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The relationship between universities' funding portfolios and their knowledge exchange profiles: A dynamic capabilities view

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ABSTRACT

This paper examines how universities' knowledge exchange (KE) profiles evolve in relation to changes in the composition of their funding sources. Using the dynamic capabilities framework as a conceptual lens, we examine how changes in the share of KE versus research income in a university's financial portfolio are related to the mix of KE channels it uses and of types of stakeholders it engages with, that is, its KE profile. Relying on an 8-year panel of 110 UK-based universities we show that, universities whose share of KE income is higher relative to others, are associated with a higher degree specialization in both KE channels and stakeholder types. Conversely, universities whose share of blue-sky research income is higher relative to others, are associated with greater diversification in both. Some of these linkages are negatively moderated by higher levels of tangible and intangible resources: universities with greater intangible resources are less responsive to variations in research and KE income shares on KE channel diversity; while universities with higher tangible resources are less responsive to variations in research income share on KE stakeholder diversity.

1. Introduction

Universities have come under increasing pressure to broaden their activities beyond the traditional research and teaching activities. They are now expected to not only explore the frontiers of knowledge through their research, but also to contribute towards utilizing new knowledge and innovations for commercial exploitation and broader social benefit (Ambos et al., 2008; Uyarra, 2010; Sengupta and Ray, 2017a). Universities have moved a long way from being "ivory towers" of knowledge and are engaged in a variety of impact driven activities alongside external non-academic stakeholders. Collectively referred to in the literature as knowledge exchange (KE) – such activities include interactions with industry, public bodies and charities, local and regional outreach programs, executive education, and academic entrepreneurship. Over time, KE has become increasingly important to universities, both strategically and financially (Guerrero and Urbano, 2012; Horner et al., 2019; Siegel and Wright, 2015), yet the management of KE has received limited attention in the academic literature (Ambos et al., 2008; Sengupta and Ray, 2017a).

Policy interventions have played a key role in turning KE into a core strategic operation in universities across many countries (Lockett et al., 2015). Globally, the last two decades have seen changes in allocation mechanisms for higher education funding, with the share of public funds falling sharply in relative terms, and business and other private sources increasing their share (except for East and Southeast Asia, notably China).[1] Reductions in public funding for academic research and education have spurred universities to increasingly rely on private sources of income (Muscio et al., 2013; Strehl et al., 2007; Shattock, 2013), including income from KE (Rosli and Rossi, 2016; Sengupta and Ray, 2017a). At the same time, policymakers in both developed economies (such as in the UK, USA, EU, Australia) and in emerging ones (Ray and Sengupta, 2021) are encouraging universities to exploit their intellectual property and to place socioeconomic impact at the core of all activities (Perkmann et al., 2021; Rosli and Rossi, 2016). Universities have responded strategically to such external challenges, altering their engagement in research, teaching and KE to best exploit competitive advantages (Hewitt-Dundas, 2012; Horner et al., 2019; Kitagawa et al., 2016; Rossi, 2018; Siegel et al., 2003; Siegel and Wright, 2015).

Universities, like any other organization, must operate within fixed budgets and within the constraints on their tangible and intangible resources. Changes to their resourcing and funding environments have led to increased pressures on these budgets and resources, increased

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[1] For detailed worldwide trends and analysis, see https://ncses.nsf.gov/pubs/nsb20201.

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managerialization (Shattock, 2013; Teixeira and Koryakina, 2013), and increasing strategic importance of impact creating activities such as KE (Rossi and Sengupta, 2022). The consequences of such changes on teaching (de Zilwa, 2005, 2007) and research related activities (Archibugi and Filippetti, 2018; Fukuyama et al., 2016; Zhang et al., 2019) have been investigated previously, but it is only recently that the strategic aspects of KE have started to be examined in more detail (Rossi and Sengupta, 2022; Sánchez Barrioluengo et al., 2019). Rising strategic importance of KE are likely to result in greater incentivization of KE among academics, and reallocation of supporting resources, leading to changes over time in both the operationalization and locus of KE activities (Rossi and Sengupta, 2022). However, there is little understanding of the *consequences* of such changes on the nature of KE activities within the university and it is here that this paper seeks to contribute. The question becomes important given that neither KE nor research income *shares* are within a university's operational control, and medium to longer term shifts in these are largely determined by a combination of external factors such as competition, policy changes and broader social, technological, and economic trends. While universities can put in resources to support these activities individually, incomes arising out of research and KE are associated with high degrees of uncertainty, especially so in the current higher education landscape (Shattock, 2013). Naturally, the question arises on how universities *react* to changes in these, particularly around how they re-organize their resources and re-orient their operations as the relative shares of these incomes rise or fall over time.

Diversification and specialization tendencies have long been identified as key strategic responses of organizations to changes in their internal and external environments. It is also becoming clear that these are important for universities within their KE activities as well, as they attempt to maximize their strategic fit to available resources to gain competitive advantage within the higher education landscape (Rossi and Sengupta, 2022). Using the lens of the dynamic capabilities framework (Teece, 2007), we examine the effect of changes in the universities' financial portfolio on their KE profiles, in terms of *how* they interact with external stakeholders, i.e. the diversity in KE channels they use, and *who* they interact with, i.e. the diversity of stakeholder types they engage with.

The dynamic capabilities framework (Teece, 2007) is used to argue that changes in the relative shares of KE and research incomes induce a realignment in a university's resources for KE engagement, leading to changes in the university's overall profile of KE engagement. We argue that universities whose share of KE income becomes relatively more important, are likely to look towards leveraging their existing resources and learning from their successful KE experience, thus leading to specialization in a narrower range of KE channels and stakeholder types. Instead, universities whose share of research income becomes relatively more important are likely to look towards reconfiguring and creatively integrating their newly created intangibles, thus leading to diversification in KE channels and in types of stakeholders engaged with. We also examine how a university's overall levels of tangible and intangible resources moderate these relationships and show that relatively more resource-constrained organizations appear to be more reactive to changes in their financial portfolio.

We rely on an eight-year panel dataset (2008-09 to 2015-16) collecting publicly available information on universities in the United Kingdom (UK) to support our analysis. The UK situation is very interesting, as the trends towards increasing importance of private sources of income and growing attention for research impact, which are present in many countries, are particularly pronounced here. Policy changes in recent years have dramatically altered the funding model for higher education by increasing universities' dependency on private funding, while at the same time placing more importance on societal impact of research.[2] This provides us with an interesting case to examine the relationship between the financial contributions made by KE and research activities and universities' overall KE profiles, making the dynamic capabilities framework particularly relevant.

We contribute towards both the theory and practice of KE within a resource constrained higher education sector facing a degree of uncertainty. Theoretically, the dynamic capabilities framework has been shown to be strategically relevant for examining KE activities and processes in competitive and dynamic environments (Li and Tang, 2021). We extend this argument by showing that universities are having to realign existing resources devoted to KE activities following changes in the composition of their financial portfolios, a key shift within respective operational environments. These changes are triggered through higher order dynamic capabilities, leading them to either reconfigure and creatively integrate their newly created intangibles, or to leverage and learn from previous KE experience (Ambrosini and Bowman, 2009), resulting in growing specialization or diversification in their KE profile. From a management practice perspective, by contributing towards greater understanding of how a university's KE engagement is linked to its funding sources, we provide implications for the management of resources across all its operations. We also contribute to the ongoing policy debate about the systemic implications of research and innovation policies that push universities to broaden their strategic focus toward KE and to rely on KE as a source of income (Archibugi and Filippetti, 2018), particularly for the UK, but generalizable to many other contexts where KE has become strategically important for universities.

2. Background and theory

2.1. Variety of university KE profiles and their antecedents

KE as a set of activities encompass engagement with multiple stakeholders in the broader society, including the private and non-commercial entities in a variety of ways (Rosli and Rossi, 2016; Uyarra, 2010). First, they use multiple KE channels, broadly incorporating both research commercialization and academic engagement related activities. Early literature and practitioners focused primarily on research commercialization, which involves contractual transfer of technology developed within universities to external parties, through licensing of university produced IP and spin-out activities. Over time, it has become clear that universities use a much wider variety of formal and informal channels broadly classified as academic engagement (Perkmann et al., 2013), which by volume and value far surpasses research commercialization (Bekkers and Bodas Freitas, 2008; Lockett

[2] The overall environment within which UK universities function has changed dramatically with the introduction of tuition fees *in lieu* of public subsidies and several policy initiatives focussing on encouraging business and societal engagement. The latter include steps such as initiation of the Catapult Network of research and technology organizations focused on technology transfer (Hauser, 2010); and stronger emphasis of impact and societal innovation in disbursement of public research funds. The well-known Research Excellence Framework (REF) evaluating university research performance in the UK, now places increased emphasis on societal impact alongside the traditional publication-based criteria (REF, 2019).

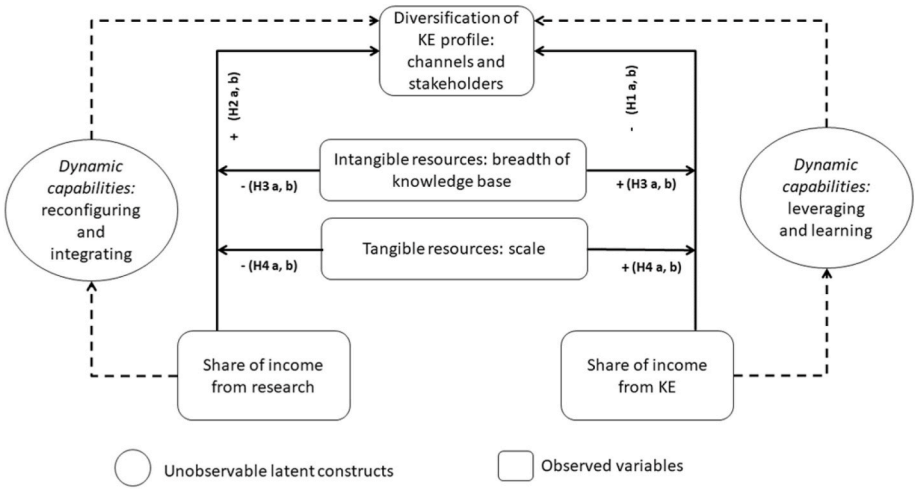

Fig. 1. Conceptual framework.

et al., 2015). Academic engagement channels include, among others: research undertaken either on behalf of, or in collaboration with external partners (contract research, collaborative research and consultancies); the provision of specialized courses and training through continuing professional development (CPD) and continuing education (CE); involvement in local development and community regeneration projects and public engagement (for example, public lectures, exhibitions and performances) (Schaeffer et al., 2020; Sengupta and Ray, 2017a). Also, both commercialization and engagement involve many different types of non-academic stakeholders, including but not limited to, industry, public sector, charities, municipalities and other communities (D'Este and Patel, 2007; Benneworth and Jongbloed, 2010; Perkmann et al., 2013).

Universities exhibit heterogeneity, not just in their choice of individual KE channels and stakeholders to engage with, but also in the KE *profiles* that, over time, result from the combinations of multiple channels and types of stakeholders. KE profiles have been previously mapped to organizational characteristics. For instance, highly research-intensive universities have been found to focus more on commercialization, contractual and collaborative channels, while their less research intensive counterparts have been found to focus more on skills and human capital development, particularly within their local and regional geographies via consultancies and entrepreneurship (Hewitt-Dundas, 2012; Sánchez-Barrioluengo et al., 2019). KE profiles differ also according to scale and breadth of research disciplines: specialist universities are more inclined towards academic engagement alone, while more generalist universities also carry out commercialization activities (Sengupta and Ray, 2017b; Ulrichsen, 2018). There are also differences between disciplines in the way they engage with external stakeholders (Benneworth and Jongbloed, 2010; Hughes and Kitson, 2012). The natural question that arises therefore is: is the choice of KE profiles a strategic one, and if so, what key factors impact such choices?

Existing literature indicates that key decisionmakers within universities – academics, senior management and KE managers – have to be strategic in their KE activities based on their goals and preferences (Buckland, 2009; Horner et al., 2019; Sengupta and Ray, 2017b) and their access to relevant resources (Siegel et al., 2003, 2007; Hewitt--Dundas, 2012; Ulrichsen, 2014; Rossi, 2018). Given the changes in the external environment, this strategic approach is relevant for most universities, from large research-intensive "top" universities to "mid-range" ones which, although research active, cannot match the quality and breadth of research and resources that the top institutions command, and consequently face a myriad of constraints in their KE activities (Wright et al., 2008).

Strategic decisions on KE profiles are likely to be driven by contextual and historical factors to begin with (Sengupta and Ray, 2017b), and subsequently be driven by the changes in the environment that universities operate within (Kitagawa et al., 2016). It is important to stress on the dynamic aspects of these relationships. Historical and contextual factors have been seen as key antecedents to overall KE strategy, at least in their origins (Sengupta and Ray, 2017b), while subsequent environmental shifts result in evolution, adaptation and re-evaluation of strategic priorities and pathways within university management. While decision making processes within universities occur at multiple levels (Chang et al., 2016), here we argue that it is possible to identify the impact of environmental changes on organizational KE strategy due to the "higher order" dynamic capabilities triggering a realignment of key resources (Ambrosini and Bowman, 2009). Such shifts then influence individual academics engaged in KE as well as the organizational sub-units of the university, such as departments, faculties and intermediaries such as the knowledge transfer organizations (KTOs), which in turn impact the universities' KE profiles (Sengupta and Ray, 2017b).

While prior studies explore the antecedents of cross-sectional differences in KE between universities, research has only recently focussed on the dynamic changes happening *within* universities and sector. Wang and Lu (2021) explore the dynamic interplay within university-industry community networks. Li and Tang (2021) explore the impact of pro-market reforms and transition from socialist to capitalist economies on university-industry interactions. Schaeffer et al. (2020) examine the dynamic interplay of formal and informal KE channels and show that cumulative effects of such activities are important for the long-term valorisation of KE activities. Sengupta and Ray (2017b) find that KE structures and business models evolve based on underlying contextual factors such as volume and breadth of applied research and strategic aims of the university. These studies shed some important insights on the dynamic shifts in KE activities of universities, and implications of organizational heterogeneity. Our paper extends these by exploring the antecedents to such changes in KE profiles, by focussing on the shifting importance of income sources as an antecedent to changing KE profiles, in the light of rapid changes in the external environment.

2.2. Dynamic capabilities in the university context

Like all organizations, universities are endowed with very different tangible and intangible resources and operate in different contexts. Thus, organizationally they will develop differing capabilities around their key strategic priorities, such as teaching, research and KE (Bowman and Ambrosini, 2003; Teece et al., 1997). Dynamic capabilities, defined "the firm's ability to integrate, build, and reconfigure internal and

Table 1
University income streams, KE channels and KE stakeholder types included in diversification indices (HE-BCI definitions).

A. University income streams	
Research income – Annual income in respect of externally sponsored research from all sources, *excluding* those included in KE income channels. These include domestic and foreign academic research funders funding open ended research.	**KE income** – Income arising from interactions with non-academic stakeholders like businesses, local bodies and charities. See below for detailed break-up of channels and stakeholders.
Tuition income – Annual income from all courses where fees are charged from students.	**Education related funding body income** – Annual funding from education related funding in UK, including Office of Students, Funding Councils, Dept of Education etc.
Other income – Income from all other sources including endowments, donations, investments etc. (Reference category in analysis)	
B. KE income channels and stakeholders	
KE Income Channels	**KE Stakeholders**
Contract research – Research commissioned by non-academic partner, involving creation of new knowledge. Income component is the contractually agreed fee received by the university.	**Commercial: SME** – Includes commercial enterprises which employ fewer than 250 people and which do not have an annual turnover above EUR 50 million, and/or annual balance sheet not above EUR 43 million.
Collaborative research – Research sponsored by public research grant involving both academic and non-academic partners and creation of new knowledge. Income component is the in-cash or in-kind component received by the university from its non-academic partners.	**Commercial: non-SME** – Includes all commercial enterprises which do not match the above definition of SMEs
Consultancies – Application of existing knowledge into solving specific problems faced by non-academic partner, without creation of new knowledge. Income component is the contractually agreed fee received by the university.	**Non-commercial** – Organizations whose shareholders and trustees do not benefit financially
IP Commercialization – Includes income from patenting, licensing activities as well as income from spin out activities License and other income – Royalty, fees, patent cost reimbursements obtained from licensed technology (both patented and unpatented) to non-academic partners Spin out income – Income from sale of shares in university owned spin out companies	
CPD & CE – Specialized and/or bespoke short or long educational programmes for executives and representatives of non-academic partners for professional development, upskilling or workforce development	
Local regeneration grants – Income received to support local development and impact, and can include European grants such as ERDF, ESF or UK local developmental grants	

external competencies to address rapidly changing environments" (Teece et al., 1997, page 516), are essential in the university's repertoire of "higher order" features and systems which enable this realignment.

The literature points towards multiplicity of types of dynamic capabilities, depending on the context being examined (Ambrosini and Bowman, 2009). *Reconfiguration* refers to the recombination of existing resources, *leveraging* refers to the replication of processes across business units, *learning* enables more efficient and effective processes to be put in place as a result of experimentation, and finally, *creative integration* refers to the integration of assets resulting in new configurations of the same. Organizations, including universities, facing internal or external pressures may embody these dynamic capabilities individually or in combination, in order to respond to environmental pressures and changing contexts (Lockett et al., 2015; Sengupta and Ray, 2017a; Sharifi et al., 2014).

Increased competition within a university's peer group or policy-driven financial changes determines the overall levels of resources available to dedicate towards its KE activities. For instance, the shift away from the traditional public funding model towards a private market-led one (Casani et al., 2014; Just and Huffman, 2009; Pietsch, 2020; Rapini et al., 2019) has led to a substantial re-evaluation of the sustainability of traditional modes of governance, accountability and operations within the sector (Muscio et al., 2013; Strehl et al., 2007).

Given the complexity in its structure and inherent autonomy of decision-making sub-units within a university, it is necessary to explore what dynamic capabilities around KE may mean within the university context. Learning as a dynamic capability will involve understanding the drivers of successes and failures in past KE initiatives. This will involve being able to scale up successful models of engagement and being able to transplant them from one department/faculty/school to another. This is also closely linked to leveraging, through which resources can be utilized to replicate previously successful arm's length decentralized business models across multiple departments, faculties and schools of the university. Sengupta and Ray (2017b) point to several examples of UK universities, where learning and leveraging have been a feature of university KTOs. Examples include creation of long-term umbrella agreements with specific stakeholders to sustain specific types of successful business models well into the future. They also include cases of decentralized KTOs, where individual schools within the same university could nurture KTO capabilities in response to diverging needs of each.

Reconfiguration and integration can be directly linked to the literature on entrepreneurial universities (Guerrero and Urbano, 2012, 2016). This literature places importance on the role of university management in shaping structures and processes, and in developing the strategic vision that governs organizational evolution, and how these can be embedded across all activities of the university, including KE (Guerrero and Urbano, 2012). Besides formal processes, it also includes informal aspects, such as attitudes and role models, which help to inculcate the entrepreneurial mindset, thereby leading to further explorative steps in both teaching, research and KE. Thanks to the creation of new knowledge through research, new ways of communication and dissemination are explored by entrepreneurial individuals, units and organizations and can lead to opening of radically new pathways of impact. As a result, existing resources need to be reconfigured and creatively integrated to address the needs of newly created intangibles.

Thus, the key components of dynamic capabilities are important elements in the strategic operations of any modern university. Vorley and Nelles (2009) argue that successful *adoption* of KE processes requires a flexible entrepreneurial approach across strategy, structure, systems, leadership, and culture. However, *adaptation* of the same is also equally important as the external environment changes. External shifts exert pressures on the internal environment, usually manifested on the overall finances of the university, but more particularly on the nature of its financial portfolio. We now discuss how such changes lead to adaptations within the KE function, particularly on a university's KE portfolio.

2.3. Impact of funding sources on KE portfolios

As financial constraints shift, universities can respond by realigning their KE activities, particularly by altering their portfolio of KE channels and KE stakeholder types. One possible response is increasing *specialization*, by building on those KE channels that have worked well previously and relying on existing stakeholder types. The opposite response is *diversification* by exploring new avenues of engagement. The former approach reduces the need for a major reorientation in resources, by

Table 2
Summary statistics of dependent and independent variables.

Statistic	Mean	St. Dev.	Min	25th Percentile	75th Percentile	Max
Dependent Variables						
(1) $v(t)$	0.62	0.14	0	0.57	0.71	0.80
(2) $w(t)$	0.43	0.16	0	0.34	0.54	0.67
Independent Variables						
(3) KE income share[a]	0.10	0.06	0	0.06	0.18	0.49
(4) research income share	0.09	0.10	0	0.02	0.14	0.65
Control Variables						
(5) tuition income share[a]	0.44	0.18	0.01	0.31	0.55	0.85
(6) funding body income share	0.27	0.13	0.02	0.16	0.37	0.73
(7) Total CPD income	5384.38	5795.22	0	1728.50	6675.00	41,696.00
(8) Number of contracts	263.99	370.86	0	47.00	292.50	2601.00
(9) Number of consultancies	693.80	2138.63	0	74.00	406.50	17,787.00
(10) Number of facilities contracts	229.12	737.05	0	7	188.00	12,186.00
(11) Number of software licenses	104.28	1187.45	0	0	12.00	24,176.00
(12) Number of non-software licenses	43.38	177.99	0	0	28.00	3028.00
(13) Current spinouts	1.31	2.28	0	0	2.00	21.00
(14) Cumulative student start ups	28.08	79.50	0	0	29.00	1715.00
(15) Staff time – public free events (days)	130.50	233.01	0	10.00	143.50	2506.00
(16) Staff time – public non-free events (days)	23.55	49.51	0	0	25.00	406.00
(17) Staff time – free performances (days)	37.23	89.29	0	0	38.00	939.00
(18) Staff time – non-free performances (days)	71.35	317.98	0	0	43.00	5227.00
(19) Staff time – free exhibitions (days)	162.65	673.21	0	0	82.00	6914.00
(20) Total income	244,010.80	222,815.20	50,908.00	118,545.80	249,258.20	1,799,472.00
Moderating Variables						
(21) Total assets	281,656.00	264,166.10	0	124,150.00	327,621.00	2,248,986.00
(22) Broadbase	0.66	0.48	0	–	–	1

[a] Represents private funding source.

relying on tried and trusted channels and stakeholders, and the latter hedges against risks in a rapidly shifting market environment by broadening the range of channels and stakeholder types considered. The literature suggests that dynamic capabilities of an organization can act as an antecedent towards both diversification and specialization tendencies (Døving and Gooderham, 2008). The key question in case of a university is, as its financial portfolio undergoes changes, what is the likely direction in which it will move as an organization.

In the following paragraphs, we develop several hypotheses linking differences in the relative importance of KE and research incomes to a university's overall diversification or specialization levels in its KE profile. We expect that for universities that exhibit a greater share of KE income vis-à-vis other income sources, their dynamic capabilities will trigger leveraging and learning tendencies, leading them to adopt more specialized or concentrated KE profiles. This is due to the following reasons.

First, the growing share of KE income affects and is affected by the incentives facing individual academics to engage in KE. Rising importance of KE income in a university is likely to coincide with greater incentivization of their researchers towards KE and has even been seen to adapt recruitment policies in favour of academics with more experience in KE (Sengupta and Ray, 2017b). At least for some researchers at the interface of academic research and external engagement, this implies a relative shift in the incentivization from blue sky research towards more applied work. This is increasingly apparent as universities strive to incentivize both commercialization and academic engagement with wider use of financial (Ankrah and Al-Tabbaa, 2015; Lach and Schankermann, 2008) and non-financial (Perkmann and Walsh, 2009; Ramos-Vielba et al., 2016) incentives. While there is evidence to show that engagement in KE does *not* impact overall scientific productivity negatively (Perkmann et al., 2021), there can be a re-orientation in research activities, especially among faculty members who are active in KE (Mowery et al., 2001; Nelson 2004). This is likely to push individuals, departments and organizations towards leveraging experience and existing capabilities in further engaging with channels and types of stakeholders which were successful in the past.

Second, universities which rely relatively more on KE as a source of regular income, as an organization would prefer KE channels and stakeholder types that can deliver a *reliable* income stream. If a university has been historically successful in certain KE activities, academics and KE support staff are likely to have developed specialist knowledge applicable to those activities. In fact, as Horner et al. (2019) stress, both supporting structures within the university and strategic choices made by university managers need *alignment* for improving and sustaining KE. And such alignment requires the ability to learn and leverage know-how from past successes and failures.

In fact, engagement with each KE channel and type of stakeholder type needs unique competencies and support structures (Bercovitz et al., 2001; Sengupta and Ray, 2017b; Siegel et al., 2007; Soares and Torkomian, 2021). For instance, patent licensing and spinning out companies may require entrepreneurial skills, including technology translation (such as adapting a prototype for exact needs of the client), new venture management, and dealing with potential investors such as angels and venture capitalists (Rasmussen and Jarl, 2010; Soares and Torkomian, 2021). For effective contract research, consultancies and CPDs, the university needs to be able to efficiently negotiate and execute contracts. Universities also need different skills (legal, managerial, financial etc.) to deal with large firms as opposed to SMEs or the public sector (Bjerregaard, 2009; Hewitt-Dundas, 2012). These different competencies and support structures usually require time and resources to develop (Siegel et al., 2003; Alexander and Martin, 2013), but once in place they result in considerable efficiencies, as the university learns to identify and rectify weaknesses as they attempt to scale up (Zheng et al., 2013; Weckowska, 2015). As KE income becomes more important, for universities it will be less risky and more cost effective to leverage the KE support structures and specialized competencies that are already delivering KE income, instead of developing new support structures and new competencies to facilitate interactions with new types of stakeholders and new channels (Guerrero et al., 2016; Rossi, 2018).

Thus, universities for whom the importance of KE income is relatively high due to good returns through specific channels and with stakeholder types, would wish to extract further value from resources already in place by leveraging their current strengths and learn from that experience. Dynamic capabilities that support leveraging and learning from experience become enablers of *path dependence*, as internal KE structures and processes become more robust and efficient with time

Table 3
Cross correlation coefficients of dependent and independent variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22
1. v(t)	1																					
2. w(t)	0.37	1																				
3. KE income share	−0.11	0.05	1																			
4. research income share	0	0.18	0.49	1																		
5. tuition income share	−0.08	−0.15	−0.36	−0.65	1																	
6. funding body income share	0.12	0.04	−0.13	−0.12	−0.53	1																
7. Total CPD income	−0.24	−0.1	0.4	0.05	0.06	−0.21	1															
8. Number of contracts	0.03	0.2	0.37	0.5	−0.39	−0.14	0.21	1														
9. Number of consultancies	0.12	0.15	0.08	0.07	0	−0.07	−0.04	0.07	1													
10. Number of facilities contracts	0.13	0.22	0.13	0.16	−0.13	−0.1	0.09	0.25	0.2	1												
11. Number of software licenses	0.05	−0.03	0.04	0.01	0.03	−0.08	0.01	0.01	−0.02	0.01	1											
12. Number of non-software licenses	0.01	0.07	0.15	0.16	−0.12	−0.07	0.19	0.27	0.01	0.11	0.11	1										
13. Current spinouts	0.09	0.18	0.19	0.29	−0.27	0.03	0.1	0.41	0.11	0.11	0.01	0.16	1									
14. Cumulative student start ups	0.07	−0.03	−0.04	−0.12	0.13	−0.01	0.1	−0.01	0.03	−0.02	0.01	0.04	−0.02	1								
15. Staff time – public free events	0.06	0.06	0.08	0.2	−0.08	−0.08	0.29	0.21	0.15	0.17	0	0.09	0.16	0.09	1							
16. Staff time – public non-free events	0.03	−0.05	−0.01	0	0.05	−0.02	0.21	0.04	0.12	0.1	0	0.07	0.01	0.04	0.49	1						
17. Staff time – free performances	−0.02	−0.01	0	0	0.05	−0.07	0.15	0.12	0.02	0.09	0.05	0.15	0.07	0.1	0.27	0.25	1					
18. Staff time – non-free performances	0.05	0	−0.02	−0.06	0.01	0.01	0.01	−0.01	−0.01	0.09	0.01	0.01	0.05	0.01	0.11	0.09	0.17	1				
19. Staff time – free exhibitions	0.03	0.08	0.06	0.15	−0.14	−0.07	0.26	0.26	−0.02	0.18	0.04	0.1	0.12	0.02	0.3	0.18	0.53	0.19	1			
20. Total income	0.06	0.2	0.26	0.47	−0.32	−0.22	0.4	**0.77**	0.09	0.26	0.03	0.36	0.4	0.03	0.37	0.16	0.24	0.04	0.48	1		
21. Total assets	0.04	0.22	0.24	0.45	−0.28	−0.26	0.31	**0.71**	0.09	0.27	0.03	0.29	0.35	0.03	0.32	0.14	0.21	0.01	0.38	**0.9**	1	
22. Broadbase	0.18	0.27	0.09	0.14	0.01	−0.21	0.14	0.34	0.1	0.15	−0.04	0.15	0.19	0.1	0.19	0.13	0.1	−0.05	0.12	0.41	0.4	1

(Zollo and Winter 2002) and better aligned with each other (Horner et al., 2019). For these reasons, we expect that, as the share of KE income becomes more important in its financial portfolio, a university will tend to specialize in engagement in those KE activities and with those KE stakeholder types that have proven to be successful at delivering KE income in the past. Therefore, we hypothesize that.

> H1a: All else held constant, a university with a relatively greater share of income from KE activities is associated with lower diversity in KE channels used.
>
> H1b: All else held constant a university with a relatively greater share of income from KE activities is associated with lower diversity in the type of KE stakeholders it engages with.

On the contrary, we expect that universities that experience a relative rise in the share of research income vis-à-vis other income sources will trigger dynamic capabilities in a way that allow for better reconfiguration and creative integration of their newly created and existing knowledge resources, and thus leading to more diversified KE profiles. This is due to the following reasons.

First, a greater share of research income is directly linked to the university's knowledge resources, and these underpin KE outcomes, both at individual and organizational levels (Perkmann and Walsh, 2009). Greater reliance on research income induces universities to encourage researchers to engage in more research, and to recruit academics with greater aptitude for research. Researchers should then have more opportunities to reconfigure their knowledge resources and to creatively integrate them with other forms of knowledge, leading to more and more varied (in terms of focus, interdisciplinarity, applicability) research outputs (Abbott and Doucouliagos, 2004; Bolli and Somogyi, 2011; Fukuyama et al., 2016). Having more varied research outputs implies opportunities for researchers to engage with new types of stakeholders and to use new KE channels different from those that they had engaged with in the past. Even if research outputs themselves are not diversified, a greater volume of research outputs can help to reach a wider spectrum of stakeholders using a wider variety of channels.

Second, an increase in the proportion of research income can have positive reputational consequences for the university, specific departments and individual researchers. Reputation in the form of citations, awards, public appearances as well as previous record of successful engagement, have been shown to be significant in explaining future KE performance by increasing visibility among potential stakeholders (Ray and Sengupta, 2021; Sine et al., 2003). Growing reputation thus is likely to result in increased interest from a wider variety of external stakeholders, especially if research reputation among peers spills over to practitioners through deliberate marketing efforts or through policy initiatives.

Third, universities with relatively higher research income shares may be under less pressure to deliver income through proven KE channels, leading them to be more risk-taking, and be more willing to seize new opportunities in relation to KE (Teece, 2007). Hence, they may be more inclined to reconfigure their resources in order to support newer or previously less used KE channels and stakeholder types (Van Looy et al., 2004; Sengupta and Ray, 2017a). Indeed, universities that are better able to sense such opportunities, will be more likely to integrate their new knowledge resources to their existing assets, in order to create new avenues of KE (Bowman and Ambrosini, 2003; Teece, 2007).

For these reasons, we expect that, as research income becomes more important in its financial portfolio, a university will tend to diversify its engagement into new KE activities and with new KE stakeholder types. Therefore, we hypothesize that.

> H2a: All else held constant, a university with a relatively greater share of income from research is associated with greater diversity in KE channels used.

Table 4
Fixed effects baseline models: Coefficients (robust standard errors).

	(A) Dependent variable: $v(t)$			(B) Dependent variable: $w(t)$		
Independent variables						
KE income share (lagged)	−0.275** (0.118)		−0.267** (0.114)	−0.541*** (0.120)		−0.520*** (0.114)
research income share (lagged)		0.418** (0.167)	0.325** (0.160)		0.917*** (0.258)	0.875*** (0.212)
Time varying controls						
tuition income share (lagged)	−0.079 (0.134)	0.002 (0.132)	−0.051 (0.130)	0.355** (0.151)	0.549*** (0.176)	0.430*** (0.147)
funding body income share (lagged)	−0.155 (0.131)	−0.055 (0.133)	−0.115 (0.131)	0.250 (0.153)	0.454** (0.179)	0.357** (0.154)
Number of consultancies (log)	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.002 (0.006)	0.002 (0.006)	0.002 (0.006)
Total CPD income (log)	0.007 (0.007)	0.004 (0.007)	0.006 (0.007)	−0.012** (0.006)	−0.017*** (0.006)	−0.013** (0.006)
Number of facilities contracts (log)	0.002 (0.003)	0.002 (0.003)	0.002 (0.003)	0.015*** (0.005)	0.015*** (0.005)	0.015*** (0.005)
Number of software licenses (log)	0.007*** (0.002)	0.006*** (0.002)	0.006*** (0.002)	0.007** (0.003)	0.006** (0.003)	0.006** (0.003)
Number of non-software licenses (log)	−0.002 (0.003)	−0.003 (0.003)	−0.002 (0.003)	0.001 (0.004)	−0.001 (0.004)	0.001 (0.004)
Current spinouts (log)	−0.007 (0.004)	−0.008* (0.004)	−0.007* (0.004)	0.011* (0.006)	0.009 (0.006)	0.009 (0.006)
Cumulative student startups (log)	−0.004 (0.004)	−0.004 (0.004)	−0.004 (0.004)	0.006 (0.004)	0.005 (0.004)	0.005 (0.004)
Staff time – public free events (log)	−0.002 (0.002)	−0.003 (0.002)	−0.002 (0.002)	−0.000 (0.003)	−0.001 (0.003)	−0.000 (0.003)
Staff time – public non-free events (log)	−0.002 (0.002)	−0.001 (0.002)	−0.002 (0.002)	−0.002 (0.003)	0.001 (0.003)	−0.001 (0.003)
Staff time – free performances (log)	0.006* (0.003)	0.006* (0.003)	0.006* (0.003)	0.003 (0.003)	0.002 (0.003)	0.002 (0.003)
Staff time – non-free performances (log)	−0.006** (0.003)	−0.005** (0.003)	−0.006** (0.003)	−0.010*** (0.003)	−0.009*** (0.003)	−0.010*** (0.003)
Staff time – free exhibitions (log)	−0.000 (0.002)	−0.000 (0.002)	0.000 (0.002)	0.004 (0.003)	0.004 (0.003)	0.004 (0.003)
Total income (log)	0.046 (0.046)	0.041 (0.045)	0.054 (0.045)	0.065 (0.046)	0.069 (0.046)	0.087* (0.045)
Constant	0.141 (0.530)	0.086 (0.532)	−0.011 (0.533)	−0.353 (0.550)	−0.657 (0.557)	−0.765 (0.552)
Fixed Effect – University	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effect – Time	Yes	Yes	Yes	Yes	Yes	Yes
Observations	742	743	742	741	742	741
Log Likelihood	1057.660	1054.090	1059.330	931.656	928.351	940.384
Wald Test	3656.569***	3600.185***	3676.817***	3207.853***	3158.997***	3302.394***

Table 5
Fixed effects moderated models: Coefficients (robust standard errors).

	Moderator: *broadbase*			
Moderated relationship:	$v(t)$ - KE income (A)	$v(t)$ – Res. Income (B)	$w(t)$ – KE income (C)	$w(t)$ – Res. Income (D)
Independent variables				
KE income share (lagged)	−0.517*** (0.165)	−0.281** (0.114)	−0.620*** (0.169)	−0.523*** (0.117)
research income share (lagged)	0.350** (0.169)	0.796*** (0.244)	0.885*** (0.208)	0.994*** (0.355)
Interaction Effects				
KE income share x *broadbase*	0.471** (0.186)		0.188 (0.229)	
research income share x *broadbase*		−0.818** (0.338)		−0.206 (0.455)
Time Varying Controls				
tuition income share (lagged)	−0.033 (0.129)	−0.108 (0.134)	0.436*** (0.146)	0.415*** (0.146)
funding body income share (lagged)	−0.090 (0.128)	−0.142 (0.130)	0.365** (0.154)	0.350** (0.152)
Number of consultancies (log)	0.007 (0.007)	0.007 (0.007)	−0.013** (0.006)	−0.013** (0.006)
Total CPD income (log)	0.001 (0.003)	0.002 (0.003)	0.015*** (0.005)	0.015*** (0.005)
Number of facilities contracts (log)	0.006*** (0.002)	0.006** (0.002)	0.006** (0.003)	0.005** (0.003)
Number of software licenses (log)	−0.003 (0.003)	−0.003 (0.003)	0.001 (0.004)	0.001 (0.004)
Number of non-software licenses (log)	−0.008* (0.004)	−0.007* (0.004)	0.009 (0.006)	0.009 (0.006)
Current spinouts (log)	−0.005 (0.004)	−0.005 (0.003)	0.005 (0.004)	0.005 (0.004)
Cumulative student startups (log)	−0.002 (0.002)	−0.002 (0.002)	0.000 (0.003)	−0.000 (0.003)
Staff time – public free events (log)	−0.001 (0.002)	−0.002 (0.002)	−0.000 (0.003)	−0.001 (0.003)
Staff time – public non-free events (log)	0.006* (0.003)	0.005* (0.003)	0.002 (0.003)	0.002 (0.003)
Staff time – free performances (log)	−0.006** (0.003)	−0.006** (0.003)	−0.010*** (0.003)	−0.010*** (0.003)
Staff time – non-free performances (log)	0.000 (0.002)	0.000 (0.002)	0.004 (0.003)	0.004 (0.003)
Staff time – free exhibitions (log)	0.054 (0.045)	0.060 (0.045)	0.087* (0.045)	0.089** (0.045)
Total income (log)	−0.033 (0.129)	−0.108 (0.134)	0.436*** (0.146)	0.415*** (0.146)
Constant	0.003 (0.534)	−0.106 (0.535)	−0.760 (0.554)	−0.789 (0.555)
Fixed Effect – University	Yes	Yes	Yes	Yes
Fixed Effect – Time	Yes	Yes	Yes	Yes
Observations	742	742	741	741
Log Likelihood	1063.580	1061.840	940.872	940.500
Wald Test	3729.717***	3707.009***	3308.003***	3303.754***

H2b: All else held constant, a university with a relatively greater share of income from research is associated with greater diversity in the type of KE stakeholders it engages with.

2.4. The role of tangible and intangible resources

The availability of key tangible and intangible resources is central to an organization's ability to develop dynamic capabilities for maintaining competitive advantage (Lin and Wu, 2014; Teece et al., 1997). This is true for the higher education sector as well, where universities operate in increasingly competitive and uncertain contexts (Kitagawa et al., 2016; Rossi, 2018). This section examines how the overall level of tangible and intangible resources the university has access to, might affect the relationship between composition of funding sources and KE engagement profiles.

KE engagement depends on a university's underlying knowledge resources, in particular, the breadth and diversity of its knowledge base, a key *intangible* asset. Prior literature has pointed out the advantages to having a broader knowledge base, measured as the breadth of research portfolio. Individual academics with more interdisciplinary profiles are

Table 6
Fixed effects moderated models: Coefficients (robust standard errors).

	Moderator: Total Assets			
Moderated relationship:	$v(t)$ - KE income (A)	$v(t)$ – Res. Income (B)	$w(t)$ – KE income (C)	$w(t)$ – Res. Income (D)
Independent variables				
KE income share (lagged)	−1.738* (0.900)	−0.261** (0.115)	−0.999 (1.107)	−0.507*** (0.115)
research income share (lagged)	0.260 (0.166)	2.399* (1.366)	0.813*** (0.226)	4.543*** (1.732)
Interaction Effects				
KE income share x Total assets	0.121 (0.073)		0.038 (0.090)	
research income share x Total assets		−0.168 (0.105)		−0.297** (0.132)
Time varying controls				
tuition income share (lagged)	−0.084 (0.134)	−0.045 (0.130)	0.418*** (0.152)	0.437*** (0.143)
funding body income share (lagged)	−0.166 (0.137)	−0.073 (0.141)	0.337** (0.164)	0.429*** (0.162)
Number of consultancies	0.048*** (0.017)	0.037** (0.018)	0.029 (0.021)	0.012 (0.022)
Total CPD income	0.052*** (0.016)	0.040** (0.018)	0.027 (0.019)	0.011 (0.020)
Number of facilities contracts	0.040*** (0.015)	0.029* (0.016)	0.034* (0.018)	0.019 (0.019)
Number of software licenses	0.041*** (0.013)	0.030** (0.014)	0.028* (0.016)	0.013 (0.017)
Number of non-software licenses	0.028*** (0.010)	0.022** (0.011)	0.020* (0.012)	0.010 (0.013)
Current spinouts	0.015* (0.009)	0.011 (0.009)	0.013 (0.010)	0.007 (0.011)
Cumulative student start ups	0.008 (0.005)	0.008 (0.005)	0.003 (0.006)	0.004 (0.006)
Staff time – public free events	0.007 (0.007)	0.006 (0.007)	−0.013** (0.006)	−0.014** (0.006)
Staff time – public non-free events	0.002 (0.003)	0.002 (0.003)	0.015*** (0.005)	0.015*** (0.005)
Staff time – free performances	0.006*** (0.002)	0.006*** (0.002)	0.006** (0.003)	0.006** (0.003)
Staff time – non-free performances	−0.002 (0.003)	−0.002 (0.003)	0.001 (0.004)	0.002 (0.004)
Staff time – free exhibitions	−0.008* (0.004)	−0.007* (0.004)	0.009 (0.006)	0.010* (0.006)
Total income	−0.005 (0.004)	−0.004 (0.003)	0.005 (0.004)	0.006 (0.004)
Total assets	−0.003 (0.002)	−0.002 (0.002)	−0.000 (0.003)	−0.000 (0.003)
Constant	0.147 (0.624)	−0.738 (0.625)	−0.483 (0.692)	−1.335** (0.641)
Fixed Effect – University	Yes	Yes	Yes	Yes
Fixed Effect – Time	Yes	Yes	Yes	Yes
Observations	742	742	741	741
Log Likelihood	1059.791	1066.008	938.740	940.830
Wald Test	3688.524***	3764.622***	3282.934***	3307.324***

associated with more KE engagement (D'Este et al., 2019). Universities that have broader research portfolios have more opportunities to support external stakeholders in their innovation processes: in fact, searching over broader knowledge bases and sources lead to higher chances of successful innovation (Leiponen and Helfat, 2010), and complex problems are more easily solvable by bringing in and connecting widely disparate knowledge spaces (Hessels and Van Lente, 2008).

A generalist university with a broad research base can use its existing resources to explore a wider variety of KE channels and stakeholder types more effectively than a *niche* university which is focussed on fewer disciplines (Hewitt-Dundas, 2012). Faced with the shifting importance of either KE or research incomes within its financial portfolio, a university with access to a wider intangible resource base will still retain greater opportunities to engage in a plurality of KE channels and stakeholder types, even as it tends to strengthen existing links. Thus, universities with wider research bases, and consequently great access to knowledge related intangibles, even in the face of greater importance of KE in their financial portfolio, can be expected to be expected to be less dependent on established lines of KE engagement. This will lead its KE profile to be relatively less responsive to external changes, either in KE income or research income shares, than that of a niche university facing comparable changes. The latter, with less variety of intangible resources to draw from, are more likely to be conditioned by past experiences and hence attached to more familiar channels and stakeholder types.

This can be explained from the dynamic capabilities perspective. First, a bigger stock of intangible resources and consequently greater potential exposure to a variety of external stakeholders provides the university with better *tacit* knowledge of KE processes at the organizational level, simply as a result of greater exposure. Thus, even as the importance of KE in its financial portfolio shifts, the need to learn and leverage from experience is likely to be lower, as the potential ability to deal with external shocks is likely to be already present within the organization. Second, a generalist university has enhanced opportunities to engage with a greater variety of stakeholders through more channels than a niche one. The former does not need to explore new avenues to cushion against shocks in research income, as resources can be moved *between* existing KE channels and stakeholders, thus reducing the need to trigger reconfiguration and integration capabilities.

In both cases, managers of a university with a bigger stock of intangibles through a broad research base have fewer incentives to actively engage their dynamic capabilities to respond to external pressures, compared to a niche university. This does not mean that the former don't engage their dynamic capabilities in this context, but that they respond less readily, or only when the magnitude of the external shifts is severe enough. This leads us to expect that the marginal effects of importance of the KE vs research shares (presented in H1 and H2), are weakened for those universities that have a broader research base, as greater intangible resources partially cushion the university from the need to respond strongly.[3]

Therefore, we present our third set of hypotheses.

H3a: Greater access to intangibles in the form of a broader research base negatively moderates the effect of a university's KE/research income shares on the diversification of its KE channels. In other words:

- *Broader research base implies that the share of KE income has a smaller absolute effect on the diversification of KE channels, making the baseline effect less negative.*

[3] Other intangibles such as reputation, entrepreneurial culture, KE management competencies might be relevant as well (Kitagawa et al., 2016; Rossi, 2018). However, our theorizing is limited to research breadth for two reasons. First, it has been shown elsewhere that factors such as reputation are correlated with breadth of research base (Ulrichsen, 2018). Second, measuring complex constructs such as reputation, culture, competencies etc are beyond the scope of the research strategy adopted here. And finally, breadth of research base has a relatively straightforward objective measure, while others are far more complex multidimensional concepts (see Section 3).

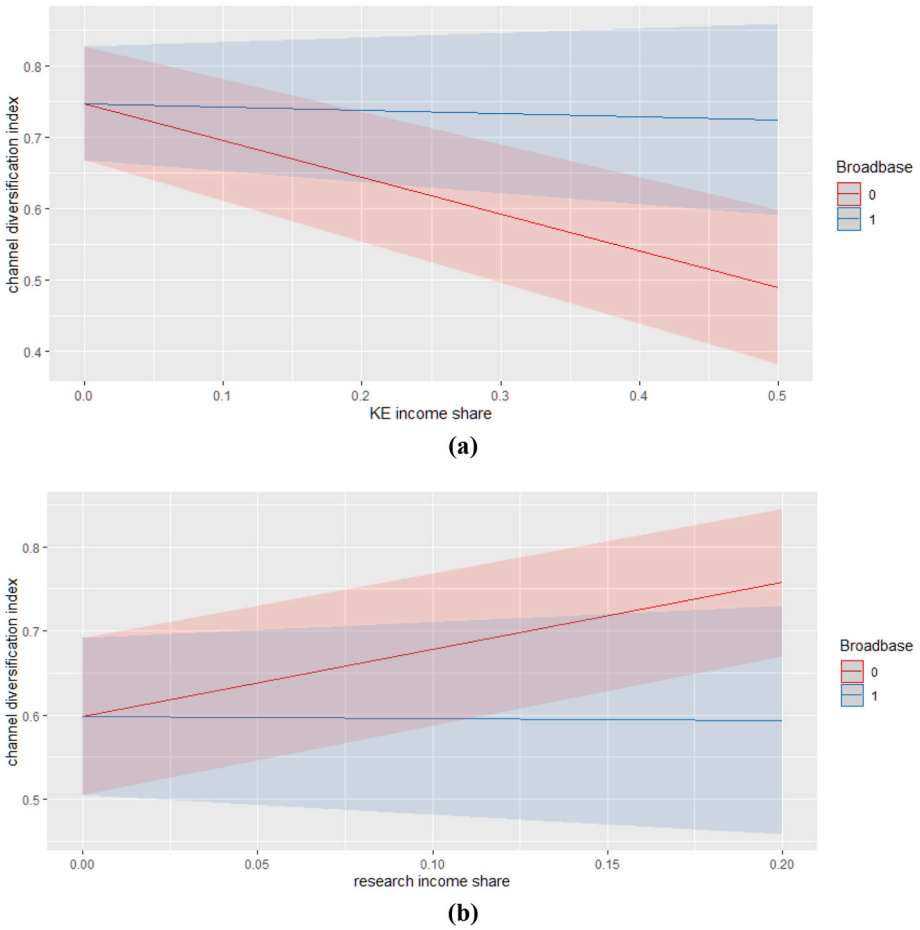

Fig. 2. Impact of (a) KE income share and (b) research income share on $v(t)$: Moderation by broadbase dummy Note: Moderator values set at 0 (red) and 1 (blue). . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

- *Broader research base implies that the share of research income has a smaller absolute effect on the diversification of KE channels, making the baseline effect less positive.*

  H3b: Greater access to intangibles in the form of a broader research base negatively moderates the effect of a university's KE/research income shares on the diversification of its KE stakeholder types.
- *Broader research base implies that the share of KE income has a smaller absolute effect on the diversification of KE stakeholder types, making the baseline effect less negative.*
- *Broader research base implies that changes in the share of research income has a smaller absolute effect on the diversification of KE stakeholder types, making the baseline effect less positive.*

Universities with more tangible resources available to them are able to carry out their research and KE functions more effectively than those that are resource constrained (Ambos et al., 2008; Perkmann et al., 2013; Wright et al., 2008). While the overall scale of the university is associated with the nature of KE activities (Wright et al., 2008), it has also been shown to influence the dynamic linkage between research and KE, as the links weaken with increasing size, thus decoupling them and making KE more self-sustaining (Sengupta and Ray, 2017a).

We expect the overall tangible assets of a university to similarly impact the dynamic link between its financial portfolio and KE diversity. This can once again be explained through the dynamic capabilities framework, as with greater access to tangible resources and hence bigger scale of operations, the university's exposure to risk through individual sources of income diminish. It is reasonable to expect that a bigger university would be less sensitive to movements within its financial portfolio (research, KE, tuition etc.), than a university operating at a smaller scale. For the former, any increase in individual income shares may be used to cross-subsidize longer-term projects in research and KE, to support the development of new generic capabilities (such as hiring new staff, opening new research centres or building infrastructure) and to enhance competitive advantage across a wide range of university functions (research, education and KE). For the latter, reinvestment in the specific income generation capability is more likely, whether its KE or research, which in turn leads to specialization or diversification respectively (as described in H1 and H2). Once again, the need to trigger dynamic capabilities is expected to be relatively lower (or the thresholds higher) for large scale universities. Therefore, their decision to diversify or specialize KE channels and stakeholder types would be less dependent on the income being generated by either KE or research, but more dependent on the nature of research outputs, strategic focus of the university, historical contexts etc., all of which are important antecedents for the structure and business model of a university's KE function (Perkmann et al., 2013; Sengupta and Ray, 2017b).

Therefore, we present our fourth and final hypothesis.

H4a: Greater access to tangible resources negatively moderates the effect of a university's KE/research income shares on the diversification of its KE channels. In other words:

- *Greater access to tangible resources implies that the share of KE income has a smaller absolute effect on the diversification of KE channels, making the baseline effect less negative.*
- *Greater access to tangible resources implies that the share of research income has a smaller absolute effect on the diversification of KE channels, making the baseline effect less positive.*

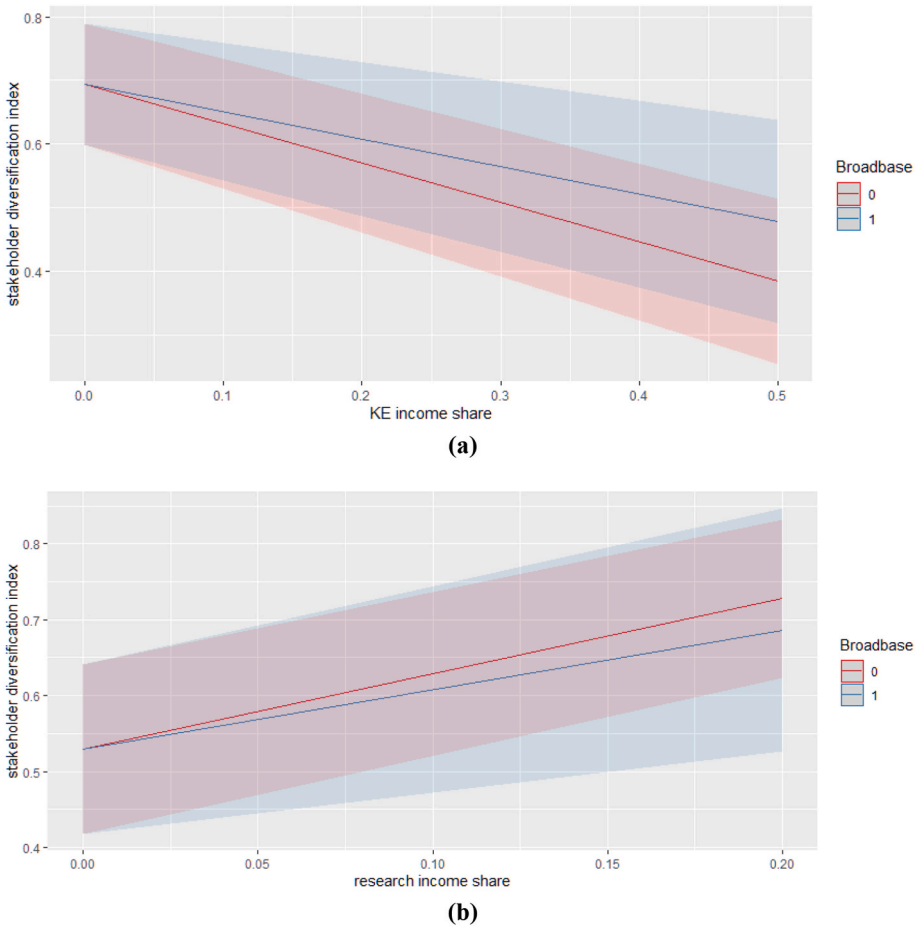

Fig. 3. Impact of (a) KE income share and (b) research income share on $w(t)$: Moderation by broadbase dummy Note: Moderator values set at 0 (red) and 1 (blue). . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

H4b: Greater access to tangible resources negatively moderates the effect of a university's KE/research income shares on the diversification of its KE stakeholder types. In other words:

- *Greater access to tangible resources implies that the share of KE income has a smaller absolute effect on the diversification of KE stakeholder types, making the baseline effect less negative.*
- *Greater access to tangible resources implies that the share of research income has a smaller absolute effect on the diversification of KE types, making the baseline effect less positive.*

The conceptual framework discussed above is represented in Fig. 1, which includes the *testable* hypotheses represented by dark solid arrows. These connect the relevant observed constructs (or variables) represented by squares. The latent constructs, representing the unobservable processes and activities underpinning the dynamic capabilities of an organization are represented in the circles, which provide the foundation for the hypotheses presented above. The dotted arrows represent the untestable mechanisms within the framework.

3. Data and methodology

3.1. Data

Our study relies on data from the higher education sector in the UK, which has seen significant shifts in the funding model of its universities (Pietsch, 2020). For our analysis, we combine data from the well-known Higher Education – Business and Community Interaction (HE-BCI) survey on UK based universities' KE incomes and activities, with additional university level income data from the Higher Education Statistical Agency (HESA) to build an annual panel of 110 universities over the academic years 2008–09 to 2015-16.

This panel contains data on various sources of income for each university reported annually (total annual income, total assets, KE income, tuition fees, research grants from research councils and other research funding bodies, income from education related funding bodies, and other sources including endowments and investments). KE income is further categorized according to the KE *channels* through which it is derived: contract research, collaborative research, consultancies, IP led commercialization (incorporates licensing and spin-outs), executive training and education (CPD), and local regeneration grants. KE income is also categorized according to stakeholder types: income from non-commercial sources and from commercial sources (in turn split between SME and non-SME). Definitions of these income sources, including income from KE channels and stakeholder types, are provided in Table 1 (panel A for overall university income sources, panel B specific to KE).

For each university in a given year, there is further information on the number of contracts (licenses, contract research, consultancies, facility leases) that the university holds, the number of entrepreneurial ventures created (faculty spin-outs, student start-ups) and the time spent by staff on informal engagement (public performance, exhibitions etc.).

Thus, our panel dataset contains exhaustive university-level information on KE activities and incomes, divided between channels and stakeholder types. We also created a dummy, *broadbase*, which indicates whether the university exhibits a broad base of research and teaching disciplines as opposed to narrow disciplinary focus (due to high levels of specialization in teaching or research or in both). This dummy variable is constructed on the basis of clustering results obtained in Ulrichsen

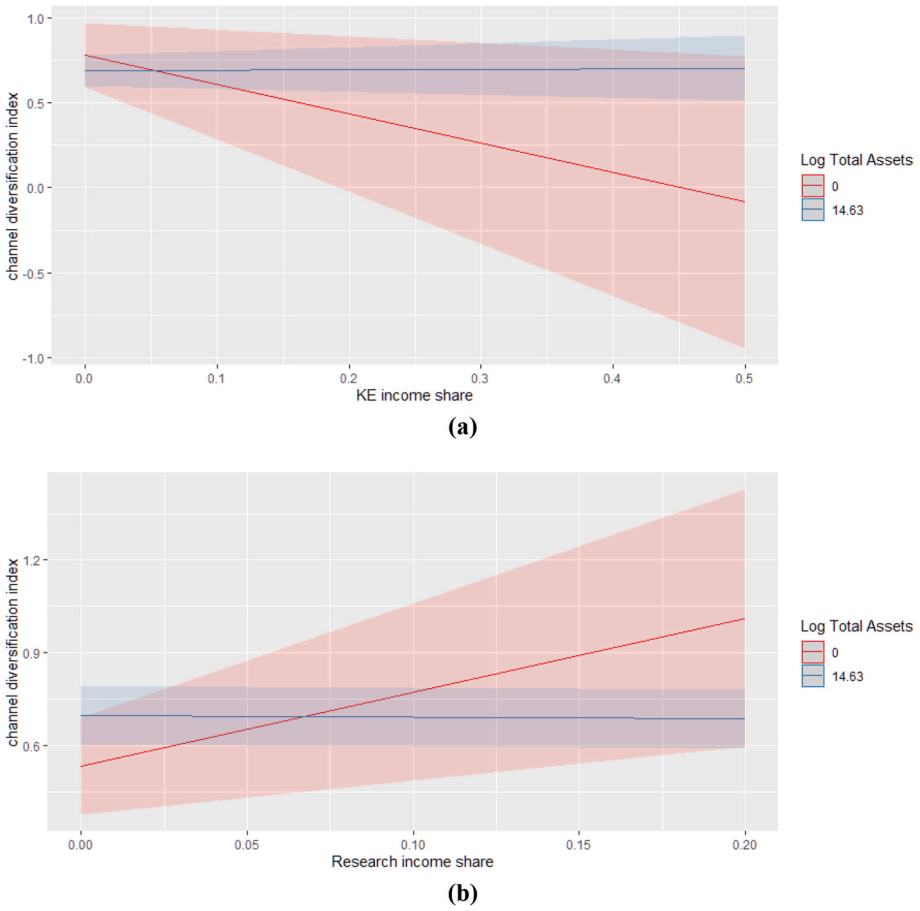

Fig. 4. Impact of (a) KE income share and (b) research income share on $v(t)$: Moderation by Total assets Note: Moderator values set at minimum (red) and maximum (blue) of log transformed value. . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

(2018) on English universities, who develops a multidimensional categorisation of broad discipline based versus specialist English universities.[4] For the non-English universities within our sample (eight in total), we assign the value of the *broadbase* dummy manually, based on each university's overall research portfolio.

3.2. Dependent variables

The two primary dependent variables (DVs) in our analysis are the *indices of diversification* in KE channels and type of KE stakeholders. These measure the extent to which a university's KE income is diversified among KE channels and among stakeholder types, respectively. For both channels and stakeholders, the appropriate Herfindahl index measuring concentration/specialization, is first computed, and then subtracted from unity to obtain the diversification index.

For a given university u at time t, the diversification index for KE channels $v(t)$ is given by:

$$v^{u}(t) = 1 - \sum_{j=1}^{M} \left(\frac{x_{jt}}{X(M,T)} \right)^2$$

$$X(M,t) = \sum_{j=1}^{M} x_{jt}$$

Here, M is the number of KE channels available to the university, x_{kt} is the income from a given KE channel j in time t, and $X(M,t)$ is the total income from all KE M channels in time t. This index is computed for every university for every time period in our data. Based on the data available, $M = 6$, incorporating the income channels in Table 1 panel B. Note that $0 \leq v(t) \leq 1$, where lower values imply higher concentration in one of the six available channels and higher values imply more diversification within the channels.

Similarly, the diversification index for the type of KE stakeholders $w(t)$ is given by:

$$w(t) = 1 - \sum_{k=1}^{N} \left(\frac{y_{kt}}{Y(N,t)} \right)^2$$

$$Y(N,t) = \sum_{k=1}^{N} y_{kt}$$

Here, N refers to the number of KE stakeholder types available to the university, y_{kt} refers to the KE income from a given stakeholder type k in time t and $Y(N,t)$ refers to the total income from all N stakeholder types for the university in time t. Based on the data available, $N = 3$, incorporating the three classifications of stakeholders in Table 1 panel B.

3.3. Independent variables and controls

The two primary independent variables for our analysis are the shares of KE income and research income in total income, where total income is the sum of all streams indicated in Panel A of Table 1. Shares of tuition fees and education-related public funding bodies are also

[4] For more details, please see the technical report available at: https://www.ifm.eng.cam.ac.uk/uploads/UCI/knowledgehub/documents/2018_Ulrichsen_KE_Cluster_Analysis_vFinal.pdf.

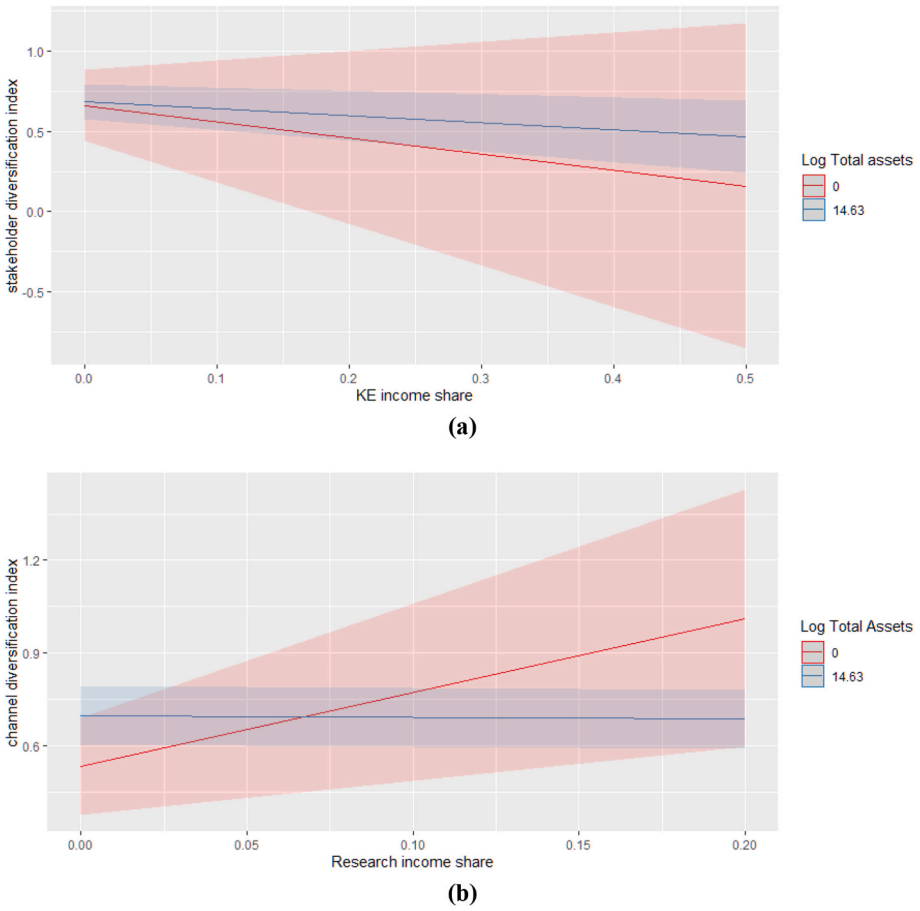

Fig. 5. Impact of (a) KE income share and (b) research income share on $w(t)$: Moderation by Total assets Note: Moderator values set at minimum (red) and maximum (blue) of log transformed value. . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

included as time-varying controls. The last source, income from endowments, investments and other sources is used as the reference (excluded) category in the analysis. All information is derived from HESA, with adjustments to ensure no double counting takes place when various income streams are derived.[5] Finally, we use the *broadbase* dummy and total (tangible) assets as moderators in the analysis to test H3 and H4 respectively.

Several additional time varying controls are included in the models to account for heterogeneity among universities. These include: total income as a proxy of size and scale; the number of contracts, consultancies, facility leases, software and non-software licenses, which indicate the degree and scale of KE activities in the university; the number of spin-outs and student-led entrepreneurial ventures, which indicate the degree of entrepreneurial support within the university; staff time on free and non-free performances, exhibitions and other events, which indicate the degree of informal external engagement between academic researchers where income may not be the appropriate measure of impact.[6] We control for time-invariant cross sectional variation using university level dummy variables. We also include time dummies for each year to account for year-on-year variations.

3.4. Estimation strategy

To test our hypotheses using the given the data, we estimate the parameters of the following *lagged* empirical model:

$$index^u(t) = \alpha + \sum_i \beta_i s_i^u(t-1) + \sum_j \gamma_j \, log \, z_j^u(t) + \sum_k a_k d_k^u + \delta_k \left(s^u(t-1) * z_m^u\right) + \varepsilon$$

In the above equation, where $index^u(t) \in \{v^u(t), w^u(t)\}$ represents the relevant diversification index for university u in time t, $s_i^u(t-1)$ represents the income shares from source i (where $i \in$ {KE, research}) in time $t-1$, z^u represents the control variables and d^u represents the dummies for university and current year. The $(s^u(t-1) * z_m^u)$ term represents interactions between the independent variables and specific moderators. Two separate equations are estimated independently, one for each dependent variable ($v(t)$ and $w(t)$).

We use the two-way *fixed effects* (TWFE) Tobit estimator with robust standard errors to fit the models specified above, where clustering of the standard errors is carried out at the organizational level. The TWFE account for both cross-sectional and systemic yearly variations in the sample. The Tobit estimator is used as both dependent variables are truncated above and below by 1 and 0 respectively. The fixed effects specification is preferred over random effects for two reasons. First, the sample of universities represents close to 75% of all universities in the population, implying that any unobserved heterogeneity is unlikely to be correlated to the independent variables and controls specified above, which in turn implies that the fixed effects estimator is consistent while

[5] HESA's report of research income includes contracts from industry and other non-academic partners, while the other income category includes IP income from licenses and patents. We adjust these so that these sources are not double counted and only appear within the relevant KE income channels (contract income and commercialization respectively). For more details, see https://www.hesa.ac.uk/support/definitions/finances.

[6] Staff time is measured in total days, where each day equals 8 h. The measures include all academic staff in the organization who are engaged in external engagement through public facing performances, exhibitions etc.

Table 8
Fixed effects individual KE channels on channel diversification index: Coefficients (robust standard errors).

	Dependent Variable: v(t)						
Independent variables							
Collaborative income share (lagged)	−0.425*** (0.151)						−0.379** (0.168)
Contract income share (lagged)		0.043 (0.276)					0.174 (0.266)
Consulting income share (lagged)			1.161*** (0.389)				1.570*** (0.383)
IP income share (lagged)				−0.221 (0.256)			−0.375* (0.209)
CPD income share (lagged)					−1.005** (0.412)		−1.019** (0.412)
Regeneration income share (lagged)						−0.272 (0.318)	−0.441 (0.321)
research income share (lagged)	0.521*** (0.172)	0.429** (0.169)	0.412** (0.169)	0.313** (0.155)	0.419** (0.165)	0.436*** (0.168)	0.449*** (0.166)
Time varying controls							
tuition income share (lagged)	−0.002 (0.130)	0.005 (0.134)	0.011 (0.133)	−0.024 (0.128)	0.042 (0.123)	−0.006 (0.131)	0.004 (0.111)
funding body income share (lagged)	−0.050 (0.131)	−0.052 (0.135)	−0.044 (0.133)	−0.094 (0.128)	−0.005 (0.122)	−0.064 (0.132)	−0.045 (0.113)
Number of consultancies	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)
Total CPD income	0.004 (0.007)	0.004 (0.007)	0.003 (0.007)	0.004 (0.007)	0.012 (0.007)	0.004 (0.007)	0.011 (0.007)
Number of facilities contracts	0.001 (0.003)	0.002 (0.003)	0.001 (0.003)	0.002 (0.003)	0.001 (0.003)	0.002 (0.003)	0.001 (0.003)
Number of software licenses	0.006*** (0.002)	0.006*** (0.002)	0.006*** (0.002)	0.006*** (0.002)	0.005** (0.002)	0.006*** (0.002)	0.005** (0.002)
Number of non-software licenses	−0.003 (0.003)	−0.003 (0.003)	−0.005 (0.003)	−0.003 (0.003)	−0.003 (0.003)	−0.003 (0.003)	−0.003 (0.003)
Current spinouts	−0.008** (0.004)	−0.008* (0.004)	−0.008* (0.004)	−0.008* (0.004)	−0.009** (0.004)	−0.007* (0.004)	−0.008** (0.004)
Cumulative student start ups	−0.004 (0.003)	−0.004 (0.004)	−0.004 (0.003)	−0.005 (0.004)	−0.004 (0.003)	−0.004 (0.004)	−0.004 (0.003)
Staff time – public free events	−0.002 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.003 (0.002)	−0.002 (0.002)
Staff time – public non-free events	−0.001 (0.002)	−0.001 (0.002)	−0.000 (0.002)	−0.001 (0.002)	−0.002 (0.002)	−0.001 (0.002)	−0.001 (0.002)
Staff time – free performances	0.005* (0.003)	0.006* (0.003)	0.006* (0.003)	0.006* (0.003)	0.006* (0.003)	0.006* (0.003)	0.006* (0.003)
Staff time – non-free performances	−0.006** (0.003)	−0.005** (0.003)	−0.005* (0.003)	−0.006** (0.003)	−0.005* (0.003)	−0.006** (0.003)	−0.005** (0.003)
Staff time – free exhibitions	0.000 (0.002)	−0.000 (0.002)	0.000 (0.002)	−0.000 (0.002)	0.000 (0.002)	−0.000 (0.002)	0.001 (0.002)
Total income	0.053 (0.045)	0.041 (0.045)	0.042 (0.045)	0.046 (0.045)	0.046 (0.045)	0.042 (0.046)	0.066 (0.044)
Constant	−0.046 (0.530)	0.079 (0.533)	0.069 (0.524)	0.058 (0.530)	−0.046 (0.534)	0.082 (0.537)	−0.238 (0.530)
Fixed Effect – University	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effect – Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	743	743	743	742	743	743	742
Log Likelihood	1057.030	1054.100	1058.530	1055.050	1065.560	1054.570	1077.030
Wald Test (df = 132)	3635.080***	3600.377***	3652.352***	3625.041***	3740.116***	3605.982***	3896.200***

Table 9
Fixed effects individual stakeholders on stakeholder diversification index: Coefficients (robust standard errors).

	Dependent variable: w(t)			
Independent variable				
SME income share (lagged)	1.317 (1.263)			1.475 (1.213)
Non-SME income share (lagged)		−1.202*** (0.358)		−1.290*** (0.341)
Non-commercial income share (lagged)			−1.187*** (0.289)	−1.307*** (0.288)
Research income share (lagged)	0.885*** (0.257)	0.669*** (0.195)	0.648** (0.258)	0.318* (0.187)
Time varying controls				
tuition income share (lagged)	0.526*** (0.175)	0.385*** (0.139)	0.475*** (0.171)	0.266** (0.130)
funding body income share (lagged)	0.426** (0.177)	0.295** (0.147)	0.397** (0.173)	0.188 (0.138)
Number of consultancies	0.002 (0.006)	0.000 (0.006)	0.004 (0.006)	0.003 (0.006)
Total CPD income	−0.018*** (0.006)	−0.018*** (0.006)	−0.009* (0.006)	−0.009 (0.006)
Number of facilities contracts	0.014*** (0.005)	0.016*** (0.005)	0.014*** (0.005)	0.015*** (0.004)
Number of software licenses	0.006** (0.003)	0.006** (0.003)	0.005** (0.003)	0.006** (0.003)
Number of non-software licenses	−0.001 (0.004)	−0.001 (0.004)	0.000 (0.004)	0.001 (0.004)
Current spinouts	0.009 (0.006)	0.007 (0.005)	0.010 (0.006)	0.007 (0.005)
Cumulative student start ups	0.005 (0.004)	0.005 (0.004)	0.006 (0.004)	0.006 (0.004)
Staff time – public free events	−0.001 (0.003)	−0.000 (0.003)	−0.001 (0.003)	−0.001 (0.003)
Staff time – public non-free events	0.001 (0.003)	−0.001 (0.003)	0.000 (0.003)	−0.001 (0.003)
Staff time – free performances	0.002 (0.003)	0.002 (0.003)	0.003 (0.003)	0.002 (0.003)
Staff time – non-free performances	−0.008** (0.003)	−0.009*** (0.003)	−0.009*** (0.003)	−0.008** (0.003)
Staff time – free exhibitions	0.004 (0.003)	0.004 (0.003)	0.003 (0.003)	0.004 (0.003)
Total income	0.069 (0.045)	0.098** (0.044)	0.051 (0.045)	0.080* (0.044)
Constant	−0.654 (0.556)	−0.863 (0.549)	−0.387 (0.553)	−0.578 (0.544)
Fixed Effect – University	Yes	Yes	Yes	Yes
Fixed Effect – Time	Yes	Yes	Yes	Yes
Observations	742	742	742	742
Log Likelihood	931.169	938.371	942.488	958.58
Wald Test	3188.785***	3267.631***	3309.907***	3491.746***

Table 7
Fixed effects income shares on Entropy measure of diversification: Coefficients (robust standard errors).

	Dependent variable: $v'(t)$	Dependent variable: $w'(t)$
Independent variables		
KE income share (lagged)	−0.252** (0.112)	−0.672*** (0.159)
research income share (lagged)	0.240 (0.174)	1.186*** (0.287)
Time varying controls		
tuition income share (lagged)	−0.041 (0.142)	0.607*** (0.202)
funding body income share (lagged)	−0.066 (0.141)	0.483** (0.207)
Number of consultancies	0.011* (0.007)	−0.018* (0.009)
Total CPD income	0.003 (0.003)	0.021*** (0.006)
Number of facilities contracts	0.007*** (0.003)	0.007** (0.003)
Number of software licenses	−0.002 (0.004)	0.002 (0.005)
Number of non-software licenses	−0.009** (0.005)	0.015* (0.008)
Current spinouts	−0.004 (0.004)	0.009* (0.005)
Cumulative student start ups	−0.002 (0.003)	0.001 (0.004)
Staff time – public free events	−0.002 (0.003)	−0.001 (0.004)
Staff time – public non-free events	0.006* (0.003)	0.003 (0.004)
Staff time – free performances	−0.006** (0.003)	−0.012*** (0.004)
Staff time – non-free performances	0.000 (0.003)	0.004 (0.004)
Staff time – free exhibitions	0.045 (0.049)	0.115** (0.058)
Total income	0.121 (0.592)	−0.940 (0.705)
Constant	−0.041 (0.142)	0.607*** (0.202)
Fixed Effect – University	Yes	Yes
Fixed Effect – Time	Yes	Yes
Observations	742	741
Log Likelihood	980.569	718.713
Wald Test	4260.836***	3498.632***

the random effects is not. Second, this is in fact supported through Hausman-Wu tests we carried out to test the appropriateness of fixed effects over random effects for the base models (without interaction effects). Given that all time-*invariant* cross-sectional variation is accounted for in the fixed effects models, we do not include other potential time invariant sources such as the *broadbase* dummy, regions, REF outcomes etc.

To test H1(a, b) and H2(a, b), we examine sign and magnitude β_1 and β_2 in each of the estimated equations, which correspond to the coefficients of lagged shares of KE income and research income respectively. These coefficients can be interpreted as the impact on the diversification index of a "marginal" increase in the share of the respective income shares. The FE estimate ensures that these are "within" university impact of variations in the income shares on the indices, once the cross-sectional time variant and invariant effects have been controlled for. Thus, these coefficients do have *causal* interpretation, *if* exogeneity can be assured. However, as will be noted in the language adopted in H1 and H2, we refrain from adopting a causal interpretation given that we cannot fully establish exogeneity – barring randomized trial or a natural experiment. To test H3(a,b), we examine the coefficients of the terms testing the interaction between lagged shares of KE and research incomes and the *broadbase* dummy variable described above. Finally, to test H4(a,b) we the do same for the interaction between lagged shares of KE and research incomes and total assets.

We ensure the robustness of our findings in several ways, through (i) using a variety of time varying controls accounting for inter-organizational heterogeity; (ii) estimating our model with different time lags; (iii) testing our model with different specification of the diversification indices (see Appendix A for details).

To gain further insights into the dynamic changes taking place within universities, we estimate a set of additional models where the share of KE income $s^u_{KE}(t-1)$ in the regression equation is replaced with shares of individual channels and stakeholder types in total income. Once H1 and H2 are tested, these additional models provide insights on what drives the link between a university's income portfolio and KE diversification. These results are presented in Appendix B, and their implications are discussed in Section 5.

4. Results

Tables 2 and 3 present the descriptive statistics and cross correlations of all dependent, independent and control variables used in the primary analysis. The standard deviations in the independent variables are quite high (0.062 for KE income share and 0.12 for research income share), when compared to the means (0.104 and 0.117 respectively), indicating a high degree of variation within the sample. The dependent variable $v(t)$, the channel diversification index, has a mean of 0.617, while that of $w(t)$, the stakeholder index, is slightly lower at 0.429. At the same time, the distributions of the two indicate that $v(t)$ is relatively more left (negative) skewed than $w(t)$, implying that on average, universities in the sample are relatively more diversified in channels than in types of stakeholders, possible due to larger number of channels available over number of stakeholders types.

As it is clear, there does exist a moderate level of correlation between KE and research income shares (0.54), which is to be expected given that research underpins KE, but is not high enough to warrant multi-collinearity concerns. There exists negative correlation between tuition and research (−0.67), and tuition and funding body income shares (−0.54), again which are not unexpected given the generally dichotomy between research and teaching focussed universities. Additionally, total income is moderately correlated with research income share (0.52), and to a higher degree with contract research (0.77), and to a very high degree with total assets (0.9), indicating that scale effects are likely to play a role within the models estimated. Generalized VIF values computed in our models indicate similar scale effects, and hence we re-estimated the equations dropping both contract research and total assets – although the latter is used as a moderator to test H4. While we present the models without these variables, the results did not vary significantly when they were included in the baseline model. Moreover, the VIF values for all estimated models were mostly low (<3), with a few moderately higher but still within acceptable ranges (<10), indicating that multicollinearity was unlikely to bias our estimates.

Table 4 presents the base model fixed effects estimates without the inclusion of the interaction terms. Sub table (A) presents the estimation results (coefficients and standard errors) of the model with channel diversification index ($v(t)$) as the dependent variable, whereas sub table (B) presents those with the stakeholder diversification index ($w(t)$) as the dependent variable. In each case, column (1) includes only the KE income share, (2) includes only the research income share and (3) includes both simultaneously.

The combined estimates in column (3) clearly point toward a large and significant negative impact of KE income share on $v(t)$ (−0.267, $p < 0.05$) and on $w(t)$ (−0.520, $p < 0.01$), and these are similar to the individual results in columns (1) and (2), for both. This supports H1(a) and H1(b). At the same time, the impact of lagged research income share is large, positive and significant on $v(t)$ (0.325, $p < 0.05$) as well as on $w(t)$ (0.875, $p < 0.01$). This supports H2(a) and H2(b). It should be noted that, for both independent variables in (A) and (B), the corresponding coefficients are at least an order of magnitude larger than those of most other time varying controls.

To test H3 and H4, we examine the impact of the interaction terms between the moderators (*broadbase* and *Total assets*) and the shares of KE and research incomes. These results are presented in Tables 5 and 6 respectively, where the impact of the moderator is examined on the relationships indicated in Columns A, B, C and D. These moderation effects are reproduced graphically in Figs. 2–5, where impact of the income shares on $v(t)$ and $w(t)$ are plotted for minimal (red) and maximal (blue) values of the moderator variable in its corresponding range.

Results for the moderation impact of *broadbase* dummy (Table 5,

Figs. 2 and 3) show that the relationships between income shares and $v(t)$ are weakened for universities where knowledge base is relatively broader. The primary direct effects of KE and research income shares are significant and as hypothesized in H1 and H2 in Columns A-D. Meanwhile the interaction terms in Columns A and B are significant and in the direction which weakens the direct effects. The coefficients for the interaction terms in Columns A and B are 0.471 and −0.818 respectively, with both significant at 5%. This can be seen in Fig. 2(a) and (b), where, with a *broader* knowledge base, the magnitudes of the *net* effect of both income shares on $v(t)$ *decreases* indicating support for hypothesis H3a. For the impact of income shares on $w(t)$, the interaction terms (with coefficients 0.188 and −0.206 respectively) are not significant. Thus, while the *direction* of the moderation is according to what has been hypothesized (see Fig. 3(a) and (b)), the evidence supporting H3(b) is weak.

Broadbase itself is not included as a main effect in the regression results in Table 5. The reason for this is that *broadbase* is a time *invariant* dummy variable, and cannot be included in a fixed effects scenario, where all the cross-sectional variation is captured by the unit level dummy – and inclusion of additional time invariant dummies result in singular solutions. However, this in no way affects the use of *broadbase* as a moderator in the analysis.

Results for the moderation impact of *Total assets* (Table 6, Figs. 4 and 5) show that the interaction terms are negative and significant for research income share only, for $w(t)$ only. The coefficient for the significant interaction term is −0.297 ($p < 0.01$). Given that the primary impact of research income share is positive, significant and relatively large on $w(t)$ (4.543, $p < 0.001$), this shows that increasing total income weakens the links between research income and the stakeholder diversification index (see Fig. 5(b)). Thus, we find evidence in favour of H4b, although partially. Note that although the rest of the interaction terms are not significant in terms of magnitude, the directions of impact are as hypothesized in H4 (Fig. 4(a), (b), 5(a)).

In summary, hypotheses H1(a), H1(b), H2(a), H2(b), H3(a) are fully supported, H4(b) is partially supported, H3(b) and H4(a) are not supported.

5. Discussion

Extant research on KE involving universities has traditionally focussed on its antecedents and consequences, at both organisational (Ambos et al., 2008; Sengupta and Ray, 2017a) and individual academic (Perkmann et al., 2013) levels. Less attention has been paid to the strategic drivers and processes involved (Siegel and Wright, 2015), and how internal changes are affected as consequence of external shifts (Sánchez-Barrioluengo et al., 2019; Schaeffer et al., 2020; Sengupta and Ray, 2017b).

This paper addresses this gap by examining the dynamic relationship between shares of KE and research income and a university's KE profile, in the context of increasing competition for public funding and increasing importance of private funding within UK universities. Conceptualizing this process based on the dynamic capabilities framework, we find that increasing research income shares are associated with relatively higher diversity in its KE channels and stakeholder types; while increasing higher share of KE income with that of higher specialization. Further analysis (in Appendix B) reveals that the movements in KE diversity are being driven via collaborative, CPD and IP channels, and by large commercial organizations and non-commercial stakeholder types.

It is only very recently that the dynamic capabilities framework has started to be used in the context of the higher education sector (Li and Tang, 2021). Used in the context of rising importance of KE in a university's financial portfolio, this framework leads to interesting theoretical implications of the above findings. Universities are complex organizations, where multiple levels of processes, activities and individuals exist and interact among themselves – with traditionally low levels of centralized controlling mechanisms in place. Thus, given the large degree of autonomy that is present in constituent sub-units of the university, including in the behaviours exhibited by its research staff, the nature of dynamic capabilities that universities develop over time is likely to be different in nature to those within traditional businesses of equivalent size. However, dynamic capabilities are learned and emerge over time as higher order capabilities and are related to how resources and processes are reconfigured in response to environmental changes (Zollo and Winter 2002). Thus, there is no doubt that universities, being a collection of tangible, intangible and human resources, and with established processes across its operations, will also be subject to similar adaptive behaviour.

That there are opposite reactions to whether KE income itself or research income gets relatively more important financially, is a key finding. We argue that this is because each type of income share increase triggers different aspects of dynamic capabilities: KE income triggers leveraging and learning processes, and research income triggers reconfiguration and reintegration processes. Given that this argument remains conjectural in the paper rather than being testable directly, it opens up rich avenues of further research, around examination of processes and intra-organizational relationships (for instance between KTOs, management and researchers) that trigger particular dynamic capabilities in universities, and the resulting response.

Leveraging and learning induce path dependence in organizations (Zollo and Winter 2002), and in the current context induces universities to specialize further in specific channels (primarily through collaborative research, CPD and commercialization) and stakeholders (non-SME and non-commercial) used. The organizational changes necessary for this may be varied, and dependent on the sub-unit concerned. For instance, with rising importance of KE, KTOs (the key players in the choice of channels and type of stakeholders to engage with) would find it preferable to utilize their collective experience, learned knowledge and established mechanisms to pursue newer KE opportunities, thus reducing risks of failure, and utilizing economies of scale, scope and experience. Experience is key for success of collaborative research projects and commercialization, both of which require specialized legal and commercial domain knowledge. These can include contract and IP related negotiations, providing support around multi-party umbrella agreements in case of collaborative research, and with commercial entities involving discussions on equity, royalty and exit, in case of commercialization routes. At the same time, channels such as CPD are likely to influence academic researchers, departments and centres to follow organizationally well-trodden paths, leveraging networks and building on past experience. CPD mostly involve departments and academics who are well versed in undertaking executive training programs, which require development of pedagogical skills different from education within degree programs. Sengupta and Ray (2017b) through qualitative studies discuss a few specific instances of such moves toward specialization in KE business models, where initial KE successes led to gradual learning, replication, and standardization of KE processes across the organization over time. We extend this to show that a similar generic pattern exists across the sector, at least for a subset of channels. The evidence related to specialization in the remaining KE routes is weaker – and in case of the consulting channel is seen to be associated with diversification. This result around consultancies is not surprising, given that they are largely initiated through individual academic contacts and networks, and the income mostly accrues to the academic involved, rather than to the university. An interesting avenue of future research would be to examine the nature of the leveraging/learning processes that are triggered as KE income share becomes more prominent, particularly, around the channel and stakeholder specific differences that exist.

On the other hand, reconfiguration and integration processes are likely to be triggered as research income becomes relatively more important in the financial portfolio. Higher research income is associated with greater prestige, as well as a university's ability to be more risk

taking and exploratory. Research income from funders may also stipulate open access research outputs along with impact creation activities. Such impact creation activities are generally researcher led, rather than centrally dictated, implying alternative avenues are likely to be explored instead of well-trodden paths. At the same time, with increasing research income shares, researchers, departments and even the university, can become more flexible. Thus, new resources and operational capabilities need to be created and absorbed into the organization, and existing resources reconfigured to a degree, to allow for newly explored channels and new kinds of stakeholder types. Hughes and Kitson (2012) emphasize that KE is a universal phenomenon, not restricted to STEM disciplines and private sector stakeholders solely, and that the evidence for the isolated "ivory tower" model for UK universities is weak. Thus, increasing research incomes relative to others is likely to act as an incentive for cross fertilization across departments and disciplines, leading to formation of interdisciplinary research centres and other means of collaborations among researchers across academic silos. As the nature of research outputs change, reconfiguration and reintegration become more important, leading to more diversified KE activities.

Given the higher degree of autonomy at various levels within universities, the above changes could also be an outcome of opportunistic behaviour on part of key organizational sub-units, rather than being a centrally strategized. Alternatively, it could be a mix of both as complex feedback and learning within and across the organization impacts strategy centrally. Clearly, this opens up the opportunity to carry out targeted micro-level research to examine the specific processes leading up to the triggering of the changes mentioned above. Of particular interest would be to contrast the roles of alternative triggers, processes and outcomes at the organization (macro) versus the business unit (meso) versus the researcher (micro) levels.

Our findings also reveal that relatively smaller more resource-constrained universities are the ones where this dynamic linkage between their financial portfolios and KE profiles are stronger while asset rich universities exhibit more inertia. Thus, universities with larger resource bases are less sensitive as far as their KE portfolio is concerned, to changes in their financial profile. The interaction between acquired resources and an organization's dynamic capabilities has been examined previously (Stadler et al., 2013), and our results seem to point towards this in universities as well. Those universities, which over time have acquired valuable resources to establish a dominant position in the sector, are less inclined to utilize their dynamic capabilities further in the context of shifting financial portfolios. Once again, there are opportunities for further research in the context of what barriers exist within universities in terms of triggering specific dynamic capabilities.

These findings should be interpreted in the context of the changes in the external environment that universities have been subjected to, not just within the UK, but across many geographies. The case of the UK is particularly striking as the higher education environment has dramatically changed in the last two decades, thus providing an interesting test bed for our hypotheses. Yet, these results have implications for policy governing the higher education sector worldwide, given that the external pressures of reduced public funds and higher focus on research impact are more general phenomena.

Of particular interest are policies that aim to increase universities' reliance on private funding by reducing public expenditure, thus encouraging universities to do more with less public funds. However, our findings suggest that such policies could have a systemic impact within the HE sector of the economy, which may not necessarily align with the policymakers' original intent. We have found that increased reliance on KE activities increases specialization within KE channels and stakeholder types, contingent on the resource levels of the university. As private KE funding increases in importance relative to other sources, universities will tend to specialize more, resulting in changes in the mix of channels and stakeholder types used across the HE sector. Leaving aside the well-resourced ones, other universities will tend to leverage their existing resources and learn from experience to carry out *more* of the same. The counter-balancing forces from increased research income will have the opposite effect. A priori it is difficult to conjecture whether the sector will move towards further homogenization or diversity in terms of the KE channels/stakeholder types used *across* all universities, given that each may have their preference of the pathway given their own dynamic capabilities. However, it is important to emphasize that there are longer term systemic impacts that policy makers need to be aware of when certain private funding sources are incentivized over others.

There are implications for university management as well. From a strategic perspective, understanding how KE activities and structures evolve would lead to a better understanding of how KE needs to be planned and managed, given a university's finite resources. Moreover, these finite resources need to be allocated across all strategic priorities of a university. Thus, an understanding of the nature of the trade-offs between these strategic priorities is critical in determining the optimal allocation among all three. While Sengupta and Ray (2017a) have examined the apparent trade-off between research and KE outcomes dynamically, this paper goes further and explores the potential impact of the research-KE trade-off on the nature of KE activities themselves.

6. Conclusion

From a theoretical perspective, the management of KE in universities is relatively under-researched, even though higher education has seen progressive managerialisation (Teixeira and Koryakina, 2013) and KE has gained greater strategic and financial importance (Guerrero and Urbano, 2012). Understanding how universities diversify or specialize their KE activities, in response to changing higher education landscape, and corresponding shifts in KE vis-à-vis research income shares in their financial portfolios, is the key novel contribution of our paper. From the dynamic capabilities perspective, an organisation's resources need to be realigned to meet the changing needs of the external environment, and our findings reveal *how* and *where* such realignment takes place. Using the case of the UK universities over an 8-year period, conditions under which such realignment leads to diversification versus specialization in KE activities are identified, as are the differences due to underlying resource constraints.

The paper is not without its limitations. First, the relative importance of KE versus research for a university is measured solely from the financial perspective. This is indeed a limited view on how universities themselves may view these two functions, and other intrinsic unobserved factors might affect the relative importance of each. Second, while hypotheses development discusses several mechanisms that can cause the dynamic movements in diversity in channels and stakeholder types, we are not able to examine the exact nature of *causality* between the mechanisms and our findings. Particularly, we are not able to pinpoint the exact reasons why some hypotheses could be verified while others remain unverified. Further in-depth exploration needs to be carried out within universities to isolate these causal factors. Third, the HE-BCI dataset, on which we base our analysis, has its own limitations being based on self-reported outcomes from universities. Finally, even though the higher education landscape in many countries has firmly moved towards reduction in public funds and greater competitiveness, the case of the UK is some respects is unique. The level of policy intervention in the sector, particularly through a steep rise in tuition fees in England and Wales, and active support for linkages with businesses is at an all-time high and hence we need to be careful while generalizing fully to other contexts, especially those where the interventions have been absent or far more modest. However, it is also true that KE is becoming an important strategic pillar within universities worldwide, and hence these results remain relevant outside the UK as well.

While there are certainly aspects of the questions which go beyond the scope of this paper, the results contribute significantly to the growing understanding of the modern dynamic university and how its KE profile reshapes itself in response to changing higher education

landscape.

B. Impact of individual channels and stakeholders

In order to explore the impact of variation in income shares on diversification indices in greater detail, we estimated two additional models. These are identical to the primary regression equation in almost every way, apart from the lagged KE income share $s_i^u(t-1)$ replaced with the lagged share of income through *individual channels* in one, and with share of income from *individual stakeholders* in the other (individual channels and stakeholders being identical to those presented in Table 1). The results are presented in Tables 8 and 9 respectively.

For channels, collaborative, CPD and IP income shares show a significant negative effect on the channel diversification index $v(t)$ (in agreement with baseline results involving overall KE income share), whereas consulting income shows a significant positive impact (opposite to the baseline). For stakeholders, the corresponding impact of income shares from non-SME and non-commercial organizations are negative and significant, that is in the same direction to the baseline. The implications of these, along with the baseline results, are explored further in the Discussion section.

Data availability

Data will be made available on request.

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Appendix

A. Robustness and endogeneity

We ensured the robustness of our findings in several ways. First, a large number of time varying controls along with fixed effects estimators were used in order to rule out any impact of unobserved heterogeneity. Second, we ran the panel estimates using lagged specification of the independent variables and considered clustered standard errors to ensure that endogeneity through simultaneity and grouping can be eliminated. We estimated our models with lags up to 3 years to ensure that the results were not sensitive to the order of the lag. Third, we tested the models with alternative specifications of diversification indices, the well-known *entropy* measure of diversification constructed using the following formulas respectively:

$$v'(t) = 1 - \sum_{j=1}^{M} \left(\frac{x_{jt}}{X(M,t)}\right) log\left(\frac{x_{jt}}{X(M,t)}\right)$$

$$w'(t) = 1 - \sum_{k=1}^{N} \left(\frac{y_{kt}}{Y(N,t)}\right) log\left(\frac{y_{kt}}{Y(N,t)}\right)$$

To obtain deeper insights into what drives the results, we additionally re-estimated the models with the KE income share (independent) variable replaced by individual channel and stakeholder specific income shares (share of total income). The magnitude and sign of the relevant coefficients were then compared with those of the coefficients of the original models with KE income share, to understand which channels and stakeholders were driving the changes in $v(t)$ and $w(t)$ as overall KE income share grew.

The estimation results from the alternative entropy measures of diversification are presented in Table 7, for both $v'(t)$ and $w'(t)$. The results largely agree with the base model estimates presented in Table 4 earlier. The only exception is the effect of the research income share on $v'(t)$, which appears to be not significant ($p = 0.131$) but has a positive coefficient (0.311). The coefficients of the other independent and control variables have similar signs, relative magnitudes and significance as the base models presented in Table 4.

Finally, the independent variables are income share components – such as KE and research, and not absolute values or their transformations. While each component in absolute terms is not exogenous, the shares of each are more likely to be, given the very limited agency that universities have in controlling each share independent of others in total income. Nevertheless, we can never rule out endogeneity completely in observational data, but in this case its risk can be reduced for the following reasons. Endogeneity results in bias and inconsistency, implying divergence of sample-based findings from the true population equivalents. In our case, the sample consists of almost 75% of all research-intensive universities in the UK – a large proportion of the population. Hence, bias or inconsistency, even if endogeneity exists, may not be a serious problem.

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