However, it is important to recognise that there are a range of KE/C services for which the income will not fully capture the value realised. Using data generated through an evaluation of the non-monetary benefits arising from HEIF funded activities, Ulrichsen (2015b) also estimated an additional component for the income-based additionality estimates focusing on the non-monetary components (Table 6).

Table 6 Estimates of additionality to HEIF funding

Period	Component	Method	Gross additionality
2009-14	Monetary component	Expert judgements	6.3
	Non-monetary component	Expert judgements	2.6
	Monetary component	Econometric modelling	7.3
2016-17	Monetary component	Expert judgements	6.4

Source: Ulrichsen (2015b), author's analysis of HEIF 2016-17 strategies

Institution-level KE/C funding has been through a number of phases since its inception in the early 2000s. The early period was characterised by relatively low levels of funding being distributed through a range of different programmes that were progressively consolidated into the HEIF funding stream. In the early period, they were initially distributed through competitions and subsequently through a mix of formula and collaborative projects. It received a boost in level of overall resource allocated to the English HE sector in round 4 (2008-09 – 2010-11), with its allocation solely driven by formula. This second phase is thus characterised by higher levels of funding that have been stable (in cash terms).

Furthermore, changes to the formula meant that the distribution of this funding across English HEIs over the past decade has changed quite considerably. These include the removal of a pure capacity component in the formula to focus entirely on performance in KE/C, and a significant increase in the funding cap from £1.9 million to £2.85 million (HEFCE, 2011b).

Table 7 KE/C income performance of HEIs experiencing different changes in HEIF funding between 2008-11 and 2012-16

Change in HEIF in average received between 2008-11 and average received between 2012-16	KE/C income from all sources				KE/C income from private sector sources (large companies and SMEs)			
	Amount (£000s), 2011	Annualised growth rate (% p.a.) 2008-11	Amount (£000s), 2016	Annualised growth rate (% p.a.) 2012-16	Amount (£000s), 2011	Annualised growth rate (% p.a.) 2008-11	Amount (£000s), 2016	Annualised growth rate (% p.a.) 2012-16
Significant gains (≥ 50% change)	2,013,547	4.7	2,539,699	4.9	524,078	-0.5	735,157	7.5
Some gains (5% < change ≤ 50%)	345,278	5.1	408,009	4.5	89,589	-2.1	113,266	3.7
Minor changes (-5% < change ≤ 5%)	74,471	-6.8	74,703	2.7	8,094	4.0	12,052	14.0
Some losses (-50% < change ≤ -5%)	377,845	-0.9	417,882	4.9	61,321	-5.0	66,537	3.5
Significant losses (Change ≥ -50%)	38,519	12.8	50,827	-2.2	5,927	11.7	4,482	-5.8

Source: Ulrichsen (2018b)

These changes to the distribution of HEIF funding over the past 10 years also provides an interesting comparison group between those that have gained in HEIF funding, and those that have suffered losses in funding (Table 7). These can be used to further explore whether changes to the funding programme have had positive effects. HEIs were grouped into one of 5 groups based on the change in the average HEIF funding received during the period 2008-11 and that received over 2012-16:

- Significant gains (greater than 50% gain)
- Some gains (between 5% and 50% gain)
- Minor changes (between 5% loss and 5% gain)
- Some losses (between 5% loss and 50% loss)
- Significant losses (greater than 50% loss)

This analysis suggests that:

- Those HEIs that gained significantly in HEIF funding between periods maintained a strong and steady growth rate of almost 5% in the period before the change and that after it. In particular, they experienced significant growth in their income from the private sector following the increase in HEIF funding. A similar story exists for those that experienced some gain in HEIF funding (between 5% and 50%)
- HEIs that experienced only minor changes in HEIF funding managed to turn their KE/C income performance around between periods, from a decline of 6.8% before the changes, to 2.7% growth following the change. They exhibited particularly strong private sector growth.
- Those HEIs that lost some HEIF funding (between 5% and 50%) similarly managed to turn around their KE/C performance both in aggregate and with the private sector.
- HEIs that experienced significant losses in HEIF funding were those that generated relatively small amounts of KE/C activity. These institutions saw their KE/C incomes suffer declines following the changes, both in aggregate and with the private sector in particular.

Overall, the evidence suggests that the changes that were meant to reward KE/C performance appears to have done so. It also tentatively suggests that those that lost some of their HEIF funding (but not all of it) have adapted to the new landscape and have managed to turn their KE/C income performance around.

5.3 The scale of institution-wide funding to meet the KE/C needs of a 2.4% R&D world

Given the above discussion, HEIs will require additional resources to support the increased KE/C activity resulting from increased public and private R&D spending in the 2.4% R&D target world.

Using the model outlined thus far it is possible to estimate the scale of KE/C funding required. I make the following assumptions in the base model:

- KE/C income and other outputs map onto the support areas for funding in the same way in 2027 as they do today. This allows us to estimate, for each HEI cluster, the amount of KE/C income and other outputs generated by area of support and thus link it to an amount of HEIF funding invested
- Not all KE/C income is influenced by HEIF. Information gathered through the HEIF 2016/17 strategies provides an indication of the proportion of different types of KE/C income believed by senior practitioners in each HEI as attributable to the funding. This proportion is estimated for each HEI cluster by area of HEIF funding support
- The ratio of the amount of KE/C income attributable to HEIF to the amount of funding invested in each area of KE/C support remains constant over time. This can be interpreted as investing £1 of HEIF in, for example, research exploitation related KE/C activities will generate the same amount of attributable KE/C income in 2027 as it does today. A key implication of this is that there are no economies of scale being realised. This is discussed in detail in section 6.1. Using data available through the 2016/17 HEIF strategies linked to HEBCI data, this ratio is estimated for each HEI cluster.

Using the above assumptions and estimates, Table 8 presents the resulting estimates of the scale and composition of HEIF funding required to support the level and mix of KE/C engagement emerging in a 2.4% R&D target world. It suggests that £342 million will be required in cash terms, compared to the £160 million allocated in 2016/17.

Table 8 Estimates of HEIF funding requirements in a 2.4% R&D world

KE/C support area	HEIF Total (£millions)			HEIF breakdown (2027) (£millions)		
	2021	2024	2027	Dedicated KE/C staff	Academic KE/C activity	Other costs and initiatives
A1. Facilitating the research exploitation process (non-technology transfer)	94.9	104.8	115.5	71.1	18.2	26.2
A2. Commercialisation (technology transfer, including spin-outs and licensing)	38.7	42.8	47.3	24.8	7.5	15.0
B. Skills and human capital development	29.2	32.5	36.0	19.7	7.0	9.3
C. Knowledge sharing and diffusion	26.7	29.4	32.4	16.4	7.2	8.7
D. Supporting the community and public engagement	14.5	15.8	17.2	7.2	3.9	6.1
E. Enterprise education and entrepreneurship	21.8	23.7	25.7	13.4	2.9	9.4
F. Exploiting the HEI's physical assets	10.4	11.4	12.4	7.1	1.6	3.7
Total (2016 prices)	236.3	260.3	286.5	159.7	48.3	78.5
Total (current prices)	**257.6**	**297.2**	**342.3**	**190.8**	**57.7**	**93.8**

6 Factors influencing the scale of KE/C funding required in a 2.4% R&D world

The estimate of KE/C funding presented in Table 8 represents a base case building on the assumptions made thus far in the report. Critically it assumes that the funding landscape within which institution-wide KE/C funding remains the same as it is today and that the funding requirements scale linearly with opportunities (i.e. there are no benefits from economies of scale). It also assumes that both the nature and distribution of public and private R&D efforts feeding into HEIs remains the same as today. These are all strong assumptions that should be explored and potentially relaxed in alternative scenarios to the base-case.

6.1 Economies of scale

A key assumption in the base case is that the funding requirements will scale linearly with the significant increases in KE/C opportunities resulting from the large uplifts in R&D spending in the UK's innovation system. The extent to which this assumption holds will depend on the ability of HEIs to realise cost advantages in supporting KE/C as the scale of activity increases – i.e. benefit from economies of scale in KE/C.

6.1.1 Evidence on economies of scale in KE/C

Economies of scale can arise from a number of sources such as:

- Large fixed costs of operations (e.g. necessary legal services/support or capital requirements) underpinning KE/C activity
- Cost savings by being able to accessing knowledge 'inputs' more easily as the scale of KE/C activity increases (e.g. through more established networks of academics becoming engaged making it easier to find expertise and get them involved)
- Specialisation of a KE/C workforce resulting from scale of operations leading to greater productivity of individual staff
- Improved synergies between different KE/C support functions resulting from increased scale of operations, as well as between KE/C and research/teaching
- More effective marketing/promotion resulting from greater scale
- Ability to spread risk more effectively

The concept of economies of scale is well established in economics. However, only a few studies could be identified which explore these issues in the context of KE/C activities. Most of them focused on technology transfer (through spin-outs and licensing) and most argued the case qualitatively rather than attempted to develop empirical evidence.

The case for economies of scale in technology transfer is typically made based on the potential for pooling of inventions (potentially across multiple universities), coordination of expertise in supporting the commercialisation process, greater visibility of inventions with commercial potential for prospective partners (making it easier to identify a potential match), and greater bargaining power (Audretsch et al., 2012; Schoen et al., 2014). Schoen et al. (2014) in particular notes that the effects of pooling will likely be much greater for smaller HEIs with smaller patent portfolios. RSM PACEC (2018) – through qualitative interviews with practitioners – suggest economies of scale in technology transfer arise through specialisation of labour to develop technology/sector-specific expertise rather than generalist knowledge; larger networks of technology entrepreneurs and serial

CEOs that can be drawn upon to get involved in the spinout process; and catalogues of past deals to provide increased information to inform deals moving forward.

The benefits of pooling inventions by Technology Transfer Offices have been explored in a number of studies. For example, Macho-Stadler (2007) predicts that a potential benefit of TTO derives from its ability to pool inventions, vetting and 'shelving' lower-quality disclosures, and raise the overall quality and selling price of deal leading to increased rewards for inventors. Furthermore, a model by Hoppe and Ozdenoren (2005) finds advantages to TTOs in their ability to pool inventions from different laboratories, thereby generating economies of *scope*, and enabling them to deliver a better service.

However, the benefits of pooling are challenged by Kenney and Patton (2009). They argue that this is problematic if technologies are derived from very different communities of practice with different application areas. This suggests that any economies of *scope* need to be accompanied by economies of *scale* as commercialisation typically requires domain-specific expertise.

One study to go beyond the typical focus on technology transfer is a working paper by Duch-Brown et al. (2010) who explore whether economies of scale and scope exist in the production of a basket of KE/C outputs covering research 'partnerships' with industry, licensing and spinouts, and 'technical support' offered by Spanish public universities. They find that the marginal cost of producing this basket out outputs decreases as the scale of output increases, and that economies of scale exist up for HEIs with smaller scales of research activity but disappear for those with much larger research bases.

Finally, Ulrichsen (2014), in a statistical analysis of the factors affecting the levels of KE/C income produced per academic finds a positive effect of HEI scale controlling for other factors. This suggests that, on average, larger HEIs are able to generate higher 'productivity' in KE/C than smaller HEIs. This suggests they may have been able to realise economies of scale in their KE/C efforts. Ulrichsen (2015b) built on his 2014 study and explored the effect of university scale on different types of KE/C, similarly finding that scale of STEM activity in particular had a statistically significant and positive effect on KE/C income per academic overall. In addition, he found that HEIs with larger amounts of high quality research generate higher research-related KE/C income per academic. He also found that KE/C engagements with SMEs benefited from larger STEM activity bases, while KE/C engagements with large companies benefited from larger high quality research bases.

6.1.2 Implications for scaling KE/C funding in a 2.4% R&D world

The above evidence on economies of scale suggests that some HEIs, particularly those smaller HEIs would realise economies of scale related benefits from increasing the scale or KE/C activity in their institutions, or through pooling of efforts with other HEIs. However, large research HEIs may not similarly generate economies of scale through increasing KE/C activities.

Recall from section 5.2 that information is collected from each HEI in receipt of HEIF on they allocate their funding across dedicated KE/C professional staff, academic staff KE/C activity (includes buying out of academic time for KE/C), and other costs and initiatives (includes projects such as proof of concept and seed-corn funding as well as KE/C project management). Intuitively, it is likely that the ability of HEIs to realise economies of scale will also vary depending on the type of support provided. For example, it is possible that, as KE/C activity increases, dedicated KE/C staff may be able to support proportionately more academics and specific engagements should efficiencies and improved processes be developed (subject also to the findings above). By contrast, if the requirements for project- or transaction-specific KE/C funds are dependent on the nature of the technology or knowledge outputs emerging from the research, rather than the processes deployed by academics to advance these outputs towards application, then it is likely that funding requirements per project will remain similar as KE/C opportunities scale.

6.2 Complementary investments

Another key factor that could influence the scale of institution-focused KE/C funding requirements in a 2.4% R&D world is the development of funds or capabilities in complementary areas that reduce the need for this type of funding. This could include, for example, the emergence of other agents in the innovation system which can act as effective intermediaries between research outputs and commercial application which reduce the need for universities to invest as much internally in advancing specific research outputs further towards application before external partners become interested. It could also include an increase in the amount of project-specific funding devoted to developing commercial applications emerging from the research base being committed by other funders in the public, charitable or private sectors. This could reduce the need for project-specific KE/C funding currently allocated through HEIF.

6.3 Individual-level factors influencing KE/C engagement

We also know that many factors influence an academic’s motivation and ability to engage in KE/C, covering individual characteristics and capabilities, organisational supports, and institution features (Davey et al., 2018; Galan-Muros and Davey, 2017; Perkmann et al., 2013). In particular research has shown that capabilities knowledge-based organisations – alongside and integrated with other resources and capabilities – are critical for developing competitive advantage (Barney, 1991; Eisenhardt and Martin, 2000; Grant, 1996). Universities are no different in this regard, whether it is in creating new knowledge or engaging in its diffusion.

Indeed, KE/C focused studies have shown that individual capabilities and prior experiences of academics, and their ability to understand the needs of external partners and how to work together, are important in shaping the nature and scale of engagement in KE/C (Bruneel et al., 2010; Muscio, 2010; O’Shea et al., 2005; Siegel et al., 2003). In addition, the overall culture of the institution, and the legitimacy of this type of activity and its sense of value amongst the academic community are also important factors (Galan-Muros and Davey, 2017; Perkmann et al., 2013).

Given the above, it is possible that if the experiences of the academic community change if favour of greater plurality of individuals with more varied non-academic backgrounds and experiences, if more academics become exposed to KE/C, if the KE/C is firmly rooted in not just in the culture of HEIs but is rewarded through promotions and new career trajectories involving active and successful KE/C, then the need for resources to be devoted to addressing these types of issues will reduce. It is likely, however, that HEIs will always need to invest in upgrading and refreshing capabilities for KE/C – both amongst their KE/C professional support staff and their academic community.

6.4 Balance between public and private R&D spending to meet target

A key assumption that was made in the base model is that the additional R&D spending required to meet the 2.4% R&D target beyond expected private spending increases and the announced UK public funding increases will be met through further increases to public spending on R&D balanced with additional spending and crowding in of private sector R&D spending. It is also assumed that the mapping between who funds R&D activity and who carries it out is the same as today.

However, depending on how policy decisions play out, it is possible that additional public spending on R&D could feed directly into R&D activity in HEIs and hence greater push-related and co-developed KE activity, or through, for example increased R&D tax credits, increased private sector R&D activity leading to increased pull-related KE activity.

In addition, where additional public R&D spending goes directly into the research base it is possible that the focus of this spending changes, for example between funding pure basic research vs user-inspired research or applied research in HEIs. The base model currently assumes that it is similar to that today. Any changes would likely change the likelihood of different types of KE/C opportunities. For example if funding is tilted more towards applied research in strategic areas of industrial innovation need this may lead to more immediate opportunities for co-developed KE/C opportunities, and increased disclosures of inventions that have commercialisable potential. However, over the longer term, it is possible that increasing spending on more fundamental research may lead to greater potential for high value spinouts built on disruptive technologies.

It is also possible that, through attempts to make the environment for investing in R&D in the UK more attractive, that private sector organisations increase the scale of activity here, reducing the need for the scale of additional public funding otherwise required. It would be instructive to consider different scenarios looking at different realistic balances between

6.5 Distribution of R&D spending across HEIs and places

The base model also assumes that the public and private R&D spending across HEIs remains similar to that today, based on the observation that there has been little observable change in the rank order of R&D activity in HEIs over the past decade. However, there are reasons to believe that this may change as the government invests to meet the 2.4% R&D target and other government priorities. If the focus of the additional public R&D spending is significantly different for that today (for example, focused much more on applied research or targeting particular technologies or sectors) it is possible that different types of HEIs are more suitable and capable to meet this need compared with those currently dominating the landscape today leading to some shift in the distribution of funding across the university system.

In addition, with the rise of place-based agenda in the industrial strategy and the ambition to reduce disparities in economic performance and industrial opportunity across the cities, towns and rural communities of the UK, it is possible that some of the additional public R&D funding may be invested disproportionately in areas to address these types of economic and industrial challenges. This may also alter the distribution of funding across the university system.

The base model also assumes that private sector R&D spending feeds into the HEI system in the same way as today. This again may change not least because it is unlikely that the significant increases in private spending on R&D will be able to come entirely from existing R&D intensive companies. It is likely that new sources of R&D spending will need to be created (new companies, increasing R&D spending in non-traditional sectors, increasing overseas investment in R&D etc.). This may create opportunities for different types of HEIs to link with this non-traditional cohort of organisations that are not (yet) locked into specific relationships with existing HEIs.

7 Conclusions

This technical report aimed to examine the potential scale of funding required to support knowledge exchange and commercialisation within English HEIs to ensure they are able to contribute actively and fully to the delivery of the UK government's target of achieving the 2.4% R&D target.

Delivering the target will require significant increases in investment in R&D by both the public and private sectors, with HEIs, firms and other organisations involved in the innovation process having to significantly increase the level of R&D activity they undertake. This will likely have significant effects on both the scale and nature of KE/C interactions between HEIs and their partners in industry and the public and charitable sectors to co-develop, exchange, diffuse and deploy knowledge in the innovation system. These interactions, in turn, have been shown to benefit from the enabling and supporting KE/C infrastructure within universities. As such, delivering on the 2.4% R&D target will require appropriately scaled investments in not just R&D, but in KE/C and the enabling infrastructure and support.

To explore the funding requirements for KE/C the report presents a simple model to link increases in R&D activity in the economy to changes in the nature/scale of KE/C activity. It then uses existing evidence on what we know about need for KE/C funding to support effective delivery of KE/C by English HEIs to project forward funding requirements in a 2.4% R&D world.

The simple model estimates that by 2027 KE/C income in a 2.4% R&D world will be approximately £5.9 billion. This translates into a requirement of approximately £342 million in cash terms of HEIF-like funding to enable the delivery of this scale of KE/C opportunities.

The model developed for this report is built on a number of important assumptions that need to be borne in mind when interpreting the results. In particular, it assumes that funding requirements will scale linearly with demand (i.e. there is limited potential for economies of scale effects). It also assumes that: the composition of the innovation system remains similar in a 2.4% R&D world compared with today; the balance between private and public sector R&D remains similar; and the distribution of funding across HEIs and places remains similar. Each of these assumptions are discussed in detail in section 6. It would be instructive to explore the implications of relaxing each of these assumptions for KE/C funding requirements in future analyses.

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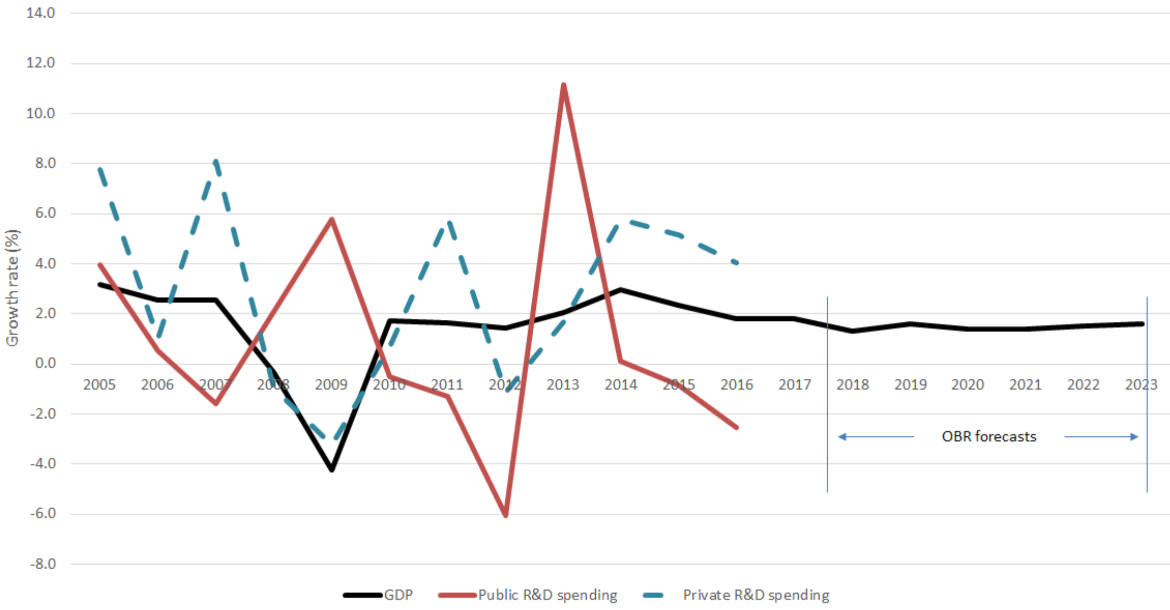
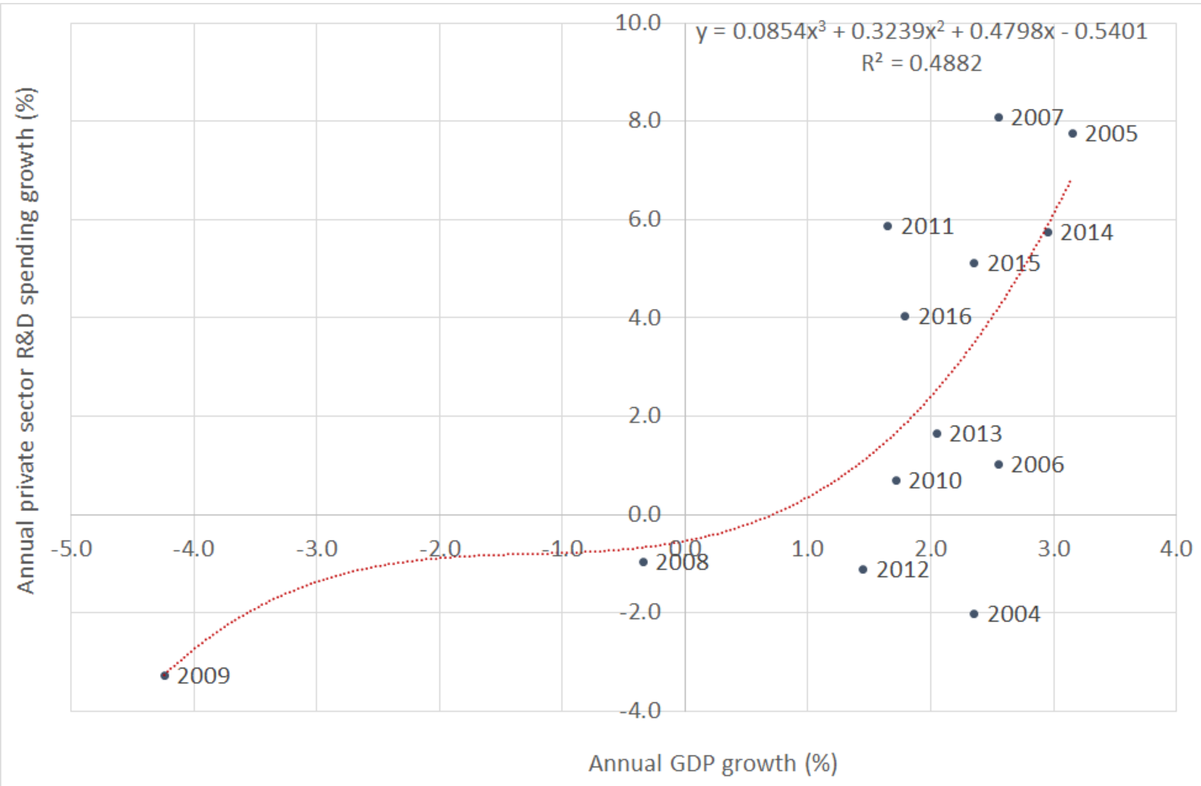
Appendix A

Figure 12 Growth rates of GDP, public R&D spending and private R&D spending (2005-2017), and OBR forecasts of GDP growth (2018-2023) (%)



Source: Office for National Statistics (ONS), Office for Budget Responsibility (OBR)

Figure 13 Relationship between GDP growth and private sector R&D spending growth, 2005 - 2016



Source: based on data available from the Office for National Statistics (ONS)

Table 9 Funding for research and innovation allocated through the National Productivity Investment Fund (NPIF), Overseas Development Assistance (ODA) and Scientific Infrastructure programmes

Agency	Funding programme	2017-18	2018-19	2019-20	2020-21
Total	NPIF	423	839	1,509	2,016
	ODA	320	414	518	642
	Scientific infrastructure	1,113	1,231	1,163	1,203
UKRI	NPIF	385	650	1,003	952
	ODA	233	306	291	240
	Scientific infrastructure	857	1,016	882	931
Allocated to UK Space Agency, National Academies, Public Sector Research Establishments and BEIS programmes	NPIF	37	119	162	203
	ODA	87	108	117	76
	Scientific infrastructure	256	215	281	271
To be allocated	NPIF		70	344	862
	ODA			110	325
Estimated allocation: UKRI*	NPIF	385	704	1,293	1,678
	ODA	233	306	372	478
Estimated allocation: Non-UKRI*	NPIF	37	129	201	302
	ODA	87	108	146	163

** Assume funds to be allocated are distributed to UKRI/non-UKRI in same proportion in given year*

Source: (BEIS, 2018)

Appendix B

Table 10 Scaling factors by HEI cluster

Source of change	Scaling factor	Cluster V	Cluster X	Cluster E	Cluster M	Cluster J	STEM Specialists	Other Specialists
Effects of public sector R&D spending	Spinoffs per £million Public R&D	18.9	18.1	51.3	148.5	116.2	31.5	147.8
	External investment per spinoff	10,605	6,439	835	64	128	449	526
	IP income from sale of shares per spinoff	454.4	120.2	5.5	0.0	0.0	0.0	0.6
	Collaborative research (public funding) as share of public RD (%)	15.8	17.0	23.1	17.2	14.7	16.5	9.0
	Ratio of collaborative research cash and in-kind contributions to public funding contributions	29.4	31.4	54.8	50.8	59.4	98.4	43.9
Effects of public & private sector R&D spending	IP income per £000s total R&D spending	8.8	8.3	22.0	39.2	8.6	102.7	20.5
Effects of private sector R&D spending	Contract research income per £ private sector R&D spending in HEIs	0.6	0.9	0.9	1.2	1.0	0.2	0.4
	Consultancy income per £ private sector R&D spending in HEIs	0.1	0.4	1.1	1.8	2.7	0.1	2.0
	Facilities & equipment income per £ private sector R&D spending in HEIs	0.1	0.3	0.3	0.8	1.3	0.0	1.2
	CPD income per £ private sector R&D spending in HEIs	0.1	0.6	2.6	8.3	4.4	0.2	24.9
Effects of increased academic staff doing non-research exploitation / tech transfer/physical assets KE	Contract research income per academic FTE	14.5	6.4	2.0	0.6	1.1	11.7	0.3
	Consultancy income per academic FTE	2.7	3.2	2.3	0.9	2.8	7.4	1.8
	Facilities & equipment income per academic FTE	1.3	2.4	0.6	0.4	1.4	1.1	1.1
	CPD income per academic FTE	2.3	4.2	5.4	4.1	4.6	9.1	22.3
	Staff start-ups per 000 academic FTE	0.2	0.3	0.2	0.8	1.2	0.1	0.5
	External investment per staff start-up	1,460	154	192	4	31	0	11

Table 11 Proportion of KE/C activity focusing on research exploitation, technology transfer, and exploitation of physical facilities

KE mechanism	Total	KEF cluster						
		Cluster V	Cluster X	Cluster E	Cluster M	Cluster J	STEM Specialists	Other Specialists
Collaborative research	0.88	0.92	0.89	0.86	0.74	0.70	0.52	0.90
Contract research	0.89	0.90	0.88	0.88	0.33	0.72	0.84	1.00
Consultancy	0.66	0.66	0.81	0.69	0.68	0.51	0.27	0.86
Facilities and equipment-related services	0.92	0.96	0.96	0.78	0.95	0.82	0.93	0.81
Continuing professional development	0.07	0.02	0.14	0.11	0.08	0.03	0.03	0.01
Regeneration and development programmes	0.52	0.79	0.66	0.37	0.20	0.19	0.00	0.00
IP process (disclosures, protection etc.)	0.96	0.98	0.93	0.90	0.00	0.93	0.74	0.60
Licensing and intellectual property	0.96	0.98	0.94	0.76	1.00	0.89	0.99	0.60
Formal (HEI's IP-based) spin-offs	0.95	0.99	1.00	0.90	0.00	0.94	0.82	0.60
Start-ups (new enterprises not based on formal IP)	0.45	0.57	0.41	0.41	0.00	0.37	0.00	0.00
Graduate start-ups	0.23	0.10	0.14	0.20	0.20	0.21	0.80	0.44

Sources: HEIF 2016/17 institutional strategies, HEBCI survey 2016/17, author's analysis

Appendix C

Allocating HEIF: the Suitability of Knowledge Exchange Income as a Proxy for Outcome Performance

This opinion piece outlines key issues and implications in using knowledge exchange (KE) income as the core metric in allocating Higher Education Innovation Funding (HEIF). Concerns have been raised about whether using KE income appropriately incentivises higher education institutions (HEIs) to maximise economic and societal impacts through their KE activities – the government's key objective for HEIF – or whether it leads to perverse behaviours, such as income maximisation to the detriment of impact. A related concern is whether using KE income results in fair allocations to HEIs given their different strengths and diverse portfolios of KE.

The importance of government funding for knowledge exchange

Knowledge produced within universities is most often a public good: it is thought to be non-excludable (there is no way to exclude anyone from its use, for example, related to payment) and non-rivalrous (consumption by one party does not diminish consumption by others). It generates significant spillovers (benefits spreading beyond immediate or obvious consumers) that can be hard to appropriate (deploy to a particular purpose). This leads to significant differences between private and social returns on investments in knowledge production – the benefits to the public outstrip those to any particular user, and there are significant challenges in how those benefits are reaped.

By the very nature of ideas generated within higher education (HE), knowledge often suffers from high degrees of technical, financial and market risk. In addition, we know that productive linkages between HEIs and firms are becoming increasingly important in the effective diffusion and exploitation of knowledge in the economy. However, increasingly well recognised 'innovation system failures' hamper the establishment of these direct linkages. These system failures flow from differences of objectives, incentives, norms and values between universities and enterprises that make sympathetic connection more challenging. In addition, both HEIs and firms require sufficient internal capabilities and processes, to transact and collaborate efficiently and effectively[i]. These have historically been significantly underdeveloped, although significant advances within HEIs have been made in recent years.

It must also be recognised that academics produce different types of knowledge which will inevitably sit at different points along the public-private good spectrum, and different segments of target 'markets' for the knowledge will face differing degrees of market and system failures. As such, the appropriate balance of public and private investment will depend critically on the type of knowledge being exchanged and the target markets for this knowledge.

Measuring KE outcomes

Measuring the impacts arising through KE is also incredibly challenging. Pathways to impact are long and varied and depend on significant complementary investments by others[ii]. Given these challenges, there is a dearth of easily measurable, auditable, and comparable impact metrics. There is thus a trend towards measures of 'implied demand' rather than 'actual outcomes'[iii].

What does KE income tell us about KE outcome performance?

The HEIF funding allocation process aims to incentivise HEIs to focus on delivering economic and societal outcomes. To do so, it aims to reward HEIs for higher KE outcome performance through relatively higher allocations. To achieve this, it uses KE income as a **proxy** for KE outcomes.

What, then, does KE income tell us about performance? **KE income provides an important indication that valued linkages are forming between the university base and the wider economy to diffuse and exchange knowledge.** If reasonably well governed and accountable organisations are willing to pay for KE, they must believe some value is being derived. **At minimum therefore, KE income represents an implied demand for the capabilities and expertise available within HEIs**.

Standard economic theories of the firm would also suggest that the price paid for a good or service reflects the marginal (the additional benefit the consumer receives from one additional unit) contribution of that good or service to their organisation. However, KE is believed to lead to complex spillovers, multiplier effects, supply chain effects, and unexpected benefits emerging through both the deployment of the acquired knowledge and through the KE process itself (for example, learning by doing and interacting). This suggests that the price paid does not fully capture the additional socio-economic benefits of the consumption of KE. **One could argue, therefore, that KE income represents a minimum bound on the monetary value of the KE**.

The amount of KE income generated (attributable to HEIF) also provides an indicator of the degree of leverage it generates for knowledge diffusion and exploitation. A distinctive benefit of the transition towards formula funding is the flexibility it gives to HEIs proactively to target and respond to emerging opportunities, and leverage other sources of KE funding. Crucially, it is also used to demonstrate the potential, and reduce the risk, of KE activity to attract subsequent investment.

KE income can also be aggregated across different KE mechanisms and compared across institutions. This is not true of non-monetary-based KE measures.

What does KE income not tell us about KE outcome performance?

Despite the above, KE income is neither a perfect, nor comprehensive indicator. Some KE engagements do not generate income, while some will generate benefits that are clearly not captured by the income generated[iv]. Currently there is little evidence on the scale of the latter.

Recent evidence showed that there is significant variation in the extent to which KE services involve monetary transactions and the degree to which these cover the full costs of engagement[v]. This relates in part to the public-good nature of the KE services and the need for the public sector to co-invest alongside the private sector to address the key market and system failures outlined earlier.

Does the use of KE income lead to a biased distribution of HEIF?

Is there a bias affecting certain types of HEIs in the HEIF allocation process purely because of the nature of the metric used? Comparing the likely income from non-transactional KE engagements[vi] and the known KE income generated by different types of HEIs shows that there is little difference in distribution between the two. This suggests that using KE income in the formula does not significantly bias against certain types of HEIs.

Does using KE income in the allocation of HEIF lead to perverse behaviours?

Does using KE income in allocating HEIF lead to perverse behaviours, with HEIs seeking to maximise income rather than impact, leading to detrimental effects on the government's objectives for KE?

I argue that there is not a dichotomous decision between generating income and generating impact. Indeed, generating impact should, in many circumstances also generate income. However, decisions should prioritise impact and then establish an appropriate level cost given the nature of the knowledge and technology in question – that is, users should be expected to pay

something. The 'appropriate' level will depend on where the knowledge or technology sits on the public to private good spectrum or the degree of other market failures present[vii].

In addition, KE transactions involve negotiations between HEIs and firms, not least around terms and conditions (including terms of use of intellectual property (IP)) and costs. Firms, operating in the interests of shareholders, will be seeking the best possible terms, and therefore have interests in arguing that universities are operating unfavourably. HEIs should be approaching negotiations with the interests of taxpayers of UK plc in mind, ensuring long-term economic and social returns with firms compensating appropriately for the (potentially significant) costs incurred by the public sector. University approaches to negotiations (including on costs) are likely influenced by a number of key factors including: (a) overall policies and guidance from university leadership on objectives for KE and approaches to costing (for example, relative prioritisation of maximising impact, income, volume etc.); (b) the competencies of the individuals involved and their ability to determine and communicate to the firm the public good content or degree of market failure and hence justify the fees; and (c) the availability of accepted practices and processes within the university to support these choices. It is possible that some HEIs, given financial pressures, limited capabilities of staff, or inappropriate guidance, are either deliberately or inadvertently focusing more heavily on maximising income.

Does the HEIF formula lead HEIs to overcharge firms systematically for a particular KE service? There is currently very little evidence on this point. Given that income generation is not inconsistent with impact maximisation, it is hard to establish whether increases in KE income are a result of a deliberate policy of income maximisation or a strengthened focus on diffusing valuable knowledge for which there is a price. The period of analysis is also complicated by the effects of the economic recession, which were most pronounced on those HEIs with perhaps a greater incentive to pursue income. Other evidence finds that most HEIs generally do not seek to maximise income or make profits from their KE, and indeed do not cover the full costs of their KE activities[viii]. Surveys of businesses provide mixed evidence on whether costs and expectations about what KE can deliver are important barriers to engagement[ix]. Lastly, if HEIs were seeking to maximise income over impact, one might expect to see a switching in academic engagement towards more income-generating activity following the introduction of formula-driven funding. This appears not to be the case[x].

In conclusion

Allocating HEIF funding through formula driven by KE income goes some way to incentivising HEIs to focus on strengthening socio-economic impacts through KE. While not a direct measure of socio-economic impacts, it does provide an auditable, easily measurable and comparable metric that provides an indicator of implied demand for knowledge exchange and the power to leverage additional funds to support the process. There is currently a lack of alternative metrics without the introduction of a major new data collection exercise. However, given the potential for HEIs to pursue income over impact in order to generate additional funding, additional safeguards could be considered and introduced operating alongside the formula to help to mitigate against this risk.

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[i] Hughes and Martin (2012).

[ii] Hughes and Martin (2012).

[iii] Coates Ulrichsen (2015).

[iv] Coates Ulrichsen (2015).

[v] This ranges from 'public space' activities such as events and networks aimed at stimulating interactions that will hopefully lead to further engagements where just 10% involve a transaction and where these transaction cover just 20-50% of costs; to enterprise support (e.g. for small and medium-sized enterprises) where around 50% involve a transaction covering between 25-75% of costs); to innovation and research-related KE where 87% involve a transaction covering between 50-100% of costs (PACEC, 2015).

[vi] The likely income from these non-transactional KE activities was estimated in Coates Ulrichsen (2015).

[vii] For example, knowledge developed through public funding to a point relatively closer to market with fewer technical risks associated with its deployment would attract a higher charge from firms looking to acquire it. Similarly, providing (part-) publicly funded support for innovative activity in small and medium-sized enterprises is relatively well accepted as a role for government.

[viii] PACEC (2015).

[ix] A survey of businesses in 2008 (Hughes and Kitson, 2014) found that the cost of interacting was not frequently cited as a reason for not engaging. By contrast, awareness issues, and understandings of potential benefits and the processes, were much more important. Interestingly, large companies were much less likely than small companies to cite cost issues as a barrier to engaging. However, a survey by Bruneel et al. (2010) of engineering and physical science collaborative research in the UK found half of the firms involved believe HEIs have unrealistic expectations and oversell their research.

[x] Another point of evidence comes from the longitudinal comparisons of academic KE activities based on surveys of academics in 2008 and 2015 (Hughes et al., 2016). If the formula was incentivising income maximisation within universities, one might expect to see a shift towards income generating KE activities on the ground. This does not appear to be the case. Note also that the picture is complicated by the effects of the recession and REF, as acknowledged in the study.