Intrinsic and strategic complementarity of research and knowledge transfer activities as determinants of knowledge transfer management: evidence from public research organisations

Maryam Ghorbankhani

Department of Management,

Birkbeck, University of London,

Malet Street, London WC1E 7HX, UK

Email: m.ghorbankhani@bbk.ac.uk

Federica Rossi

Department of Management,

Birkbeck, University of London,

Malet Street, London WC1E 7HX, UK

email: f.rossi@bbk.ac.uk

Note: This is a post-peer review accepted version, please cite:

Ghorbankhani, M. and Rossi, F. (2022) Intrinsic and strategic complementarity of research and knowledge transfer activities as determinants of knowledge transfer management: evidence from public research organisations. *Journal of Technology Transfer*

Acknowledgements: We are grateful to Birkbeck, School of Business, Economics and Informatics, for funding which supported the data collection. Maryam Ghorbankhani gratefully acknowledges funding from The Research and Development Management Association (RADMA)'s Doctoral Fellowship Scheme and Postgraduate Research Support Scheme. We are grateful to Suma Athreye and Abhijit Sengupta for their helpful comments. Any errors and omissions are our own.

Intrinsic and strategic complementarity of research and knowledge transfer activities as determinants of knowledge transfer management: evidence from public research organisations

Abstract

While public research organisations (PROs) are increasingly expected to actively transfer knowledge to business, government and wider society, limited research exists about how they manage this important function. Particularly, we do not know under what conditions it is more effective for PRO to vertically integrate knowledge transfer management, or to outsource it to specialist providers. Extending the theory of firm boundaries to PROs, we argue that this choice is influenced by two types of complementarity between research and knowledge transfer: *intrinsic complementarity* (occurring when the knowledge transfer process requires unique tacit knowledge) and *strategic complementarity* (occurring when the nature of the knowledge recipients matters to the PRO). By exploiting a unique six-year panel dataset of 33 PROs in the United Kingdom, we confirm that higher degrees of both types of complementarity are associated with greater likelihood to vertically integrate knowledge transfer management, and that these effects are independent of economies of scale and sector specificities.

Keywords: Public research organisations, research commercialisation, knowledge transfer management, vertical integration, complementarity, intellectual property management

JEL codes: O32 - Management of Technological Innovation and R&D; 34 - Intellectual Property and Intellectual Capital; O36 - Open Innovation

1. Introduction

Knowledge transfer management is increasingly considered an important function of the public research system, including universities and government-funded research institutions, the latter also known as public research organisations (PROs). Government-funded research performed in these organisations can not only advance the scientific frontier but also provide useful knowledge inputs for business innovation (Bozeman, 1994; Vorley and Lawton-Smith, 2007; Mazzuccato, 2015), this way supporting businesses' long-term economic competitiveness. Universities and PROs are under increasing pressure to engage with external stakeholders within industry, the public sector, and society more generally (Maxwell-Jackson, 2011; Ankrah, et al., 2013), in order to demonstrate their public value to the policymakers and to the taxpayers they are accountable to, as well as to supplement dwindling public investment in research with private income arising from knowledge transfer activities.

Despite the growing relevance of knowledge transfer management as a crucial activity within the public research system, there are very few studies that have analysed how this new activity should be organised, particularly whether it would be more efficient and effective for it to be vertically integrated within research organisations, or outsourced to specialised providers. Where this issue has been investigated, it has usually been done in relation to universities rather than PROs (Sengupta and Ray, 2017). Moreover, there is a lack of convincing theoretical explanations for the organisational choice whether to vertically integrate or outsource knowledge transfer management. This study aims to fill this gap in research by making a theoretical and empirical contribution to the understanding of what drives PROs to vertically integrate or outsource knowledge transfer management.

We articulate a conceptual framework to describe how the 'make or buy' decision, which so far has been investigated mainly in relation to firm boundaries, applies to a less studied context – the public research sector – and to a specific type of knowledge process – knowledge transfer from research performers to external stakeholders. The organisational literature on firm boundaries suggests that firms should integrate certain activities (or capabilities) when they are complementary to other activities in ways that generate unique bundles capable to deliver competitive advantage (Mahoney and Pandian, 1992; Milgrom and Roberts, 1995; Argyres and Zenger, 2012). We apply and extend the theory of firm boundaries to the case of PROs, where the objective function is not directly related to profit but to the attainment of their institutional mission, and where we look specifically at the complementarity between research and knowledge transfer. We argue that two types of complementarity between research and knowledge transfer - generating unique bundles of activities that fulfil the PRO's institutional mission better than if they were unbundled - matter in order to decide whether the knowledge transfer management activity should be integrated. One is what we term *intrinsic complementarity*, which occurs when effective knowledge transfer requires tacit knowledge, which is uniquely possessed by the research performers. The other is what we term *strategic complementarity*, which occurs when effective knowledge transfer involves some control on which external stakeholders knowledge is transferred to. We hypothesise that both types of complementarity lead PROs to integrate knowledge transfer management functions, and that these are independent of other efficiency considerations, like economies of scale and sector specificities. We test these hypotheses empirically by exploiting a unique, purposefully constructed panel dataset of 33 PROs in the United Kingdom (UK), built from public administrative records (annual reports and financial

statements) for the six financial years between 2011/2012 and 2016/2017, combined with information derived from other publicly available sources like publications and patent databases, and the PROs' websites.

This study is innovative in several respects. First, although there has been much research on the outsourcing of knowledge processes, it has mainly focused on private firms, driven by profit-making considerations. These studies have explained the 'make or buy' decision using capabilities (Demsetz, 1988; Kogut and Zander, 1992; Langlois, 1992; Barney, 1999) or transaction costs (Williamson, 1975) as determinants of firm boundaries, or more recently, in a dynamic perspective, a combination of both (Odagiri, 2003; Jacobides and Winter, 2005, 2012; Foss and Foss, 2008; Argyres and Zenger, 2012). Less has been done in relation to public sector organisations, where studies have discussed the cost efficiency and political expediency of outsourcing public services (e.g. Grimshaw et al., 2002; Jensen and Stonecash, 2004; Elinder and Jordahl, 2013), rather than how complementarities between activities influence the decision to outsource. Second, the studies of public services outsourcing usually focus on generic services, some of which may be knowledge-intensive (Avery, 2000; Young, 2005), but they do not focus specifically on the outsourcing of knowledge transfer management functions on the part of research performers. Third, studies of knowledge transfer management in research organisations, have mainly focused on universities rather than PROs.

Since this study contributes to better understanding of the phenomenon of knowledge transfer management, it can provide useful guidance to PROs that wish to boost the effective exploitation of their research, and to policymakers that intend to support them in doing so. In fact, studies show that boosting innovation in the public sector requires an overarching strategy on the part of government to introduce organisational

innovations and practices that support knowledge transfer (Lee et al., 2012; Cervantes and Meissner, 2014).

The UK is an interesting setting for this study for several reasons. First, the country possesses a sizeable (although it has shrunk in recent years) and very heterogeneous PRO sector, characterised by a variety of ownership and funding arrangements, making this an appropriate scenario in order to investigate organisational differences across PROs. Second, the UK experience can be of interest to other countries, given that the adoption of managerial practices in the public sector is widespread (Boden et al., 2004; James, 2009), anticipating trends that have been replicated in many countries in Europe and elsewhere (Nedeva and Boden, 2004; Senker, 2000; Cruz-Castro et al., 2020). Despite its importance, the PRO sector in the UK is under-studied compared to the university sector. One of the problems might be the lack of publicly available data. While the UK government has invested substantially in understanding and promoting universities' knowledge transfer engagement (Huggins and Kitagawa, 2012; Rossi and Rosli, 2015), it has paid less attention to PROs: the Department of Business, Innovation and Skills carried out a few surveys of PROs' knowledge transfer activities in the early 2000s, but this exercise stopped after 2012/13 (see BIS, 2007, 2011, 2014). More recently, a survey of individual researchers working for a set of PROs (Research Council Institutes) has uncovered widespread engagement with industry and other stakeholders (NCUB, 2016).

The paper is structured as follows. In section 2, we review the literature on PROs' knowledge transfer activities, and we draw on organisation theories to identify the determinants of the choice to vertically integrate or outsource knowledge transfer management functions. In section 3, we describe our data and methodology. In section 4, we present and discuss our findings. Section 5 concludes.

2. Literature review

2.1. Knowledge transfer management in PROs

PROs are an important component of the public research systems of most countries including, or even particularly, in emerging economies (WIPO, 2011). They are positioned between the fundamental science carried out in academia and the industrial R&D carried out by business (Mazzoleni and Nelson, 2007; Maxwell-Jackson, 2011). PROs are very heterogeneous in relation to aspects like their mission (which ranges from 'pure' knowledge development, to the provision of evaluation, testing, emergency response and consultancy services to government, industry and the general public), scientific disciplines, legal status, and ownership (Cruz-Castro et al., 2020). This heterogeneity reinforces the importance of analyzing them separately from universities, also in relation to their knowledge transfer management.

PROs, in fact, are increasingly expected to contribute to national economic growth by transferring knowledge to external stakeholders, and they do so through a variety of engagement channels, which they combine in different ways (de la Torre et al., 2021). Recent studies show that PROs engage in contract research with industry, patenting and licensing, mobility of staff and conferences, promotion of start-ups (Rubenstein, 2003; D'Este and Patel, 2007; Perkmann and Walsh, 2007; NCUB, 2016) and in more market-oriented activities like the provision of prototyping, analysis and testing, calibration and certification services (Coccia and Rolfo, 2002). PRO staff also participate in more informal knowledge transfer activities, such as providing informal advice and participating in networks, and contribute to public and community engagement through activities like taking part in educational projects, delivering lectures, organizing exhibitions (NCUB, 2016). The management of these

multifaceted activities has become a more pressing concern for PROs (Cervantes and Meissner, 2014).

We analyse the determinants of PROs' approaches to knowledge transfer management by specifically focusing on the choice whether to vertically integrate or outsource knowledge transfer management functions to specialised companies. Outsourcing key business functions is increasingly seen as a crucial component of contemporary organisational business models (Merino and Rodríguez, 2007), and it is increasingly discussed in relation to knowledge processes (Mudambi and Tallman, 2010). Organisations in the public sector might benefit from the advantages of outsourcing, which include efficiency gains (Quinn, 1999), the possibility to access specialist knowledge and capabilities (Hayer, 2016; Wright et al., 2008), the development of greater business focus (Quinn and Hilmer, 1994) and flexibility (Kremic et al., 2006) and of greater absorptive capacity (Un, 2017). This organisational model might become particularly attractive to PROs as their volume of knowledge transfer activities increases in response to policy pressures.[1] Hence, the choice whether to vertically integrate or outsource some knowledge transfer management functions is likely to become increasingly relevant to PROs. Better understanding of the drivers of this choice allows us to identify which PROs are more likely to need support with outsourcing, or to benefit from interventions that improve their in-house knowledge transfer management abilities.

While a substantial amount of literature has investigated the engagement of the public research sector in knowledge transfer to industry, the specificities of the knowledge transfer activities of PROs remain under-researched. Most studies in this stream of literature focus on universities only. When non-university PROs are studied, they are

[1] Indeed, studies of universities have shown that, as their knowledge transfer engagement intensifies, they increasingly rely on intermediaries and specialists to manage some of their knowledge transfer functions (Yusuf, 2008; Hayer, 2016).

often part of larger samples that include universities as well (e.g. Mazzoleni and Nelson, 2007; Dutrénit and Arza, 2010; Arza and Lopez, 2011; Arnold et al., 2010; Fudickar and Hottenrott, 2019). Some studies deploy even more heterogeneous samples that combine both government research institutes and private non-profit organisations engaged in R&D activities such as research foundations (Mina et al., 2009; Teirlinck and Spithoven, 2012; Landry et al., 2013).

A growing literature on knowledge transfer management in the public research sector, mainly focused on universities, has identified a variety of organisational arrangements used to support this activity. Their choice increasingly results from strategic decisions, aimed at fitting the institution's resources with the constraints and opportunities present in its rapidly changing external environment (Hewitt-Dundas, 2012; Martin, 2012; Kitagawa et al., 2016; Rossi, 2018). In turn, organisational arrangements have been found to impact the nature of the institution's engagement in knowledge transfer (Ambos et.al., 2008; Perkmann et.al., 2013; Lockett et al., 2015; Sengupta and Ray, 2017). Studies of universities' knowledge transfer management have documented a progressive diversification of knowledge transfer activities and organisational approaches. Earlier efforts focused mainly on the process of research commercialisation through the sale and licensing of intellectual property (IP), using either internal units, or various kind of external units (profit or non-profit making, owned or not by the university) providing advice, funding, and expertise in exchange for payment of a fee and/or of a share in the university's IP (Rogers et al., 2009; Tang et al., 2009). Over time, universities have diversified their knowledge transfer activities beyond IP commercialisation, and knowledge transfer management has become more varied and more decentralised, often involving several layers within the university, and combining internal structures and outsourcing in different ways

(Sengupta and Ray, 2017; Sánchez-Barrioluengo et al., 2019).

With respect to our objective to understand what drives PROs to vertically integrate or outsource knowledge transfer management activities, this literature suffers from two main limitations. First, findings from studies of universities cannot be immediately transposed to PROs, which are different in many respects, including: (i) their activities (PROs' teaching activities, when they exist at all, are limited to doctoral supervision and professional training, and PROs' research activities are often closely directed to the achievement of government objectives (Cruz-Castro et al., 2015); (ii) their subject focus (PROs tend to specialise in one field or a few closely related fields, while universities can have very diversified subject portfolios); (iii) their governance (PROs can have varied ownership and management structures, and can be affiliated with different parts of government (Sanz-Menéndez et al., 2011), whereas universities usually maintain an arms' length relationship with government whose role is limited to funding provision). Secondly, studies in this stream of research tend to be descriptive, paying limited attention to the conceptualisation of the choice of organisational approach in more theoretical terms.

In the next section, we rely on the organisational literature about firm boundaries more generally, and about the outsourcing of knowledge processes in particular, in order to develop a conceptual framework linking the knowledge transfer management 'make or buy' decision to the nature of the complementarity between research and knowledge transfer in light of the PRO's objectives.

2.2. Research and knowledge transfer complementarity and the organisation of knowledge transfer management

The theory of outsourcing has made a lot of progress over the last decade. Initially,

the decision to outsource activities was explained on the basis of transaction costs, building on Williamson's pioneering work (1975). The key argument here was that activities are integrated if the cost of outsourcing is higher than the cost of integrating, where the outsourcing cost includes the transaction costs deriving from imperfections in factor markets. The latter comprise the costs of searching for and screening potential suppliers, as well as the cost of the potential holdup problem arising when the supplier is able to acquire crucial capabilities that render the outsourcing firm vulnerable to increasing prices (Brandenburger and Stuart, 1996, Lippman and Rumelt, 2003). The other viewpoint came from the resource-based theory of the firm and its extensions, such as the knowledge-based theory of the firm (Grant, 1996) and the dynamic capability theory (Teece et al., 1997). This stream of literature argues that firms should produce internally what they can do better than other firms, and outsource what they can do less well than other firms. Any activities for which the firm does not possess superior capabilities should be outsourced to suppliers that, by virtue of specialising in a specific activity and of performing it on a larger scale, are both more capable (Argyres, 1996; Kaufman et al., 1996; Mudambi and Tallman, 2010) and more efficient (Kakabadse and Kakabadse, 2000).

More recently, some approaches have combined the two perspectives, suggesting that capabilities and transaction costs are interlinked (Argyres and Zenger, 2012). On the one hand, current superior capabilities can be explained as the outcome of past governance decisions driven by transaction costs, so transaction costs considerations underpin the emergence of capabilities. On the other hand, transaction costs continue to matter even once superior capabilities have been established, since capabilities are changeable and a company can build superior capabilities (or vice versa other companies can steal a company's superior capabilities) through the purchase of

strategic factors, including key human resources (Capron and Mitchell, 1998; Nagarajan and Mitchell, 1998).

According to this combined view, a firm should vertically integrate activities[2] when they are complementary to its other activities, in ways that generate unique bundles capable to deliver competitive advantage (Dierickx and Cool, 1989; Ghemawat, 2005; Argyres and Zenger, 2012). The value of an activity is therefore strongly firm-specific, as it depends on the relationship between this activity and the other activities in the firm's bundle: when the activity is complementary in ways that confer unique competitive advantage, it is said to enjoy a relationship of unique complementarity. Table 1 summarizes the predictions of this view: firms are likely to integrate activities that are uniquely complementary to their other activities, whereas they are unlikely to integrate unique activities that are not complementary to their other activities, or generically complementary activities (Argyres and Zenger, 2012).

Table 1. Integration outcomes of different types of complementarity

State of activity	Generic	Unique
Complementary with other activities in the bundle	Outsource	Acquire or develop internally
Non complementary with other activities in the bundle	Outsource	Outsource

Source: adapted from Argyres and Zenger (2012)

Managers who are able to detect and combine uniquely complementary activities can enjoy substantial rents (Barney, 1986) provided that: first, they do not reveal to others the value of the bundle of activities while they are assembling them (if they did, the

[2] The literature on firm boundaries talks of assets, resources, and activities, which are seen as the underlying components of configurations out of which capabilities emerge (Amit and Shoemaker 1993). For ease of exposition, in this paper we use the term 'activities' to refer to the combinations of physical assets and human and intellectual resources that are used in the production of a good or service, which the organisation can decide to vertically integrate or outsource. Some studies in the organisational studies literature prefer the term 'assets' (sometimes intended as also encompassing 'resources' and 'activities'; Argyres and Zenger, 2012).

owners of the complementary activities might attempt to extract higher rents from the sale of these activities), and, second, they do not allow others to appropriate the value of the bundle through unfavourable governance arrangements (for example, by outsourcing some of the uniquely complementary activities to others, who might then be able to keep the focal firm hostage).

Application of this framework to the case of PROs in order to predict when research and knowledge transfer activities should be bundled or not, requires us to make some adaptations. Most studies in the firm boundaries literature take it for granted that the feedback as to whether a bundle comprising a particular activity delivers competitive advantage, comes from the profit signal: the ability to generate returns from the bundle greater than the returns that would be generated from a bundle that includes an alternative activity. However, the rate of return for the investment made is not a relevant success metric for all kinds of organisations. Jacobides and Winter (2012) indeed noted that what organisations find 'rewarding' depends on what the system around them rewards – which could be administrative goals in a state bureaucracy, or key performance indicators in a business department of a large corporate structure. Hence, they argued that the reward system that the organisation operates under influences the operation of the feedback processes through which the value of bundles of activities is established, and consequently also the decisions whether to integrate or outsource such activities. Since government-funded research institutions are evaluated by the government on the basis of their success in fulfilling their institutional mission, this criterion should provide the feedback process regarding whether the knowledge transfer management activity should be integrated within the PRO or not.

The PRO's institutional mission is not directly to generate external revenue (although this is encouraged), but rather to produce and diffuse knowledge for the benefit of the

PRO's relevant stakeholders. The latter can be internal - government, other stakeholders represented in governing bodies – and external – businesses and other communities, depending on the PRO's focus (for example, for a PRO in the public health sector the whole population potentially affected by a disease can be a relevant stakeholder)[3]. Accordingly, PROs should integrate knowledge transfer management activities when these are uniquely complementary to the PRO's core research activity, so that their bundling allows the PRO to achieve its institutional mission better than the unbundling of these activities and the outsourcing of knowledge transfer.

We argue that the extent to which the bundling of knowledge transfer with research in a PRO allows it to benefit its relevant stakeholders better than outsourcing, depends on two sources of unique complementarity, which we term intrinsic complementarity and strategic complementarity.

Intrinsic complementarity between research and knowledge transfer management occurs when knowledge has a strong tacit component[4] so that its effective transfer requires the involvement of people who possess this tacit knowledge element - typically the people who have themselves performed the underpinning research. In the presence of tacit knowledge, the bundling of research and knowledge transfer management within the PRO leads to more effective diffusion of knowledge to relevant stakeholders, and hence better fulfillment of the PRO's institutional mission, for several reasons.

First, bundling facilitates the circulation of tacit knowledge between the people

[3] These missions are often explicitly noted by PROs, for example: "*We have a duty to maximise the benefit to the UK of the new technologies and knowledge that are developed during the course of our defence work*" (DSTL, Annual Report 2016/17); "[*The PRO] promotes technology growth in the UK, with new enterprises acting as a catalyst for UK industry and enabling broader utilisation of skills now and in the longer term*" (UKAEA, Annual Report 2016/17); "*We support businesses, agencies and governments in making short and long-term decisions, making the world a safer and more resilient place tomorrow, and for the years – and decades – to come*" (Met Office, Annual Report 2016/17).

[4] Tacit knowledge is defined as the non-codifiable accumulation of skills that arise from the learning gained from practice (Reed and DeFillippi, 1990). It is non-verbalised, intuitive, scarce, difficult to imitate, and therefore it is an important source of competitive advantage (Becerra et al. 2008).

involved in research and those involved in knowledge transfer. The organisational setting is able to generate common language, a shared identity, and a more trusting social environment (Kogut and Zander, 1992; Nahapiet and Ghoshal, 1998; Monteverde, 1995; Gertler, 2003) which promotes the circulation of knowledge, including tacit knowledge, between the various people involved in the process of knowledge transfer, something that would be difficult to achieve if some of the latter were based in a different organisation. The organisational setting is also able to mandate the involvement of specific people in the knowledge transfer process, including the researchers themselves, which is particularly important when tacit knowledge is involved. Instead, reliance on an external organisation would require a costly process of communication and education (Demsetz, 1988; Conner and Prahalad, 1996) on the part of the PRO to make sure that the correct people are involved in the process.

Second, in the presence of tacit knowledge there are difficulties in the use of strategic factor markets. If effective knowledge transfer requires the people involved in the transfer process to deeply understand the research performed by the PRO, a specialised provider of knowledge transfer management services might need to invest a lot of resources in developing knowledge specific to the research of the client PRO – for example by seconding staff to the PRO so they can understand their activities better, by developing client-specific software and by recruiting highly specialised human resources. Suppliers are unlikely to make such co-specialised investment in absence of carefully crafted safeguards (Klein et al., 1978; Williamson, 1985; Ceccagnoli et al., 2010). Because of the high costs of creating and enforcing these safeguards contractually (Teece, 1986), this makes it more likely that the PRO will integrate knowledge transfer. There might also be a risk of opportunism on the part of

the supplier if they were to indeed acquire co-specialised knowledge (Narula, 2001; Holcomb and Hitt, 2007; Spithoven and Teirlinck, 2015) particularly in commercially or security sensitive areas of research, which would make the PRO hostage to the supplier's pricing.

Finally, since markets function better when they are able to effectively link reward with productivity (Alchian and Demsetz, 1972), outsourcing is more likely if organisations are able to compensate suppliers based on an accurate measurement of their performance (Poppo and Zenger, 1998). In the presence of tacit knowledge, the value of the transferred knowledge is difficult to measure since it depends highly on who is doing the transfer. It is therefore difficult to price, and to compensate the supplier accordingly[5].

Hence, we argue that:

H1: The greater the intrinsic complementarity between research and knowledge transfer, the greater the PRO's likelihood to vertically integrate knowledge transfer management.

Strategic complementarity between research and knowledge transfer management occurs when the fulfillment of the institution's mission is strongly related to the ability to direct knowledge to particular stakeholders. If the PRO's mission is linked to transferring knowledge to specific external stakeholders, it becomes very important for the PRO to maintain some degree of control on the knowledge transfer process to ensure that it is primarily directed to the intended recipients. When this occurs,

[5] Arora (1996) makes the argument that contractual problems in contracting for know-how in the presence of tacit knowledge can be overcome by bundling technical services (which have a component of tacit knowledge) with complementary inputs such as patents or equipment. Arora's argument however applies to the relationship between an organisation transferring knowledge and a client organisation wishing to receive that knowledge. This study instead focuses on the organisational arrangement used by PROs in order to manage the process of knowledge transfer, rather than on the management of relationship with the knowledge transfer recipients. Indeed, complex arrangements that bundle technical services and complementary inputs are probably more likely to occur if knowledge transfer management is vertically integrated within the PRO, as the process of bundling these activities itself requires tacit knowledge.

knowledge transfer management is strategically complementary to the PRO's core research activity, because the way in which knowledge transfer is managed (and particularly, the type of stakeholders it is designed to benefit) is integral to the fulfillment of the PRO's mission. By vertically integrating knowledge transfer management, the PRO can keep under control the knowledge transfer opportunities that are pursued to make sure they are aligned with institutional objectives.

This argument has been under-developed in the literature on firm boundaries as an explanation for the 'make or buy' decision, as the need to control the nature of the clients to which a product or service is sold does not appear to be very prominent for the majority of firms (with the exception of firms in sensitive sectors like defense, for example). Nonetheless, some firm studies have noted that vertical integration is preferred when the supplier might exploit its knowledge of the firm's research, or its proposed solution to a problem, outside the original contract with the focal firm (Martínez-Noya et al., 2013) and to the benefits of others. While this could be framed purely as a problem of opportunism which might be dealt with through appropriate contractual safeguards, it also highlights a concurrent problem that the supplier might decide to transfer knowledge to stakeholders that were not intended to receive it.

Other studies have noted that firms tend to outsource to specialist suppliers when their client base is larger and more heterogeneous (Choi and Hong, 2002; Jones and Hill, 1988; Kistruck et al., 2015), since it is difficult for firms to efficiently connect with many different clients across multiple product and geographic markets (Jones and Hill, 1988); conversely, organisations whose activities are intentionally directed to a smaller client base (e.g., in our case, PROs that direct their knowledge transfer activities to a smaller pool of stakeholders) should be less likely to outsource these activities.

Hence, we argue that:

H2: The greater the strategic complementarity between research and knowledge transfer, the greater the PRO's likelihood to vertically integrate knowledge transfer management.

3. Data and methodology

3.1. Data collection

This study exploits a unique, purposefully constructed panel dataset of 33 PROs in the United Kingdom for six financial years from 2011/2012 to 2016/2017, built from public administrative records (annual reports and financial statements). The development of the sample of PROs to include in the study has been quite laborious, since no comprehensive official list of PROs in the country exists, and since the sector has seen numerous changes, with several mergers between institutions, dismissals of institutions or transfer of institutions to the private or charity sector.

We created a comprehensive list of currently active PROs by analysing eight recent studies of PROs in the UK[6]. These studies adopted various definitions of PROs, but most of them included the following three categories: (a) Departmental Research Bodies and Cultural Institutions: institutes affiliated to one or more government departments, whose mission is to perform research and/or cultural activities (76 institutions); (b) Research Council Institutes: institutes affiliated to one or more of the UK's seven research councils[7] (27 institutions); (c) Medical Research Council (MRC)

[6] These are: Lyall et al. (2004), BIS (2007), BIS (2011), Maxwell-Jackson (2011), Government Office for Science (2013), BIS (2014), Smith (2015), Hughes et al. (2016).

[7] These are: Arts and Humanities (AHRC), Biotechnology and Biological Sciences (BBSRC), Engineering and Physical Sciences (EPSRC), Economic and Social Research (ESRC), Medical Research (MRC), Natural Environment (NERC), and Science and Technology Facilities (STFC). Following the passage of the Higher Education and Research Bill (2017), the seven councils have been merged into a single agency called UK Research and Innovation (UKRI) which also includes the innovation funding agency Innovate UK.

units: units that received funding by the MRC but are based within universities (34 units).

We carried out an in-depth search of each of these institutions' websites to ascertain whether they were still active, and whether they were actually involved in research activities. This led us to exclude organisations that primarily engaged in cultural missions, such as museums and film and sports councils, as well as institutions that no longer engaged in research, for example an institute that has now become purely a payment agency. We also excluded the 34 MRC units which, although funded by the Medical Research Council, are not stand-alone organisations but are based within universities, and rely on university staff and structures. This way the sample was reduced to 49 organisations, of which 28 are Departmental Research Bodies and 21 are Research Council Institutes. For each of the 49 PROs in the sample, we collected information from their websites about their main demographic characteristics: founding date, legal status, mission, department of affiliation, location, ownership structure.

Geographically, PROs are concentrated in London, the South East and the East of England (many around Cambridge and Oxford) and in Scotland. PROs are characterised by a varied range of ownership and management arrangements. In particular we distinguish three main types of arrangements. Executive Agencies are clearly designated units of a central government department, administratively distinct, but remaining legally part of it; they have a clear focus on delivering specific outputs within a framework of accountability to ministers (Cabinet Office, 2016). Non-departmental public bodies (NDPB) "have a role in the processes of national government, but [they are] not a government department or part of one, and accordingly [they operate] to a greater or lesser extent at arm's length from ministers"

(Cabinet Office, 2016, p.13). Public Corporations are partly or fully owned by the government using a variety of legal arrangements (e.g. Company limited by guarantee; Government owned, Contractor operated); these tend to be much more independent of government control (Royal Society, 2020).

We have then collected information from the PROs' annual financial statements for six financial years (2011/12, 2012/13, 2013/14, 2014/15, 2015/16 and 2016/17). The information from annual financial statements could only be collected from 33 organisations that report independently, six (18%) of which are affiliated to a research council (BBSRC), and the remaining 27 (82%) are affiliated to government departments. Table 2 shows the distribution of PROs in the population and in our sample.

Table 2. The population of active PROs in the UK and our sample

	Population		**Sample**	
	Number of PROs	**% PROs**	**Number of PROs**	**% PROs**
Departmental Research Bodies	28	57.1%	27	82%
Research Council Institutes	21	42.9%	6	18%
Total	49	100.0%	33	100.0%

Hence, we have a 6-year balanced panel of 33 organisations, for a total of 198 observations. The information from financial statements includes:

a) number of employees (full time equivalent, FTE);
b) governing board information: size, gender composition, presence of members disclosing external interests;
c) funding sources, distinguishing between public funding (core grant from government and competitive grants from government and other public bodies, including research foundations) and private funding (income from industry contracts, royalties and other sources; excludes investment income and income

from equity ownership);

d) number of subsidiary companies (wholly owned by the PRO) and associate companies (partly owned by the PRO);
e) number of incubators and/or science parks the PRO is directly or indirectly affiliated with.

By searching the websites of the PROs and of the subsidiaries and associate companies mentioned in the financial statements (as well as by reading the PROs' annual reports) we were able to distinguish between: subsidiaries and associate companies to which the PRO outsources knowledge transfer management functions (research commercialisation, including IP licensing and research contracting; service provision including testing, consultancy, other business services) and subsidiaries and associate companies dedicated to exploiting research outputs (spinoff companies).
We collected additional information from external sources. We collected information about the PROs' patenting activities in each year (number of patent applications, IPC categories, number of co-applicants from industry, university, other PROs, other organisations, number of citing documents) from the European Patent Office's database. We collected the number of scientific publications of each PRO in each year, divided by field of science, from the Scopus database. We also collected information about the main sectors that are users of the PROs' knowledge, divided into 21 categories (Smith, 2015, p.19).

3.2. Variables construction

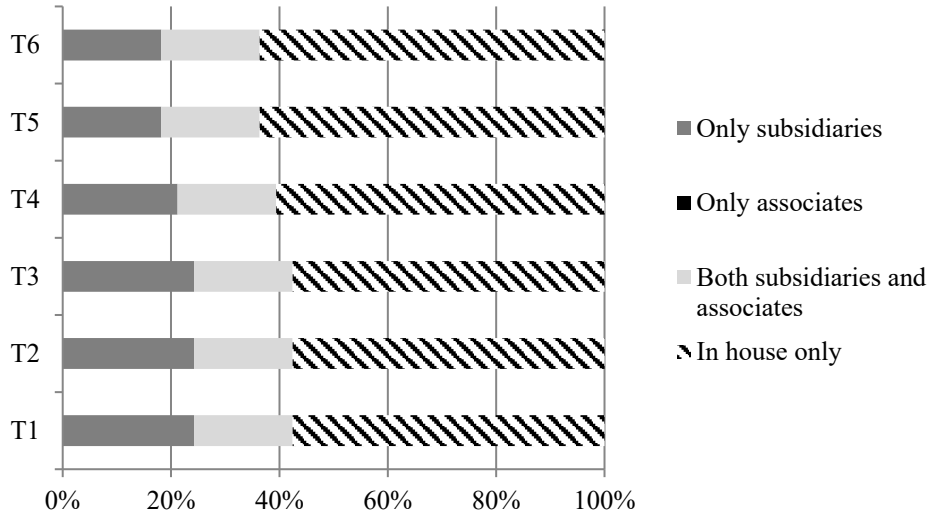
3.2.1. Dependent variables

Our dependent variable is a binary variable called *In_house* which is equal to one when the PRO does not outsource its knowledge transfer management activities to

external (subsidiary or associate) companies. On average, 40% of PROs have outsourced some or all of their knowledge transfer management activities over the period considered. Of these, 22% relied only on subsidiaries, while 18% relied on both subsidiary and associate companies (these companies are sometimes partly owned by more than one PRO). None of the PROs relied on associate companies only. The remaining 60% did not outsource their knowledge transfer management activities to subsidiaries and associate companies. Figure 1 shows the shares of PROs that rely on in-house and outsourced knowledge transfer management (in the latter case, distinguishing between outsourcing to subsidiaries and to associate companies) by year.

While our dependent variable measures whether PROs do not outsource knowledge transfer management activities to subsidiaries and associate companies only, rather than to external companies more generally, we have several reasons to believe that this variable is a good proxy for vertical integration of knowledge transfer management. First, the literature on knowledge transfer management shows that, in the public research sector, external technology transfer offices very often take the form of subsidiary companies (Hughes et al., 2016; Sengupta and Ray, 2017; Prokop, 2021), therefore this does not appear to be an unusual arrangement. Second, to further validate our variable, we read the annual reports of the PROs that did *not* outsource knowledge transfer management activities, to check whether there was any mention of outsourcing to external companies other than the subsidiary and associate companies mentioned in the financial statements; we did not find any mentions of other external companies.

Figure 1. Shares of PROs that rely on in-house and outsourced knowledge transfer management



3.2.2. Independent variables

In order to test H1 (*The greater the intrinsic complementarity between research and knowledge transfer, the greater the PRO's likelihood to vertically integrate knowledge transfer management*) we try to measure the extent to which the knowledge transfer process relies on tacit knowledge developed in the course of the underlying research. We argued earlier, in fact, that PROs should vertically integrate intrinsically complementary activities involving tacit knowledge and the consequent development of organisation-specific capabilities (Kogut and Zander, 1996; Martínez-Noya and García-Canal, 2016). Instead, if the knowledge involved in the performance of the activity allows some degree of codification (Mithas and Whitaker, 2007), the process would require a lower degree of organisation-specific knowledge, and production by a specialised supplier in an outsourcing relationship could be a more attractive option.

In the case of research activities, it has been argued that the objectives underpinning

the research have a bearing on the extent of codification of the resulting research outcomes. It has been argued that research that is more basic in nature, that is, research that seeks to understand fundamental phenomena without an immediate concern for specific applications (Stokes, 1997), tends to result in knowledge that is more abstract and universal, based on a commonly accepted language that has relatively constant meaning across context (Autio 1997; Johnson et al. 2002). This knowledge is therefore easier to fully convey in codified form (Cowan et al., 2000). Instead, more applied research, that is, research that seeks to produce knowledge for a specific end-use (Stokes, 1997), tends to produce knowledge that is more context-dependent and therefore more difficult to codify entirely (Johnson et al. 2002). Hence, we expect that a greater share of applied knowledge in the PRO's knowledge base will increase its likelihood to vertically integrate knowledge transfer management activities. Indeed, there is some evidence that academics working in fields where applied research is prevalent, such as engineering, are more actively engaged in knowledge transfer activities than academics working in fields with a greater presence of basic research, such as the natural sciences (Landry et al. 2007). This evidence is aligned with the argument that the greater role of tacit knowledge in fields with a greater component of applied knowledge, requires a more direct involvement of researchers in the knowledge transfer process.

To operationalise the prevalence of applied research in PROs' knowledge production activities, we exploit information about the journals in which the PROs' publish, based on the argument that journals that are more highly cited by published articles tend to focus on more basic research, whereas journals that are less cited tend to focus on more applied research (Lim, 2004). This is because basic scientific breakthroughs provide the foundation upon which more applied research is developed, and therefore

basic research articles are more heavily cited than applied ones. We therefore construct the variable *Share_journals_applied* as the share of journals in which the PRO publishes that are *not* in the top quartile of the ranking of most-cited journals (based on the Science Citation Index produced by Scimago[8]).

In order to test H2 (*The greater the strategic complementarity between research and knowledge transfer, the greater the PRO's likelihood to vertically integrate knowledge transfer management*) we try to capture the extent to which the transfer of knowledge to specific stakeholders is important to the PRO. In fact, we argued that if the PRO fulfills its institutional mission by transferring knowledge to specific stakeholders, the PRO would wish to maintain some degree of control on the knowledge transfer process to ensure that it is primarily directed to the intended recipients. Based on this argument, we would expect that PROs whose knowledge transfer stakeholders have greater influence on its governance (and hence are better able to determine how the PRO should fulfill its mission) will be more likely to vertically integrate knowledge transfer management: through vertical integration, in fact, the PRO can keep under greater control the knowledge transfer opportunities that are pursued, to make sure they are aligned with the objectives of its stakeholders.

To operationalise the influence of the stakeholders that are the main recipients of PRO's knowledge transfer, government and industry, on the PROs' governance, we exploit information about the PRO's governing board and relationship with government. In the case of industry, we capture the presence of industry representatives in the governing board; we expect that industry representatives on the board will be keen to ensure that the PRO's knowledge transfer activities primarily benefit their sector, and will prefer such activities to remain under the control of the

[8] Available at: https://www.scimagojr.com/journalrank.php (accessed June 2022).

PRO through vertical integration. Since few PROs provide information about the professional background of their board members, we consider the presence of disclosure of external interests on the part of board members as a proxy for the members' involvement in commercial ventures. We use a binary variable that takes value 1 if any of the board members have disclosed external interests in the annual reports of the PRO (*External_interests*) and zero otherwise. In the case of government, we measure the influence of government on the PRO's governance based on the accountability of the PRO to ministers. We expect that PROs that are more directly accountable to government ministers will want to ensure that their knowledge transfer activities are aligned with the government's objectives, and will prefer to vertically integrate the management of these activities. As a measure of the PROs' direct accountability to government, we built an ordinal variable, *Government_control*, that takes value 3 if the PRO is an executive agency accountable to a central government department, 2 if the PRO is an executive agency accountable to a devolved administration or another government agency, 1 if the PRO is a NDPB, and zero if the PRO is a public corporation.

Based on these arguments, we expect *External_interests* and *Government_control* to positively influence the likelihood to vertically integrate knowledge transfer management functions.

3.2.3. Control variables

We control for the current age of the PRO (*Age*) and its size measured in terms of number of full time equivalent employees (in thousands) (*Employees*). We expect larger PROs to have more internal competences, and more resources to invest in knowledge transfer management. Additionally, larger PROs might have a larger scale of knowledge transfer operations (since the size of the organisation is positively

related to the level of knowledge transfer; Belenzon and Schankerman, 2009).[9] If PROs perform knowledge transfer activities on a large scale, this activity might be more routinised (Ponomariov, 2008), and it might be more efficient for them to develop the competences to manage the knowledge transfer process internally. So, we would expect a larger scale of knowledge transfer operations to be associated with greater probability to vertically integrate knowledge transfer management activities. [10] We also control for the PRO's main user sectors, to account for the specificities of those sectors that might influence the likelihood of performing knowledge transfer management in-house (for example, clients' concerns about safety and security might make vertical integration more likely). We use several binary variables that aggregate the sectors proposed by Smith (2015): *Health* (includes Human Health and Wellbeing, Disease Control), *Agrifood* (includes Agriculture, Animal Health, Food, Biological Sciences, Plants, Marine Environment and Aquatic Life), *Environment_protection* (includes Climate Change, Environmental Science, Sustainability), *Defense_space* (includes Security and Space and Earth Observation). Each PRO can have more than one main user sector.

The following table presents some basic descriptive statistics for the dependent, independent and control variables mentioned, for each period and aggregated over the six periods. None of the time-varying variables have significantly different means across the six periods. The variables' correlation matrix is reported in Appendix 1.

[9] In the case of universities, size has been found to be positively related to the amount of private research funds (Von Tunzelmann and Kraemer Mbula, 2003), interactions with companies (Bruno and Orsenigo, 2003; Landry et al., 2007) and spinoff creation (O'Shea et al., 2005).

[10] While it might have been appropriate to use the income from private sources as a measure of the scale of the PRO's knowledge transfer operations, we cannot do so because in our dataset the reported private income is endogenous to the choice of governance model for knowledge transfer management. In fact, those PROs that outsource will report some of their knowledge transfer income in the accounts of the subsidiary or associate, and hence their accounts are likely to understate the amount of income they derive from private sources. Hence, we do not include the PRO's amount or share of private income in our models.

Table 3. Descriptive statistics for dependent, independent and control variables

	Time varying	Mean T1 N=33	Mean T2 N=33	Mean T3 N=33	Mean T4 N=33	Mean T5 N=33	Mean T6 N=33	Mean T1-T6 N=198	Std.dev. T1-T6 N=198	Min T1-T6 N=198	Max T1-T6 N=198
In_house	YES	0.58	0.58	0.58	0.61	0.64	0.64	0.60	0.49	0.00	1.00
Government_control	YES	1.33	1.33	1.33	1.33	1.24	1.24	1.30	1.22	0.00	3.00
External_interests	YES	0.39	0.36	0.39	0.42	0.45	0.52	0.42	0.50	0.00	1.00
Share_journals_applied	YES	0.61	0.63	0.60	0.60	0.60	0.57	0.60	0.20	0.08	1.00
Employees	YES	1.27	1.31	1.36	1.30	1.28	1.28	1.30	2.03	1.35	11.18
Age	NO	87.55	87.55	87.55	87.55	87.55	87.55	87.55	89.71	5.00	348.0
Health	NO	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.45	0.00	1.00
Agrifood	NO	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.43	0.00	1.00
Environment_protection	NO	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.41	0.00	1.00
Defense_space	NO	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.39	0.00	1.00

4. Findings

We present the outcomes of a panel logistic regression model on the variable *In_house*, explaining the PRO's likelihood to vertically integrate knowledge transfer management activities on the basis of proxies for the intrinsic and strategic complementarity between research and knowledge transfer management, as well as a range of control variables. The baseline model (a) includes only the control variables. Models (b), (c), and (d) add the three main independent variables proxying for the extent of intrinsic complementarity (*Share_journals_applied*) and strategic complementarity (*Government_control*, *External_interests*).

We use the random effect model because of the nature of our variables, which include some time invariant independent variables (*Government_control*) as well as time-varying independent variables that exhibit limited variability over time (*External_interests*). If predictor variables vary greatly across individuals but have little variation over time for each individual, then fixed effects estimates will be imprecise and have large standard errors (Allison, 2009). With relatively small T there is also a risk of

inconsistent fixed effects estimates. To further check the appropriateness of our random effect model, we also include the hybrid model proposed by Allison (2009) (model (e)). In this approach, each time-varying variable is replaced with the deviation from the individual-specific mean, while also including the individual-specific means of time-varying variables and all the time-invariant variables. According to Allison, this approach produces the same coefficients and standard errors as the fixed effects model for time-varying variables, while allowing for the inclusion of time invariant variables. The model also provides a way to further test the appropriability of the random effect models by checking whether the coefficients of the mean-difference and mean variables are significantly different from each other. If they are not significantly different, then the assumptions of the random effect model (that the individual error is uncorrelated with the time-varying variables) are met. If they are significantly different, then the assumptions of the random effect model do not hold and the fixed effect model would be more appropriate.

Because the variable *Share_journals_applied* is computed using information about publications in the Scopus database, we drop the observations where the number of Scopus publications in a certain year was zero, which reduces the size of the sample to 186 observations (31 PROs).

Table 4. Regressions on the determinants of PROs' integration of knowledge transfer management activities

VARIABLES	(a) In_house	(b) In_house	(c) In_house	(d) In_house	(e) In_house
Government_control				5.592***	5.564***
				(1.428)	(1.750)
External_interests		12.598***	13.436***	6.669*	6.855*
		(3.541)	(3.656)	(3.412)	(3.693)
Share_journals_applied			16.853*	21.094*	
			(8.997)	(12.476)	
Mean_diff_share_journals_applied					11.452
					(15.798)
Mean_share_journals_applied					36.096
					(29.085)
Employees	1.502**	2.168**	0.992	1.162	
	(0.759)	(1.055)	(0.863)	(0.824)	
Mean_diff_employees					-0.811
					(6.801)
Mean_employees					0.964
					(0.871)
Age	-0.039**	-0.090***	-0.118***	-0.099***	-0.121***
	(0.017)	(0.025)	(0.020)	(0.022)	(0.030)
Health	-0.473	0.722	0.111	0.515	-0.577
	(3.255)	(5.056)	(4.760)	(4.657)	(6.437)
Agrifood	-1.421	1.581	-0.914	3.151	2.023
	(2.659)	(4.244)	(3.560)	(4.297)	(4.200)
Environment_protection	4.997+	7.186*	5.570	9.568**	9.423*
	(3.098)	(4.351)	(4.091)	(4.432)	(5.238)
Defense_space	23.002***	14.677***	13.994***	14.428***	12.304**
	(3.606)	(4.289)	(4.430)	(4.190)	(5.336)
T2	-0.045	0.049	-2.042	-2.507	-1.722
	(2.555)	(2.677)	(3.116)	(3.687)	(3.631)
T3	-0.063	0.099	-0.340	-0.358	-0.381
	(2.545)	(2.615)	(3.161)	(3.909)	(3.550)
T4	3.068	3.142	1.604	1.873	1.959
	(2.604)	(2.713)	(3.032)	(3.568)	(3.462)
T5	5.617**	5.931**	5.000+	6.303+	6.126+
	(2.577)	(2.981)	(3.395)	(4.082)	(4.009)
T6	5.634**	5.418*	5.390*	6.916*	6.072+
	(2.571)	(2.835)	(3.201)	(3.899)	(3.719)
Constant	-3.020	-2.529	-6.470	-18.366*	-23.565+
	(3.928)	(6.630)	(7.719)	(10.321)	(16.209)
lnsig2u	5.806***	5.706***	5.708***	5.679***	5.792***
	(0.473)	(0.501)	(0.529)	(0.507)	(0.566)
Observations	186	186	186	186	186
Number of ID	31	31	31	31	31

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1, +p<0.15.

The models are all significant with p<0.001; rho is also significant in all model, confirming that the panel estimator is preferable to a pooled approach. The coefficients and their significance are stable across all models. Finally, the tests on the equality between the mean differences and the means of the time-varying variables cannot reject the null hypothesis of equality of the coefficients, suggesting that the

random effects model is appropriate (Allison, 2009).

The models suggest that stronger government influence on the PRO's governance significantly increases the likelihood of vertically integrating knowledge transfer management activities. Also the presence of board members declaring external interests has a positive and significant effect. Both results are consistent with our hypothesis that the greater strategic complementarity between research and knowledge transfer management increases the likelihood of vertical integration of the latter.

Greater share of applied knowledge in the PRO's knowledge base has a positive and significant effect on the likelihood of vertically integrating knowledge transfer management activities, which is consistent with our expectations. Hence we support our hypothesis that greater intrinsic complementarity between research and knowledge transfer management increases the likelihood of vertical integration.

In terms of control variables, we find that *Age* has a negative and significant effect on the likelihood of performing knowledge transfer management in-house. We might have expected older PROs to be have more internal competences and to be more likely to vertically integrate knowledge transfer management activities, however we find the opposite, that is, that older PROs are less likely to vertically integrate.

Sectoral effects are present, with PROs working with the environment protection and defense and space sectors significantly more likely to vertically integrate knowledge transfer management activities; particularly in the latter case this is probably due to sensitivities around the use of the PRO's knowledge.

Finally, the size of the PRO has a positive effect on the probability to vertically integrate, in line with our expectations, but with a very small coefficient. We explore the role of size further in the next section.

4.1. Robustness checks

To further investigate the effect of the PRO's size, we introduce the quadratic term for the variable *Employees* measuring the size of the PRO, *sqempl* (this regression is shown as model (a1) in Appendix 2). The coefficient of *Employees* becomes negative and significant (p=0.10), and increases in size, while the coefficient of the quadratic term is positive (but very small) and significant. This suggests that size has a positive effect on the likelihood to vertically integrate knowledge transfer management activities but only for larger PROs (approximately above 3,282 employees). Since the variable Employees is quite skewed with a couple of large outliers with more than 5,000 employees, it is possible that the quadratic effect is driven by the outliers. If we remove these outliers from the sample the variable *Employees* and its square are no longer significant (table (b1) in Appendix 2). Hence, there is evidence of a critical mass effect, whereby it makes economic sense to have certain functions internally for PROs that are bigger than a certain size (as larger PROs are better resourced and can acquire the internal competences to deal with knowledge transfer management), but this only holds when two very large PROs are taken into consideration.

In model (c1) in Appendix 2 we consider different proxies for our independent variables. Since the binary variable *External_interests* suffers from low variability, which reduces its explicatory power, we try an alternative measure for the presence of external stakeholders in the PRO's governing body: the number of members of the governing board (*Board_members*). The rationale for using this variable is that in the literature it has been found that larger boards are more diverse from a demographic and cognitive perspective (including occupational diversity) (Carter et al., 2003; Barroso Castro et al., 2009). The results show that *Board_members* has a positive but

not significant effect on the likelihood to vertically integrate.

In the same model we also consider an alternative proxy for the presence of tacit knowledge and therefore intrinsic complementarity. In the case of knowledge transfer, some activities are characterised by a greater degree of knowledge codification than others. The sale or licensing of a piece of intellectual property (IP), like patents or software copyright, will have a greater component of codified knowledge than consulting activities aimed at solving a client's specific problem. Thanks to the codified nature of the IP, it is possible for specialist suppliers to develop capabilities in the sale and licensing of IP that are to a large extent independent of the specific organisation that produced the IP (PraxisUnico, 2016). Conversely, activities like problem solving for clients involve a high degree of tacitness (Asheim and Gertler, 2005). It would be difficult for a specialised supplier to develop all the capabilities needed to manage knowledge transfer processes involving many different PROs and their many different potential clients. Building on these arguments, we can expect vertical integration to be more likely when the PRO engages only in activities with a high tacit knowledge component, like research contracting and consulting, and outsourcing to be more likely when the PRO also engages in activities involving the transfer of codified IP, like patenting. The variable *Nopatents* is a binary variable equal to one when the PRO does not engage in patenting, and zero otherwise (e.g. the PRO engages in patenting). The results show that lack of patents has a positive and significant effect on the probability to vertically integrate, as we expected. This is consistent with findings from studies of university researchers, which show that researchers transfer knowledge much more actively when no patenting is involved (Landry et al., 2007) suggesting that in this situation there is greater intrinsic complementarity between research and knowledge transfer.

Finally, in model (d1) we introduce an alternative size measure, the absolute level of public (core and competitive) funding received by the institution (*Income_public_funding*) and its square. This variable behaves similarly to *Employees*, having a positive and significant effect on the likelihood to vertically integrate knowledge transfer management only above a certain amount.

5. Conclusions

Our evidence suggests that the degrees of intrinsic and strategic complementarity of knowledge transfer capabilities with core research capabilities play a role in the decision whether to outsource or vertically integrate knowledge transfer management. The more intrinsically and strategically complementary knowledge transfer is to research, the more likely knowledge transfer management is to be performed in-house. The extent of intrinsic and strategic complementarity is determined on the basis of the extent to which the bundling of knowledge transfer together with the core activity (that is, research) allows the institution to perform its institutional mission (benefiting its stakeholders) better than unbundling knowledge transfer through contracting with specialised suppliers – either because bundling increases the effectiveness of knowledge transfer (intrinsic complementarity) or allows to direct knowledge transfer to strategic beneficiaries (strategic complementarity).

These findings have theoretical and practical implications. In theoretical terms, we have extended the theory of firm boundaries relating to knowledge processes to the case of public research organisations, which are not primarily driven by the profit motive and whose core activity is research. This conceptual framework could be applied to public research organisations in other national settings. It might also provide useful insights for the understanding of outsourcing choices in relation to

knowledge transfer management for other types of public and private organisations that have research as their core activity, including universities, private research companies, and other companies that have research as their primary activity.

In terms of policy, our findings suggest that governments intending to encourage PROs to improve their knowledge transfer management capabilities should not assume that all PROs should follow the same governance models. Some PROs, namely those that carry out research that has a high tacit knowledge component and those that intend to transfer knowledge to specific stakeholders, should be incentivised to improve their internal capabilities for knowledge transfer management. Other PROs, namely those that perform research whose outputs can be easily codified and those that aim to transfer knowledge to a broad variety of stakeholders, should be encouraged to rely on specialised suppliers, and when those suppliers are not available perhaps some efforts should be invested in their creation, as such suppliers might ensure efficiency gains thanks to their scale and specialisation.

The present paper aims to open up a research agenda into knowledge transfer management within PROs, and, given its limitations, can be considered as a first step leading to further investigations. First, this is a small scale study, and it would be interesting to replicate this study on a larger scale, possibly by means of surveys of PROs of different types and in different countries. Second, the constructs of intrinsic and strategic complementarity are not observable, and in this study they have been proxied using the few variables at our disposal, based on publicly available sources, which could indicate the presence of tacit knowledge and of a strong role for external stakeholders in the governance of the PRO. Data collected directly from PROs by means of surveys, for example, might allow to develop variables that more closely

measure the constructs of intrinsic and strategic complementarity. As a direction for future research, it would also be interesting to explore in greater detail the patterns that we have identified, by complementing this quantitative investigation with qualitative analyses of PROs' approaches to knowledge transfer management. These might include the collection of more detailed information about the different possible ways to organise in-house knowledge transfer management, and the analysis of how PROs' approaches to knowledge transfer management have changed over time, how approaches differ across countries, and what comprehensive strategic choices have led to the adoption of certain models.

Declarations

The authors have no relevant financial or non-financial interests to disclose.

References

Alchian, A.A. & Demsetz, H. (1972). Production, information cost and economic organization. *American Economic Review*, 62(5), 777-795

Allison, P. (2009) *Fixed effects regression models*. Sage, London.

Ambos, T.C., Kristina, M., Birkinshaw, J. & D'Este, P. (2008). When does university research get commercialized? Creating ambidexterity in research institutions. *Journal of Management Studies*, 45(8), 1424-1447.

Amit, R. & Shoemaker, P. J. H. (1993) Specialized assets and organizational rent. *Strategic Management Journal*, 14(1), 33-47.

Ankrah, S.N., Burgess, T.F., Grimshaw, P., & Shaw, N.E. (2013). Asking both university and industry actors about their engagement in knowledge transfer: What single-group studies of motives omit. *Technovation*, 33, 50-65

Arora, A. (1996). Contracting for tacit knowledge: the provision of technical services in technology licensing contracts. *Journal of Development Economics*, 50, 233-256.

Argyres, N. (1996). Evidence on the role of firm capabilities in vertical integration decisions. *Strategic Management Journal*, 17(2), 129-150.

Argyres, N.S, & Zenger, T. (2012). Capabilities, transaction costs, and firm boundaries: An integrative theory. *Organization Science*, 23(6), 1643-1657.

Arnold, E., Barker, K. & Slipersæter, S. (2010). *Research institutes in the ERA*, Technopolis Group, http://ec.europa.eu/research/era/docs/en/research-institutes-in-theera.pdf.

Arza, V. & Lopez, A. (2011). Firms' linkages with public research organizations in Argentina: Drivers, perceptions and behaviours. *Technovation,* 31(8), 384- 400.

Asheim, B.T. & Gertler, M.S. (2005). The geography of innovation: regional innovation systems, In Fagerberg, J. & Mowery, D.C. (Eds.) *The Oxford Handbook of Innovation*.

Autio, E. (1997) New technology-based firms in innovation networks: Symplectic and generative impacts, *Research Policy*, 26(3), 263–81.

Avery, G. (2000). Outsourcing public health laboratory services: A blueprint for determining whether to privatize and how. *Public Administration Review*, 60 (4), 330-337.

Barney, J. B. (1999). How a firm's capabilities affect boundary decisions. *Sloan Management Review,* 40(3), 137-146.

Barney, J. B. (1986). Strategic factor markets: expectations, luck, and business strategy. *Management Science*, 32(10), 1231-1241.

Barroso Castro, C., Dominguez De La Concha, M., Vecino Gravel, J., Villegas Periñan, M.M.. (2009) Does the team leverage the board's decisions? *Corporate Governance: An International Review*, 17(6), 744-761.

Becerra, M., Lunnan, R. & Huemer, L. (2008). Trustworthiness, risk, and the transfer of tacit and explicit knowledge between alliance partners. *Journal of Management Studies*, 45, 691-713.

Belenzon, S. & Schankerman, M. (2009). University knowledge transfer: private ownership, incentives, and local development objectives. *Journal of Law and Economics*, 52(1), 111-144.

BIS (2007). *Third annual survey of knowledge transfer activities in Public Sector Research Establishments and Research Councils*. Department for Business Innovation and Skills. The Stationery Office, London.

BIS (2011). *Sixth annual survey of knowledge transfer activities in Public Sector Research Establishments and Research Councils*. Department for Business Innovation and Skills. The Stationery Office, London.

BIS (2014). *Seventh annual survey of knowledge transfer activities in Public Sector Research Establishments and Research Councils.* Department for Business Innovation and Skills. The Stationery Office, London.

Boden, R., Cox, D., Nedeva, M., & Barker, K. (2004). Scrutinising science: The changing UK government of science. Houndmills, New York: Palgrave-Macmillan.

Bozeman, B. (1994). Evaluating government technology transfer: early impacts of the cooperative technology paradigm. *Policy Studies Journal*, 22 (2), 322-327.

Brandenburger, A. M. & Stuart, H.W. (1996). Value-based business strategy. *Journal of Economic and Management Strategy,* 5(1), 5-24.

Bruno, G. & Orsenigo, L. (2003). Variables influencing industrial funding of academic research in Italy. An empirical analysis. *International Journal of Technology Management ,*26(2/3/4), 277-30.

Cabinet Office (2016) Classification of Public Bodies: guidance For Departments, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/519571/Classification-of-Public_Bodies-Guidance-for-Departments.pdf (accessed June 2022).

Capron, L. & Mitchell, W. (1998). Bilateral resource redeployment and capabilities improvement following horizontal acquisitions. *Industrial and Corporate Change*, 7 (3), 453-484.

Carter, D.A., Simkins, B.J., Simpson, W.G. (2003). Corporate governance, board diversity, and firm value, *Financial Review*, 38(1), 33-53.

Ceccagnoli, M., Graham, S. J. H., Higgins, M. J. & Lee, J. (2010). Productivity and the role of complementary assets in firms' demand for technology innovations. *Industrial and Corporate Change*, 19(3), 839-69

Cervantes, M. & Meissner, D. (2014). Commercialising public research under the open innovation model: new trends. *Foresight and STI Governance*, 8(3), 70-81.

Choi, T.Y. & Hong, Y. (2002). Unveiling the structure of supply networks: Case studies in Honda, Acura, & DaimlerChrysler, *Journal of Operations Management*, 20 (5), 469-493.

Coccia, M. & Rolfo, S. (2002). Technology transfer analysis in the Italian National Research Council. *Technovation,* 22, 291-299.

Conner, K.R. & Prahalad, C.K. (1996). A resource-based theory of the firm: knowledge vs. opportunism. *Organization Science*, 7, 477-501.

Cowan, R., David, P. & Foray, D. (2000) The explicit economics if knowledge codification and tacitness, *Industrial and Corporate Change*, 9, 211–253.

Cruz-Castro, L., Jonkers, K. & Sanz-Menéndez, L. (2015) The internationalisation of research institutes". In Linda Wedlin and Maria Nedeva (eds.). Towards European science. Dynamics and policy of an evolving European Research Space. Cheltenham: Edward Elgar, 175-198.

Cruz-Castro, L., Martínez, C., Peñasco, C. & Sanz-Menéndez, L. (2020) The classification of public research organizations: Taxonomical explorations, *Research Evaluation*, doi: 10.1093/reseval/rvaa013

D'Este, P. & Patel, P. (2007). University-industry linkages in the UK: what are the factors underlying the variety of interactions with industry? *Research Policy*, 36, 1295-1313.

de la Torre, E., Ghorbankhani, M., Rossi, F. & Sagarra, M. (2021) Knowledge transfer profiles of public research organisations: the role of fields of knowledge specialisation, *Science and Public Policy*, https://doi.org/10.1093/scipol/scab061

Demsetz, H. (1988). The theory of the firm revisited. *Journal of Law, Economics and Organization*, 4(1), 141-161.

Dierickx, I. & Cool, K.L. (1989). Asset stock accumulation and sustainability of competitive advantage. *Management Science*, 35(12), 1504-1511.

Dutrénit, G. & Arza, V. (2010, Channels and benefits of interactions between public research organizations and industry: comparing four Latin American countries. *Science and Public Policy,* 37(7), 541-553.

Elinder, M. & Jordahl, H. (2013). Political preferences and public sector outsourcing. *European Journal of Political Economy*, 30, 43-57.

Foss, K. & N. J. Foss (2008). Understanding opportunity discovery and sustainable advantage: The role of transaction costs and property rights. *Strategic Entrepreneurship Journal*, 207(2), 191-207.

Fudickar, R., Hottenrott, H. (2019). Public research and the innovation performance of new technology based firms, *Journal of Technology Transfer*, 44, 326-258.

Gertler, M.S. (2003) Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there), *Journal of Economic Geography*, 3, 75-99.

Ghemawat, P. (2005). Regional strategies for global leadership. *Harvard Business Review*, 83(12), 98-108.

Government Office for Science (2013). Current PSREs affiliated with Government Departments.

Grant, R. M. (1996). Prospering in dynamically-competitive environments: Organizational capability as knowledge integration. *Organization Science*, 7, 375-387.

Grimshaw, D., Vincent, S. & Willmott, H.C. (2002). Going privately: partnership and outsourcing in UK public services. *Public Administration*, 80(3), 475-502.

Hayer, C.S. (2016). A trajectory of early-stage spinoff success: the role of knowledge intermediaries within an entrepreneurial university ecosystem. *Small Business Economics*, 47(3), 633-656.

Hewitt-Dundas, N. (2012). Research intensity and knowledge transfer activity in UK universities. *Research Policy*, 4, 262-275.

Holcomb, T.R. & Hitt, M.A. (2007. Toward a model of strategic outsourcing. *Journal of Operations Management*, 25(2), 464-481.

Huggins, R. & Kitagawa, F. (2012). Regional policy and university knowledge transfer: perspectives from devolved regions in the UK. *Regional Studies*, 46(6), 817-832.

Hughes, A, Lawson, C, Salter, A, Kitson, M, Bullock, A. & Hughes, R. (2016). *The changing state of knowledge exchange: UK academic interactions with external*

organizations 2005-2015, NCUB.

Jacobides, M. G. & Winter, S.G. (2005). The co-evolution of capabilities and transaction costs: Explaining the institutional structure of production. *Strategic Management Journal,* 26(5), 395-413.

Jacobides, M.G. & Winter, S.G. (2012). Capabilities: structure, agency, and evolution. *Organization Science*, 23(5), 1365-138.

James, A. (2009). Organisational change and innovation system dynamics: the reform of the UK government defence research establishments, *Journal of Technology Transfer*, 34, 505–523.

Jensen, P. H. & Stonecash, R.E. (2004). The efficiency of public sector outsourcing contracts: a literature review. *Melbourne Institute Working Paper,*29(04).

Johnson, B., Lorenz, E., & Lundvall, B-Å. (2002) Why all this fuss about codified and tacit knowledge?, *Industrial and Corporate Change*, 11(2), 245–62.

Jones, G.R. & Hill C.W.L. (1988). Transaction cost analysis of strategy-structure choice. *Strategic Management Journal*, 9(2), 159-172.

Kakabadse, A. & Kakabadse, N. (2000). Sourcing: new face to economies of scale and the emergence of new organizational forms. *Knowledge and Process Management, The Journal of Corporate Transformation,* 7(2), 107-118.

Kaufman, A., Merenda, M. & Wood, C.H. (1996). Corporate downsizing and the rise of 'problem-solving suppliers': the case of the Hadco Corporation. *Industrial and Corporate Change,* 5(3), 723-59.

Kistruck, M., Morris, S.S., Webb, J.W. & Stevens, C.E. (2015). The importance of client heterogeneity in predicting make-or-buy decisions. *Journal of Operations Management,* 33/34, 97-110.

Kitagawa, F, Sánchez-Barrioluengo, M. & Uyarra, E. (2016). Third mission as institutional strategies: between isomorphic forces and heterogeneous pathways. *Science and Public Policy*, 43(6), 736–750.

Klein, B., Crawford, R. G. & Alchian, A.A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. *Journal of Law and Economics*, 21, 297-326.

Kogut, B. & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3(3), 383-397.

Kogut, B. & Zander, U. (1996). What firms do? Coordination, identity, and learning, *Organization Science*, 7(5), 502-518.

Kremic, T., Tukel, O. I. & Rom, W. O. (2006). Outsourcing decision support: a survey of benefits, risks, and decision factors. *International Journal of Supply Chain Management,*11(6), 467-482.

Langlois, R. N. (1992). Transaction-cost economics in real time. *Industrial and Corporate Change,*1(1), 99-127.

Landry, R., Amara, N., Cloutier, J.S. & Halilem, N. (2013). Technology transfer organizations: Services and business models. *Technovation*, 33(12), 431-449.

Landry, R., Amara, N. & Ouimet, M. (2007). Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. *Journal of Technology Transfer*, 3(6), 561-592.

Lee, S.M., Hwang, T. & Choi, D. (2012). Open innovation in the public sector of leading countries. *Management Decision*, 50(1), 147-162.

Lim, K. (2004) The relationship between research and innovation in the semiconductor and pharmaceutical industries (1981–1997), *Research Policy*, 33, 287-321.

Lippman, S. A. & Rumelt, R. P. (2003a. A bargaining perspective on resource advantage. *Strategic Management Journal*, 24(11), 1069-1086.

Lockett, A., Wright, M. & Wild, A. (2015). The institutionalization of third stream activities in UK Higher Education: The role of discourse and metrics. *British Journal of Management*, 26, 78-92.

Lyall, C., Bruce, A., Firn, J., Firn, M. & Tait, J. (2004). Assessing end-use relevance of public sector research organizations. *Research Policy*, 33 (1). 73-87.

Mahoney, J. T. & J. R. Pandian, J.R. (1992). The resource-based view within the conversation of strategic management. *Strategic Management Journal*, 13(5), 363-380.

Martin, B.R. (2012). Are universities and university research under threat? Towards an evolutionary model of university speciation. *Cambridge Journal of Economics,* 36(3), 543-565.

Martínez-Noya, A. & García-Canal, E. (2016). The framing of knowledge transfers to shared R&D suppliers and its impact on innovation performance: a regulatory focus perspective. *R&D Management*, 46 (2), 354-368.

Martínez-Noya, A., Garcia-Canal, E. & Guillen, M.F. (2013). R&D outsourcing and the effectiveness of intangible investments: is proprietary core knowledge walking out of the door? *Journal of Management Studies*, 50 (1), 67-91.

Maxwell-Jackson, Q. (2011). *Getting better value from public sector research establishments*. CentreForum.

Mazzoleni, R. & Nelson, R.R. (2007). Public research institutions and economic catch-up. *Research Policy*, 36, 1512-1528.

Mazzucato, M. (2015) Building the entrepreneurial state: A new framework for envisioning and evaluating a mission-oriented public sector, Working Paper, No. 824, Levy Economics Institute of Bard College.

Merino, F. & Rodríguez, D. (2007). Business services outsourcing by manufacturing firms. *Industrial and Corporate Change*, 16(6), 1147-1173.

Milgrom, P. & Roberts, J. (1995). Complementarities and fit: strategy, structure and organizational change in manufacturing. *Journal of Accounting and Economics*, 19(2-3), 179-208.

Mina, A., Bascavusoglu-Moreau, E. & Hughes, A. (2014). Open service innovation and the firm's search for external knowledge. *Research Policy*, 43(5), 853-866.

Mithas, S. & Whitaker, J. (2007). Is the world flat or spiky? Information intensity, skills, and global service disaggregation. *Information Systems Research*, 18(3), 233-365.

Monteverde, K. (1995). Technical dialog as an incentive for vertical integration in the semiconductor industry. *Management Science*, 41, 1624-38.

Mudambi, S. & Tallman, S. (2010). Make, buy or ally? Theoretical perspectives on knowledge process outsourcing through alliances. *Journal of Management Studies*, 47 (2), 1434-56.

Nagarajan, A. & Mitchell, W. (1998). Evolutionary diffusion: internal and external methods used to acquire encompassing, complementary, and incremental technological changes in the lithotripsy industry. *Strategic Management Journal*, 5, 477-96.

Nahapiet, J. & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, 23(2), 262-266.

Narula, R. (2001). Choosing between internal and non-internal R&D activities: Some technological and economic factors. *Technology Analysis & Strategic Management*, 13(3), 365-387.

NCUB (2016). *Knowledge exchange and Research Council Institutes; interactions with external organizations 2012-2015*, National Centre for Universities and Business, October.

Nedeva, M. & Boden, R. (2006). Changing science: The advent of neo-liberalism. *Prometheus*, 24(3), 269–281.

Odagiri, H. (2003). Transaction costs and capabilities as determinants of the R&D boundaries of the firm: a case study of the ten largest pharmaceutical firms in Japan. *Managerial and decision economics*, 24 (2/3), 187-211.

O'Shea, R.P., Allen, T.J., Chevalier, A. & Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities. *Research Policy,* 34, 994-1009.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Brostrom, A., D'Este, P., Fini, R., Geuna, A., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A. & Sobrero, M. (2013). Academic engagement and commercialization: a review of the literature on university-industry relations. *Research Policy*, 42, 423-442.

Perkmann, M. & Walsh, K. (2007). University-industry relationships and open innovation: towards a research agenda. *International Journal of Management Reviews*, 9(4), 259-280.

Ponomariov, B. L. (2008). Effects of university characteristics on scientists' interactions with the private sector: an exploratory assessment, *Journal of Technology Transfer*, 33, 485–503.

Poppo, L. & Zenger, T. (1998). Testing alternative theories of the firm: transaction cost, knowledge-based, and measurement explanations for make-or-buy decisions in information services. *Strategic Management Journal*, 19 (9), 853-877.

PraxisUnico (2016). *Knowledge Exchange and Commercialization: The state of the profession in UK Higher Education*.

Prokop, D. (2021). University entrepreneurial ecosystems and spinoff companies: Configurations, developments and outcomes, *Technovation*,107.

Quinn, J.B. (1999). Strategic outsourcing: leveraging knowledge capabilities. *Sloan Management Review,* 40(4), 9-21.

Quinn, J.B. & Hilmer, F.G. (1994). Strategic outsourcing. *Sloan Management Review*, 35(4), 43-45.

Reed, R. & DeFillippi, R. (1990). Causal ambiguity, barriers to imitation, and sustainable competitive advantage. *Academy of Management Review*, 15(1), 88-102.

Rogers, M., Helmers, C., Baghurst, D. & Pollard, T. (2009). *A literature review on the efficiency and effectiveness of University technology transfer offices and hybrid commercialization models*. Strategic Advisory Board for Intellectual Property, UK.

Rossi, F. (2018). The drivers of efficient knowledge transfer performance: evidence from British universities. *Cambridge Journal of Economics*, 42(3), 729-755.

Rossi, F. & Rosli, A. (2015). Indicators of university-industry knowledge transfer performance and their implications for universities: evidence from the United Kingdom. *Studies in Higher Education*, 40 (10), 1970-1991.

Royal Society (2020) A list of public and non-profit research organisations in the UK. Available at: https://royalsociety.org/-/media/policy/Publications/2020/2020-09-list-of-public-and-non-profit-research-organisations.pdf (accessed June 2022).

Rubenstein, K.D. (2003). Transferring public research: the patent licensing mechanism in agriculture, *Journal of Technology Transfer*, 28(2), 111-130.

Sánchez-Barrioluengo, M., Uyarra, E. & Kitagawa, F. (2019) Understanding the evolution of the entrepreneurial university. The case of English Higher Education institutions, *Higher Education Quarterly*, 73(4), 469–495.

Sanz-Menéndez, L., Cruz-Castro, L., Jonkers, K., Derrick, G. E., Bleda, M., & Martínez, C. (2011) Public Research Organizations. Paris: OECD-IPP Policy Briefs. https://www.researchgate.net/publication/287595871_Policy_Brief_-_public_research_organisations (accessed June 2022).

Senker, J. (2000). Introduction to a special issue on changing organization and structure of European public sector research systems. *Science & Public Policy*, 27(6), 394–396.

Sengupta, A. & Ray, A. (2017). Choice of structure, business model and portfolio: organizational models of knowledge transfer offices in British universities. *British Journal of Management,* 28, 687-710.

Smith, K. (2015). *Research and innovation organizations in the UK: innovation functions and policy issues*. BIS Research Paper n. 226, Department for Business Innovation and Skills. The Stationery Office, London.

Spithoven, A. & Teirlinck, P. (2015). Internal capabilities, network resources and appropriation mechanisms as determinants of R&D outsourcing. *Research Policy*, 44, 711-725.

Stokes, D.E., (1997) Pasteur's Quadrant: basic science and technological innovation. Brookings Institution, Washington, DC.

Tang, P., Wecowska, D., Campos, A. & Hobday, M. (2009). *Managing intellectual property in universities: patents and the protection failure problem*. Report prepared for the Gatsby Charitable Foundation.

Teece, D.J. (1986). Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy*, 15, 285-305.

Teece, D. J., Pisano, G. & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509-533.

Teirlinck, P. & Spithoven, A. (2012) Fostering industry-science cooperation through public funding: differences between universities and public research centres, *Journal of Technology Transfer*, 37, 676–95.

Von Tunzelmann, N. & Kraemer Mbula, E. (2003). Changes in research assessment practices in other countries since 1999. Annex G to the Report by Sir Gareth Roberts, *Review of Research Assessment*.

Vorley, T. & Lawton-Smith, H. (2007). Universities and the knowledge-based economy. *Environment and Planning C: Government and Policy*, 25(6), 775-778.

Williamson, O. E. (1975). *Market and hierarchies: analysis and antitrust implications*. Free Press, New York.

Williamson, O. E. (1985). *The economic institutions of capitalism.* Free Press, New York.

WIPO (2011). Harnessing public research for innovation: the role of intellectual property, Chapter 4 In *World Intellectual Property Report 2011 The changing face of innovation*, 139-182.

Young S. (2005). Outsourcing in the Australian health sector: the interplay of economics and politics. *International Journal of Public Sector Management,* 18(1), 25-36.

Yusuf, S. (2008). Intermediating knowledge exchange between universities and businesses. *Research Policy*, 37, 1167-1174.

Appendix 1. Correlation matrix

	In_house	Government_control	External_interests	Share_journals_applied_	Employees	Age	Health	Agrifood	Environment_protection
Government_control	0.41***	1.00							
External_interests	0.40***	0.44***	1.00						
Share_journals_applied	0.19***	0.31***	0.17**	1.00					
Employees	0.29***	0.19***	0.08	0.10	1.00				
Age	-0.31***	0.05	0.17*	0.28***	-0.25***	1.00			
Health	-0.03	-0.06	-0.11	-0.31***	-0.03	-0.44***	1.00		
Agrifood	-0.09	-0.17**	-0.20***	-0.15**	-0.23***	-0.16***	0.27***	1.00	
Environment_protection	0.05	0.03	-0.15**	-0.11	-0.18**	0.08	-0.36***	-0.14*	1.00
Defense_space	0.26***	0.25***	0.11	0.17**	0.12	0.07	-0.31***	-0.29***	-0.07

Appendix 2. Robustness checks

VARIABLES	(a1) In_house	(b1) In_house	(c1) In_house	(d1) In_house
gov_control3	5.507***	6.548***	4.426***	8.579***
	(1.926)	(1.638)	(1.436)	(1.560)
External_interests	5.921+	6.738*		
	(3.832)	(3.826)		
Share_journals_applied	17.252	20.742+		
	(14.054)	(13.251)		
Board_members			0.141	0.048
			(0.530)	(0.531)
Nopatents			9.895***	9.381***
			(3.271)	(3.184)
Employees	-6.886*	-5.445	-2.939	
	(3.792)	(5.408)	(3.453)	
sqempl	1.049+	0.055	0.620	
	(0.669)	(1.131)	(0.725)	
Income_public_funding				-0.033+
				(0.023)
sqIncome_public_funding				0.00003
				(0.000)
Age	-0.118***	-0.134***	-0.085***	-0.144***
	(0.029)	(0.028)	(0.022)	(0.021)
Health_sector	0.748	-3.070	-4.259	-7.651**
	(4.459)	(3.783)	(3.511)	(3.763)
Agrifood_sector	-6.214*	-2.868	0.740	-6.814*
	(3.567)	(3.864)	(3.347)	(3.608)
Sustainability_sector	6.460	4.314	3.698	4.467
	(4.552)	(4.502)	(3.518)	(4.206)
Security_space_sector	19.367***	19.194***	8.277**	8.707**
	(5.209)	(4.981)	(3.865)	(3.935)
T2	-1.961	-2.147	-0.680	-0.737
	(3.620)	(3.442)	(2.774)	(3.022)
T3	0.181	0.219	0.040	-0.202
	(3.853)	(3.726)	(3.115)	(3.333)
T4	2.186	2.233	5.201+	5.732*
	(3.624)	(3.422)	(3.237)	(3.367)
T5	7.026*	6.795*	5.815*	6.393*
	(4.044)	(3.857)	(3.256)	(3.360)
T6	7.387*	7.408*	5.379*	6.200*
	(3.936)	(3.805)	(3.172)	(3.246)
Constant	-5.255	-7.630	-5.340	-0.181
	(8.952)	(8.768)	(6.393)	(7.242)
lnsig2u	5.890***	5.795***	5.345***	5.869***
	(0.591)	(0.551)	(0.659)	(0.553)
Observations	186	174	198	198
Number of ID	31	29	33	33

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. In italics: p<0.15