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Managerial Challenges of Publicly Funded Principal Investigators

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Abstract: Principal investigators (PI) are at the nexus of university business collaborations through their leadership of funded research grants. In fulfilling their multiple roles, PIs are involved in a range of different activities, from direct scientific supervision of junior scientists, the organisation of new scientific avenues to engaging with industrial partners. With the increased impetus for public research to produce wealth through science commercialisation, research is increasingly orchestrated through programmes which seek to connect research avenues and markets. The role of PIs is of growing importance. The extent of managerial challenges encountered by scientists in the context of their PI role has not been the focus of any empirical studies. This paper examines the managerial challenges experienced by publicly funded PIs. Our study, set in the context of the Irish research system, found three foci of PI managerial challenges – project management, project adaptability and project network management.

Keywords: public funded principal investigators; managerial challenges; boundary spanners; role; responsibilities; third missions

1. Introduction

Triple helix (Etzkowitz and Leydesdorff, 2000; Leydesdorff and Etzkowitz, 1996), third mission (Philpott et al., 2010) or university-industry relationships (Joly and Mangematin, 1996): each expression details how university missions have expanded to incorporate and combine commercial and managerial environments. Such changes have meant that universities have established formal structures to support these activities and to engage with industry communities. Universities have established technology transfer offices and created senior top management organisational positions to reflect the institutional importance they attach to university business collaborations (Cunningham and Harney, 2006). Many universities have gone beyond this and adopted characteristics of the entrepreneurial university (Guerrero and Urbano, 2012; Kirby et al., 2011). In doing so they are adopting an entrepreneurial culture that is underpinned by high quality research and organisational strategies that establish clearer linkages between education and research (Kirby 2005). Such changes, and the increasing demands from industry in the development and exploitation of research, have changed the nature of the academic profession and the daily lives of scientists.

To produce high quality research scientists have to compete for funding and collaborate with industrial partners as well as undertaking and leading research. As described by Latour (1987), academics are not only performing experiments and shaping theories and scientific evidences, they are also articulating research to different audiences including academics, higher education bodies, firms and policy makers. Knorr-Cetina (1982) describes these audiences as the transepistemic arena i.e., simultaneous involvement in the academic profession, national system of innovation, and education. Such activities mean that scientists need a broad range of managerial skills beyond their core research skills to perform effectively in order to realise their scientific mission. As funding and multiple industry partners increase so too do the complexities that individual scientists have to face, which places additional professional and managerial pressures on them. As Clark (1984, p. 112) notes: "Academics are caught up in various matrices, with multiple memberships that shape their work, call upon their loyalties and apportion their authority."

In successfully competing for public funding, scientists take on the role and responsibility of becoming a PI for projects. These funded projects can vary from conducting fundamental to applied research and involve wide participation and industry engagement. For a scientist, becoming a PI is seen as prestigious and a significant milestone in their careers. They are expected to be excellent scientists and to contribute to knowledge creation. While public authorities are organising scientific activities by designing programmes led by agencies

such as the European Commission, National Institute of Health, National Science Foundation, PIs are the knowledge agents who propose and deliver research projects in response to national programme requirements. In addition to producing original research results, PIs must design, coordinate and align research avenues for the scientific community, funding agency priorities and programmes, industry needs and societal preoccupations. The varied activities that PIs must undertake require effective technical, strategic and managerial capabilities. Despite the complexities of the role, PIs receive little if any formal managerial training or development, with the majority learning on the job and adopting the management practices of other PIs (Cunningham et al., 2014). Given such changes in the practice of science and in the nature of the academic profession, it is surprising that virtually no empirical research has been undertaken into the managerial challenges faced by PIs. To begin addressing this gap in the literature, our research examines the managerial challenges faced by PIs of publicly funded research projects. Such a focus of inquiry is important given the critical role these actors have in today's publicly funded research system.

Our contribution lies in identification of three overarching managerial challenges - project management, project adaptability and project network management - confronting publicly funded PIs. We conclude that while more experienced PIs appear adequately equipped to cope with these managerial challenges, if PIs are to fulfil increasingly complex responsibilities in the delivery of public science, then there is a need to supplement their current on-the-job experiential learning with more structured human resource development interventions. We begin our paper by reviewing some of the empirical evidence on PIs. We then present and discuss some definitions and expectations of publicly funded PIs before discussing the managerial nature of the PI role. Following on from this, we describe our methodology and data collection. We conclude with our key findings, discussion and conclusions and recommendations.

2. Literature review

Our review of the literature begins with an overview of existing empirical attention on the subject of PIs and how they undertake their role. We then review some of the more widely cited definitions of publicly funded PIs before highlighting the managerial expectations that are associated with the role.

2.1 *Principal investigators: What we know*

Empirical research studies on PIs have illustrated the wide variety of activities they are involved in. Kidwell (2014) emphasised how PIs are very strategic in selecting their institutions in order to progress their research agenda, while Baglieri and Lorenzoni (2014) noted how some PIs make the deliberate decision to leave a university setting to set up their own firm so that they can enhance their sphere of influence and use it as a mechanism to shape their research agenda and the market opportunity. In terms of strategic behaviours, O'Kane et al., (2013) reported on how PIs utilise proactive and reactive strategic postures with differing levels of funding conformance when designing publicly funded research projects. Similarly, Casati and Genet (2014) found that PIs engage in a variety of practices when undertaking their duties including focusing on scientific discipline, innovating and problem solving, sharing new paradigms and brokering science. This brokering role that highlights the pivotal role PIs play in university-industry interactions is supported by a number of scholars. Kidwell (2013) argued that PIs are knowledge brokers who create value by bridging structural holes and building trust between the lab and industry through four distinct activities - extrapolation, seeking, aligning and anticipating. Furthermore, Mangematin et al., (2014) make the point that PIs are the linchpin of the knowledge transformation through the articulation of research programmes, the shaping of research avenues and the bridging of academia and industry. Despite their increasingly strategic approach and importance, there remains significant confusion around what expectations and requirements should be associated with the position of PI. To gain some clarity on this we next draw on a range of definitions from some highly reputable research organisations.

2.2 *Publicly funded principal investigators: definitions and expectations*

Taking on the role of lead researcher or PI represents an important landmark in the career of a research scientist. As PI, the lead researcher will be expected to moderate their role identity from that of scientific researcher to incorporate the other duties involved in being PI (Jain et al., 2009). Traditionally an agent of research management and science policy, the duties of the PI have typically been confined to forging goals, defining research programmes and planning and implementing the research strategy. More recently, however, in line with the changing research environment and need to coordinate with multiple organisations, including industry, the PI has become increasingly important and a key agent of economic development and innovation policy. There is, however, no universal description or definition for publicly funded PIs. Definitions and descriptions vary among funding agencies and higher educational institutions. For example, many PI role descriptions from key funding agencies in the United States of America clearly highlight the leadership position and scientific

direction responsibilities, while others emphasise the research management and reporting requirements (see Table 1). The European descriptions of PIs are somewhat looser but similar to the USA descriptions in emphasising scientific leadership, as well as the research management and reporting aspects of the role. Table 1 presents an overview of these definitions and their key emphasis.

- Insert Table 1 about here -

Interestingly, descriptions of PIs from Ivy League universities in the USA place the total responsibility at an individual level for all aspects of the publicly funded project. Some descriptions of PIs provide degrees of freedom to allow other scientists to become co-PIs as in Princeton University or individuals from the university community to become PIs such as Brown University (see Table 2). What is striking also about these descriptions is the emphasis on internal management with only one explicitly outlining an external engagement focus. This clearly signals that PIs have managerial responsibilities associated with publicly funded research that coalesces with their scientific project responsibilities. These PI descriptions outline internal management responsibilities focused on financial, day-to-day management, intellectual integrity as well as the scientific leadership. In the cases of Yale and Princeton, PIs are selected by institution rather than self selected by applying for public funding. Table 2 presents an overview of these Ivy League university definitions and their key emphasis.

- Insert Table 2 about here -

What becomes apparent from these descriptions is that PIs are, at a minimum, expected to complete the research project within the funding limits awarded and in accordance with the policies, terms and conditions of the funding agency and their institutions. To become a PI, the core expectation is that the scientist has to have demonstrated research excellence and outlined a research project plan which will deliver original scientific outcomes. In doing this, scientists outline the necessary resources, human, infrastructural and capital resources as well as key milestone deliverables in addition to defined outcomes. Together with the important and formal status of the scientific role, it is evident that there is a strong managerial focus inherent in the expectations of many universities and funding bodies. We next turn our attention to discussing these responsibilities further.

2.3 Principal investigator managerial responsibilities

Despite the increased attention by policy and funding agencies on the role of the PI the literature offers limited consideration of the managerial nature and challenges experienced by PIs. Indeed, a difficult issue for our study was that much the literature relating to research management and leadership in a publicly funded PI context is historic and did not focus on the managerial nature of the role (e.g. Peltz and Andrews, 1976). The deficiency of empirical research into the managerial challenges faced by PIs on these issues is all the more surprising given the rich context it provides for management researchers, not to mention the proximity of the research subjects to these management researchers. There are however a few notable exceptions. Boardman and Ponomarev (2014), for example, in their purposeful sample of research centres established by the US National Science Foundation found that some PIs demonstrated managerial capabilities and some did not, but suggested that managerial capabilities matter with respect to how research gets done effectively. They argue that the link between managerial capabilities and research productivity requires further empirical investigation. Furthermore, Boehm and Hogan (2014) argue that the managerial capabilities of PIs are essential to deal with internal project issues but are even more critical for sustainable inter-organisational relationships such as industry collaborations. Adler et al. (2009) also make an interesting contribution to the literature on research management when identifying six important managerial issues that are encountered when managing research activities which include (i) a lack of focus on research management and unsatisfying prerequisites; (ii) weak identity and low status of the role of the research managers; (iii) few incentives for research management; (iv) lack of leadership development opportunities for researchers; (v) multiple (and sometimes contradictory) expectations and logics from different stakeholders, and (vi) sustained funding.

Nevertheless these contributions do little to advance our understanding of what managerial challenges publicly funded PIs actually encounter in their role and how they address these. The reality for many modern day PIs, as outlined in the definition overview above, is that PI managerial responsibilities now include the overseeing of the day to day management of the project, recruitment, supervision and mentoring of staff, conducting the research, signing off on the project's budgets and financial management, ensuring all deliverables and deadlines are met, and submitting technical documentation and progress reports. PIs are also expected to take on more significant management roles whereby they are expected to design and schedule the research project, coordinate and direct a research team, liaise with stakeholders, act as a primary contact point with the funding agency, and flag and respond to institutional or project issues. All of the funders mentioned in the preceding section determine that the PI has primary fiduciary responsibility and accountability for carrying

out the research within the funding limits awarded and in accordance with the terms and conditions of the award. Funders clearly require PI and institutional compliance to the terms and conditions of grant awards. Other responsibilities enshrined in the PI role by the funders include: leading the project's scientific and technical direction; ensuring compliance with intellectual property requirements of the award; and maintaining proper conduct on the project and appropriate use of funds.

How PIs address these wide ranging managerial challenges has not been the subject of much empirical investigation in the research management literature. They do however resonate with the more classical management literature. Similar to that which Drucker (1974) and Fayol (1950) outlined as the core functions of management, for instance, these PI activities essentially involve the planning, leading, organising and controlling that are required to achieve set goals. The managerial work of PIs also include interpersonal, informational and decisional roles (Mintzberg, 1971). However, as Chapman (2001) suggests, the responsibility and scrutiny that educational managers such as PIs face has intensified with managerial positions and responsibilities now less static, more open-ended and entail greater expectations for organisational arrangements that will integrate people, opportunities and resources. Finally, within the management literature it is reported that managerial challenges have broadly concentrated on three areas. First, at a more macro level, the managerial challenges are focused on issues that impact all firms and their management teams. For example, Barkema et al. (2002) noted that globalisation is the significant managerial challenge facing firms as it is changing competitive forces and is challenging the way firms do business. The second area of focus is on studies that deal with managerial challenges in respect to specific organisational level issues within a firm such as human resources, innovation, product development etc. An example of this is provided by Ballou et al. (2000) who suggest that new managerial challenges for supply chains are based on metrics, information sharing and benefit allocations. The third area of focus for managerial challenges is how firms engage and interact with external networks. In particular how firms engage with supplier and buyer networks in a networked era has become a particular focus in industrial management. As argued by Moller and Halinene (1999, p.416): "No firm can afford to be a self-contained "island" anymore; learning through relationships is crucial for the battle over the future". Interestingly, these broad managerial challenge areas in some ways reflect how publicly funded project PIs have to now deal with three layers of control mechanisms, the public funding agency, their own institution and aligning the requirements of industry partners and other internal and external stakeholders engaged in the research. We next turn our attention to the study's research design.

3. Research design

To examine the managerial challenges of PIs, we focus on Ireland's publicly funded science, engineering and technology research environment. Interviewing thirty PIs leading recently completed and on-going publicly funded research projects we studied their managerial actions and practices. Studies that attempt to uncover the nature of persons' experiences with a social phenomenon are more suited to qualitative types of research (Strauss and Corbin, 1998). Furthermore, using such a qualitative approach is consistent with previous research studies that have examined boundary-spanning actors (Adler et al., 2009; Ashill et al., 2001; Druskat and Wheeler, 2003; Lehtonen and Martinsuo, 2008; Suchitra and Sankaran, 2007).

3.1 Data collection

There were two key phases in data collection. The first involved compiling a dataset of publicly funded research projects and PIs in Ireland's science, engineering and technology sector between 2006 and 2011. A total of 1,096 individual PIs were identified across the selected national and EU research funding programmes. This phase also involved identifying thirty PIs within this sample for closer examination. Our primary selection criteria were that only multi-annual and collaborative research projects with a funding value over €250,000 were considered. To gather a sufficiently holistic view of PI managerial challenges our final sample of thirty PIs were purposefully cross-disciplined, -gendered, -aged, and at different levels in their career. Our final sample of PIs included eleven professors, four research directors, four senior researchers, nine research leaders, one lecturer and one research officer. There were twenty-five males and five females; twenty were based in universities, five in institutes of technologies, and five in state research centres. In terms of the projects, sixteen were national and fourteen international; seventeen were completed and thirteen were on-going; and, the exact subject areas varied within the broader areas of natural and agricultural sciences, and engineering and technology. Table 3 categorises the PIs included in the sample.

- Insert Table 3 about here -

The second phase of data collection involved face-to-face semi-structured interviews with each PI. Semi-structured interviews were an appropriate instrument due to the depth of inquiry they can generate (Bell, 1987

Yin, 2004). Interview discussions focussed on three broad areas namely, research management and administrative duties 1) during project formation, 2) during project execution and (where applicable) 3) during research dissemination. The interviews conducted averaged 90 minutes in duration. We also examined documentation relevant to both the CV of the PI and the project in question (e.g., press releases, interim reports, final reports and workshop brochures, publication listings, patent listings, etc.) and this secondary data complemented our data analysis. Thirty interviews, amounting to just over 400 pages in transcripts was deemed an appropriate method, and indeed repetition in the final few interviews suggested a saturation point had been reached. To safeguard confidentiality, all respondents were allocated a unique identifier based on their position/status and the nature of the research they were involved in. For example “P1.T” referred to professor one who was involved in research exploitation (P2.E referred to professor two who was involved in explorative research).

3.2 Data analysis

All transcripts were stored using the Nvivo qualitative software program. From here our analysis utilised a number of levels of coding and integration (Strauss and Corbin, 1998). Specifically, interview transcripts were first coded for evidence of research management and administration duties, the core topic area of each interview. A second round of coding (axial coding) identified those management and administration duties that were considered challenging by the PIs (‘PI managerial challenges’). A third stage of selective coding was then used to compare and contrast the type of challenges uncovered and why they were regarded as challenging (e.g. PI skillset deficiency, unforeseen project occurrence, troublesome team members etc.). This final stage of coding involved members of the research team iteratively coding and discussing the ‘PI managerial challenges’ category over the course of a day until agreement was reached on key data patterns. Secondary material was also consulted during this stage of the analysis. This process resulted in the data being reduced into three grouping categories (or managerial challenges), with a number of task commonalities emerging within each:

- (i) Project Management challenge – This sub-group detailed tasks specifically related to the management of human resource during the project’s implementation.
- (ii) Project Adaptability challenge – This sub-group detailed how PIs managed the project’s direction and looked to keep its focus relevant.
- (iii) Network Management challenge – This sub-group detailed tasks relating to the management of the projects internal and external stakeholder network.

In its entirety this process unearthed a holistic understanding of the relationship between the higher-level organising categories – research management and administration – and the PI managerial challenges identified at a micro-level. We next present some illustrative findings and discuss their implications.

4. Findings

From our analysis we identified three main categories of managerial challenges that PIs experienced – project management, project adaptability, and project network management. Figure 1 presents an overview of these category and sub-category tasks together with details of what respondents they specifically related to.

-Insert Figure 1 about here-

4.1 Project management

The first managerial challenge we uncovered had a clear focus on operational-type tasks. In all six tasks were uncovered for PIs within this project managerial challenge. Details on each of these are now presented.

Talent recruitment and management: Assembling and managing the research team for a project was highlighted as a most significant management task by the majority of the PIs in our study. The recruitment of researchers to work on projects represented an area of significant concern and complexity for PIs. One PI commented: “you need to choose your people carefully, so you need be very focused and careful at the recruitment stage. If you get the wrong post-doctoral researcher usually they are on a contract and it is difficult to get them out of it.” For the majority of PIs in our study recruiting the right research team with respect to skills, flexibility and fit can be problematic both in terms of successful selection of project recruits but also administratively in terms of compliance with institutional recruitment policies. A number of the PIs noted that institutional arrangements regarding staff recruitment often added unnecessary complications and distractions to the recruitment process, resulting in project delays. In this respect the ability of the PI to organise so as to efficiently process the necessary project recruitments in compliance with institutional arrangements was endorsed.

Once the optimal research team is assembled the task of ensuring a productive work environment for research teams and groups is highlighted as necessary to ensure that “a harmonious work atmosphere is maintained”. From a PI managerial perspective this includes, as one PI suggested: “being a good listener and getting people involved and letting them air their views is crucial.” Other PIs outlined the need to use informal occasions during project meetings to build social capital with teams as well as proactively dealing with any potential team conflicts before it impacts on the team morale and work atmosphere.

Supervision: How to effectively supervise funded projects and teams was an ongoing managerial challenge for all of the PIs in our study. Supervision had a duality of focus - ensuring scientific rigour and quality in the research carried out and of monitoring project partner delivery. We found that all PIs were actively involved in the supervision of their projects. Depending on the scientific domain, some PIs were involved in day-to-day supervision to, as one PI put it: “verify the quality of the data produced by the investigators in the labs”. Other PIs described they were not as hands on in the day-to-day but they would track results and ensure rigour and integrity of results from experiments. All PIs in our study highlighted the managerial challenge of balancing the day-to-day supervision with overall project supervision of partners to ensure they were adhering to the funder’s guidelines, work programme and the terms and conditions regarding time spent on the project so that there was: “some sort of proof of work”. In this respect, PIs are dependent on co-PIs and their institutions to ensure funder compliance.

Maintaining project focus and alignment: All of the PIs studied identified that maintaining the overall project focus and implementation of project objectives a feature of these management challenges. Balancing the collective versus individual partner objectives was an ongoing managerial challenge. Many PIs in our study spoke about the danger of project partners going off doing their own thing as one PI noted: “Given half a chance research groups will do their own thing in silos so that had to be watched out for.” The challenge of maintaining compliance to project objectives was highlighted as particularly important in projects with industry partners, as explained by one PI “if you have an industrial partner that is involved in the direction of the project the research goals can change easily. Six months in they might say that they want something else and they might want you to change.” The same PI noted that these tensions are exacerbated in projects where such changes can impact significantly on the work programmes of doctoral students assigned to these projects.

Balancing these competing and sometimes conflicting needs was difficult. In dealing with this managerial challenge, some PIs stated the need for them to take a stronger leadership position at the start of the project and to spend time building up relationships with different stakeholders internal and external to the project. This meant PIs accumulated social capital that they could use during the project to support their efforts in maintaining project focus. Others described how they spent time and effort consistently communicating overall project objectives through formal and informal means. As stated by one PI, the need to maintain a project focus means: “when you are leading a group everyone has to have a clear vision and everyone has to know where they fit in. They have to understand the strategy and how what we are doing is relevant.”

Managing across disciplines: With an increasing trend of funding bodies requiring cross-disciplinary teams to undertake public research this challenges PIs to use approaches that enable different disciplines to engage effectively for the purposes of project delivery. As multidisciplinary in projects was not a pre-requisite for inclusion in the research, a significant number of projects were relatively narrow in terms of their composite disciplines. However, a number of the projects, particularly the larger scale EU funded projects did require effective integration of disciplines and this was identified as an issue for PIs on these projects. There are two aspects to this managerial challenge. One is finding the common project and language and second using PI role to enable cross disciplinary interaction to occur effectively for the funded project. The PI’s role in managing this challenge is best described by an experienced PI who explained: “They very often won’t talk to each other; they will just work in their own particular tracks and mind their own business and affairs. So I have to try and bring it all together.”

Managing cultural diversity: With funding agencies and host institutions putting in place different layers of project reporting and control systems, managing a funded project over multiple institutions across different countries adds to the complexities and managerial challenges for PIs. While the sample included only fourteen international projects it was observed that cultural diversity challenges tend to be a more significant issue in the projects with significant numbers of partners. It was observed that smaller projects tended to involve partners with prior experience working together and therefore diversity has most likely been overcome through familiarity. The managerial challenge with managing cultural diversity is best described by one PI who observed that: “in some cultural institutions a deadline is just an approximate target. So I had to get across to them that if they do not submit their documentation then everything in project grounds to a halt, everyone would be waiting from them to submit that form and no one will get paid until they did.” Some PIs in our study

commented that they give different nationalities ‘room to manoeuvre’ as a way of dealing with this cultural diversity as well as understanding partners cultural and institutional perspectives and differences

Performance management: Within any team or project environment it is inevitable that there will be partners and individuals who will not meet their objectives. Our findings indicate that this can cause difficulties in the effective implementation of research projects and represents an ongoing managerial challenge for PIs. In dealing with under-performance we found that PIs took different approaches. Some used public forum meetings to ‘expose’ under-performers, others took a more personal one-to-one approach to understanding the difficulty while another PI elicited the support of other project partners to outline a potential exit from the project. Several PIs observed the importance of stimulating and maintaining goodwill within the project. Another common practice, identified by one PI as the “safe option” was to bring the team back to what was originally agreed. Related to managing performance is maintaining project engagement from all partners. It was observed that this is particularly difficult with industry partners, as explained by one PI: “Keeping industry engaged and interested can be quite tricky...there is nothing tangible happening for them in the next few months and they often get dragged away to other projects or internal activities that can deliver more immediately”.

4.2 Project adaptability

As well as dealing with the project management orientated challenges we found that PIs were also focused on challenges related to maintaining project relevance. Specifically, project adaptability consisted of two PI tasks; environment scanning and maintaining project agility. In dealing with this management challenge we found that PIs took different approaches. Experienced PIs were more likely to engage in environmental scanning and to purposefully develop flexibility within projects, while less experienced PIs tended to be more concerned with completing the project as per the details of their research proposals.

Environmental scanning: All PIs in our study had a clear appreciation of the need for their research projects to be relevant to the market place, societal issues or challenges as articulated by funding agencies. Consequentially, PIs were challenged to scan the environment for strong and weak signs that would support the relevance of their research from a scientific and market perspective. Some of our PIs invested resources and time as part of their project developing an in-depth understanding of the external environment from a demand and supply side. In certain cases PIs factored in work packages that enabled them to undertake this external environmental analysis. Such analysis unearthed potential new industrial partners, identified key disruptive technologies and firms as well as new business models. Moreover some of the monitoring was undertaken through systematic means such as scanning the literature, picking up market intelligence through other projects and having research team members at key international meetings so as to “pick up and track things.”

Maintaining project agility: PIs must undertake science and market shaping as their projects evolve. Together with environmental scanning this required engaging with funders and industrial partners. Some of the PIs noted that the focus of funding agencies shifted more to economic and social outputs during the project, with scientific excellence being a given output at all times. Such external changes meant that some PIs had to adapt their projects to these new circumstances. As one PI explained: “state of the art moved on an awful lot in relation to the class of material we were looking at so we had to adapt. We looked to see how do we make or keep our project relevant. We actually developed a different set of materials that we envisaged at the start of the project.” However, a major source of frustration for a number of PIs was the failure of the funding programmes to adapt to changing project contexts, with one PI observing how the funder of their project “can for the most part operate in ignorant bliss of any key shift in the climate”. In such instances PIs are expected to meet the agreed deliverables, regardless of their currency following the shift in the research context. Again, to ensure project relevance was maintained a number of PIs incorporated processes within their project structures that facilitated flexibility in research agreements with funders whereby the project situation could be reviewed at set points. For example, one PI set out specific review tasks in their project proposal from which the project team could make changes to the project plan.

4.3 Project network management

The final management challenge detailed how PIs had to interact with key parties in both their internal and external project networks.

Internal network management: A significant number of the PIs had developed a relatively negative view of project stakeholders that were based in their own institution. In particular, PIs expressed concern with the level of bureaucratic demands placed on them by internal stakeholders. Commenting on excessive bureaucracy one PI explained: “this is supposed to be a research organisation – you would think that scientists would be driving the organisation – instead it is driven by administrators”. Another noted that the main hindrances to their work

were “the failures of others that draw on you – I mean you are as much a part of the university as they are but they act like you are the opposition – I have to remind some people that we are all on the same team”. Such scenarios require the PI to steer the project through internal stakeholder demands. An experienced PI observed that this is done in one of two ways: “I can work patiently with the different offices in the university and do what they want me to do or I can shout and force my own way – regardless, I use up a lot of time and energy”. Another PI who was generally satisfied with the level of support offered to him from his university noted that a PI requires “a level of support that is not too interventionist... a feeling of support and knowing where the boundaries lie”.

A key internal stakeholder identified by a number of the PIs was their institution’s technology transfer office and different approaches to working with these units were identified. The importance of PI and inventor engagement to technology transfer success has been raised previously in the literature (Thursby and Thursby 2004). Our findings indicate that the quality of the relationship between the PI and the technology transfer office was observed to be somewhat dependent on the PI’s disposition to engaging in technology transfer. Senior PIs leading larger research programmes tended towards having structured relationships with their technology transfer offices. However several of the PIs who were relatively early in their PI career tended to have concerns that intellectual property issues were more likely to hinder their career progression by reducing their publishing opportunities. Other PIs observed difficulties and some frustration with their technology transfer office when developing consortia agreements with industry partners. Where this occurred they found themselves acting as a broker between their own university’s technology transfer office and the industry partner.

External network management: A range of external network stakeholders were identified including industry, regulatory bodies, research funders, and government. A number of the projects in the study involved industry partners. In the main, PIs had positive relationships with their enterprise partners, although some noted that maintaining the enterprise commitment to a project over several years could be very difficult. In these cases, the PI strategy was to incorporate a certain amount of caution in the project design phase in terms of how reliant the research project will be on the enterprise partner. After this stage it was the task of the PI to motivate and stimulate the continued commitment of the enterprise partners, as there was little scope for mandating compliance. Several PIs identified that their role as PI sometimes required them to negotiate with the enterprise on behalf of the scientific research partners and their institution.

PIs working in public research centres, particularly those centres with designated sectoral missions, found themselves having to manage the politics of their interactions with industry and regulatory bodies in their sector. One PI who had presented results of his research found an important regulatory body registering their concerns with the management of the research centre with the PI observing: “our research findings caused quite a stir and a lot of heat was put on us – regulatory bodies do not like to be caught cold and in future I will move with more caution”. In the main, research funders were identified as relatively hands-off, although some PIs noted a preference for greater engagement from the funders with their funded projects. The availability of administrative support staff was identified by a number of PIs as essential in managing internal and external stakeholder requirements. Such staff tended to be available to projects located in larger research centres and institutes, and particularly for senior PIs leading larger research programmes. One such PI observed: “I don’t find myself being more of a manager... we have a good management team and it frees me up to follow the science in great detail”. In this context it is perhaps not surprising that these PIs tended to have a more positive disposition towards their institutions with several noting that their institution had been very supportive towards their work.

5. Discussion

Our findings highlighted three key managerial challenges that PIs face in leading publicly funded research. The managerial challenges of a PI are akin to that of a manager’s in other organisational contexts around the core functions of management; planning, leading, organising and controlling. The significant managerial challenges that PIs faced in our study are focused around organising and controlling. The majority of PIs studied experienced managerial challenges of assembling and managing the research team, project supervision and project alignment. PIs have to ensure that they have the best research team fulfilling the publicly funded project objectives. Having control over the project is important for PIs, as they have to ensure that the project is executed in line with the project plan and, from a fiduciary perspective, they are fulfilling their obligations under the terms and conditions of the project. Managing project focus was also found to be challenging for the majority of PIs studied. This required careful organisation of work plans between different partners and controlling the overall project in order to realise the project goals. In doing so the leadership function of management was critical in order to provide the overall vision so all partners knew what they have to deliver in

the context of the whole project. The managerial challenges that PIs experienced in our study reflect the operational and day-to-day realities that scientists face in taking on the PI roles and responsibilities.

In terms of project adaptability what was interesting to find was that the PIs studied were proactively seeking ways to exploit their projects. The managerial challenge for PIs is how to do this effectively. The majority of PIs in our study embraced planning, a core function of management. We found mixed approaches of how PIs dealt with this challenge. Some PIs formally invested in environmental scanning through the funded projects, whereas others were more ad-hoc about their approach. Moreover, ensuring project agility was important for PIs to ensure that their project was relevant to science and the market. Some of the PIs were innovative in terms of how they dealt with this managerial problem. What our findings highlight is the challenging nature of university business collaboration from a PI perspective. PIs have to balance scientific and market relevance and, in achieving this, they must maintain as much project flexibility as they can within the confines of the stated project goals and outcomes.

Project network management relates to challenges PIs have to deal with when working in their own institutions and also highlighted the range of external stakeholders that PIs engage with for publicly funded projects. From an internal network management perspective, most of the PIs had negative views based on the level of bureaucracy that they experienced in their own institutions. To negotiate their way through such bureaucracy required PIs to have built up significant levels of institutional social capital. When it comes to dealing with technology transfer, an important aspect of university business collaboration, the PIs approached this challenge in different ways. Some have a more structured approach, relying on the control and organising functions of management, whereas other PIs experienced difficulties in developing consortia that required institutional support. In dealing with external network the overall disposition of PIs is the need to have a range of external stakeholders to assemble project teams and for project execution. However, PIs are cautious in terms of the type of commitments they seek from these external stakeholders. We found that the significant managerial challenge here is how PIs can exert influence rather than control. The managerial function of organising is critical for PIs in dealing effectively with external network management.

We found that more experienced PIs, particularly those in senior research leadership posts and leading extensive research programmes, were able to cope more effectively with the managerial challenges than less experienced PIs. Several factors appear to facilitate this. First, these more senior PIs tend to be leading larger research programmes and as an outcome of this have administrators and project managers in place to support them. In some cases these teams have been built up over many years with trust and experience significantly embedded in their operation. Second, the PIs have greater experience and are able to draw upon it when faced with particular situations. And third, these PIs have both a community and institutional standing and reputation and have built up significant social capital both within their research networks, with research funders and, critically, within their own institution where they are better able to design the operations of their relationships with constituents such as the research offices and the technology transfer offices. We suggest that this area warrants closer empirical consideration and investigation.

6. Conclusions

Before discussing our main conclusions our study is not without limitations. A key limitation is that this study was conducted in the Irish research system and would benefit from being internationalised further, particularly as the Irish system is a relatively young research system in comparison to other European countries and is bound further by particular small state conditions (size of national research community, level of funding, scale of industrial research, etc.). A further limitation is that the interviews were centred on PI managerial experiences using the context of an identified publicly funded project as a proxy for their experience managing publicly funded research. It would be interesting to expand the analysis to examine PI management of their overall programme of research, including research funded from non-public sources to identify whether their managerial behaviours change across different types of projects and other research related activities.

There are a number of conclusions that can be drawn from our study. First, there is clear evidence that PIs are heavily involved in operational management of their project and active in project compliance with respect to funding awards. We found some evidence of different approaches being used by PIs to deliver publicly funded projects. Our study builds on the brokering of science as posited by Casati and Genet (2014) and highlights that PIs are undertaking project brokering with other partners in a more intensive manner. The managerial challenges we found relate to the maintenance of a balance between change and stability as posited by Mintzberg (1971). We found some evidence that more established and experienced PIs were able to achieve research team stability while maintaining some degrees of flexibility. Moreover, our findings suggest that the project management managerial challenges are focused on providing the stability that is required for the successful execution of projects. Project adaptability is focused on the dynamic managerial nature of the PI role, akin to role modification. Jain et al. (2009), for instance, found that scientists engage in role modification when

they engage in research commercialisation. This involves the scientist adopting a hybrid role identity that comprises a focal academic self and a secondary commercial persona. Our research suggests that some PIs may also develop a similar hybrid role identity that coordinates their scientific and managerial responsibilities. The research suggests that researchers might preserve their academic identity and their management identity by organising their priority commitments in a salience hierarchy. However, this research falls short of identifying specifically how researchers develop this hybrid role and there is a need for additional research to address this.

Second, our study finds commonality with Adler et al.'s (2009) study of research managers, in that while the managerial role has a low status among PIs, it remains an intensive part of their engagement with research. PIs are involved many of the managerial roles that Mintzberg (1971) described. Our study highlights that multiple and contradictory demands and expectations extend to PIs particularly in dealing the project focus, cross-cultural, cross-disciplinary and under-performance. Moreover, our study reinforces and extends, at a micro level, the study of Boardman and Ponomarev (2014) that managerial capabilities do matter in terms of how research gets done effectively. As initially suggested by Boehm and Hogan (2014), our study also highlights that PIs do recognise interorganisational relationships and this manifests itself into cross-cultural, cross-discipline and under-performance managerial challenges. We suggest that PIs need to consider their managerial profile in the context of the managerial challenges they face and the impact of these challenges on their research performance.

Third, our study illustrates the managerial challenges faced by PIs and indicates that they use a variety of approaches and strategies to deal with them. All the PIs in our study acknowledged the role endows a certain prestige on them and their institution as suggested by Colyvas and Powell (2006) and Rausser (1999), however the role involves greater managerial responsibilities than they had anticipated or estimated. Our study highlights that managerial skills of PIs are learned on the fly, as Kreeger (1997) suggests, and that the narrow technical training that PIs received in the formation of their careers is insufficient to deal with the managerial challenges that they face in their role as a PI.

Fourth and finally, our study highlights the totality of the managerial burden and extent of the managerial work that PIs have to deal with in the role. It is more extensive and has a compliance focus. Given these managerial challenges, it is not surprising that more PI are exiting universities to set up through spin-out (Baglieri and Lorenzoni, 2014), given the managerial experiences they will have attained are transferable to such a context.

7. Implications and future research avenues

Our research raises the potential for changes in the organisation of research management in public science. If PIs are to continue to undertake core function of management in fulfilling their PI responsibilities in the delivery of public science, then there is a need to supplement the current on-the-job experiential learning PIs undertake with a more structured human resource development intervention. Some funding agencies are beginning to address this requirement, however the focus in many of these interventions to date is on commercialisation and technology transfer competency development, rather than the overall managerial context requirements. An alternative approach may be to provide PIs with effective project managers in order that the PIs can focus on the scientific objectives of their research programmes. While this will possibly increase research project costs, these may be overcome with improved project outcomes. However, in this regard, some interesting observations were suggested from a study of scientific leadership by Sapienza (2005). Her study of the experiences of 200 scientists working under good and bad management found that a key attribute of the effective leader is that the person is 'technically accomplished to lead a scientific effort.' She also confirmed however that scientists are not trained to manage and perhaps more worryingly that academic training is more likely to produce solo contributors.

We recommend that PIs consider and reflect on their own managerial challenges and approaches. Like any manager, a real understanding of self, strengths and weaknesses will contribute to PI effectiveness in delivering public science programmes. While learning on the fly, as Kreeger (1997) notes, has its advantages we would suggest that PIs need more sustained and tailored professional development support to develop their managerial skills. We suggest that as well as developing the technical skills of doctoral and post-doctoral students, academic institutions should put in place specific career development programmes that support their managerial skills development. High performance PIs need to have customised professional development supports not generic ones. Public funding agencies need to give greater recognition, in the evaluation of projects, to the managerial skills and experience as well as scientific excellence to ensure that the most talented and experienced PIs are committed to applying and utilising publicly funding to advance scientific discovery. Further empirical research needs to be undertaken to extend our study and to explore the extent of managerial work undertaken by PIs. In addition, while our study has focused on publicly funded PIs, some empirical focus should be given to other forms of funding of PIs such as industry sponsored research, philanthropy etc. Our

concern from the findings of this study would be that a failure to address the development of managerial skills of PIs means sub-optimal impacts and outcomes for public science and, over the long-term, the potential to undermine the ‘ethos of science’ (Merton, 1968).

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Figure 1 Principal investigator managerial challenges

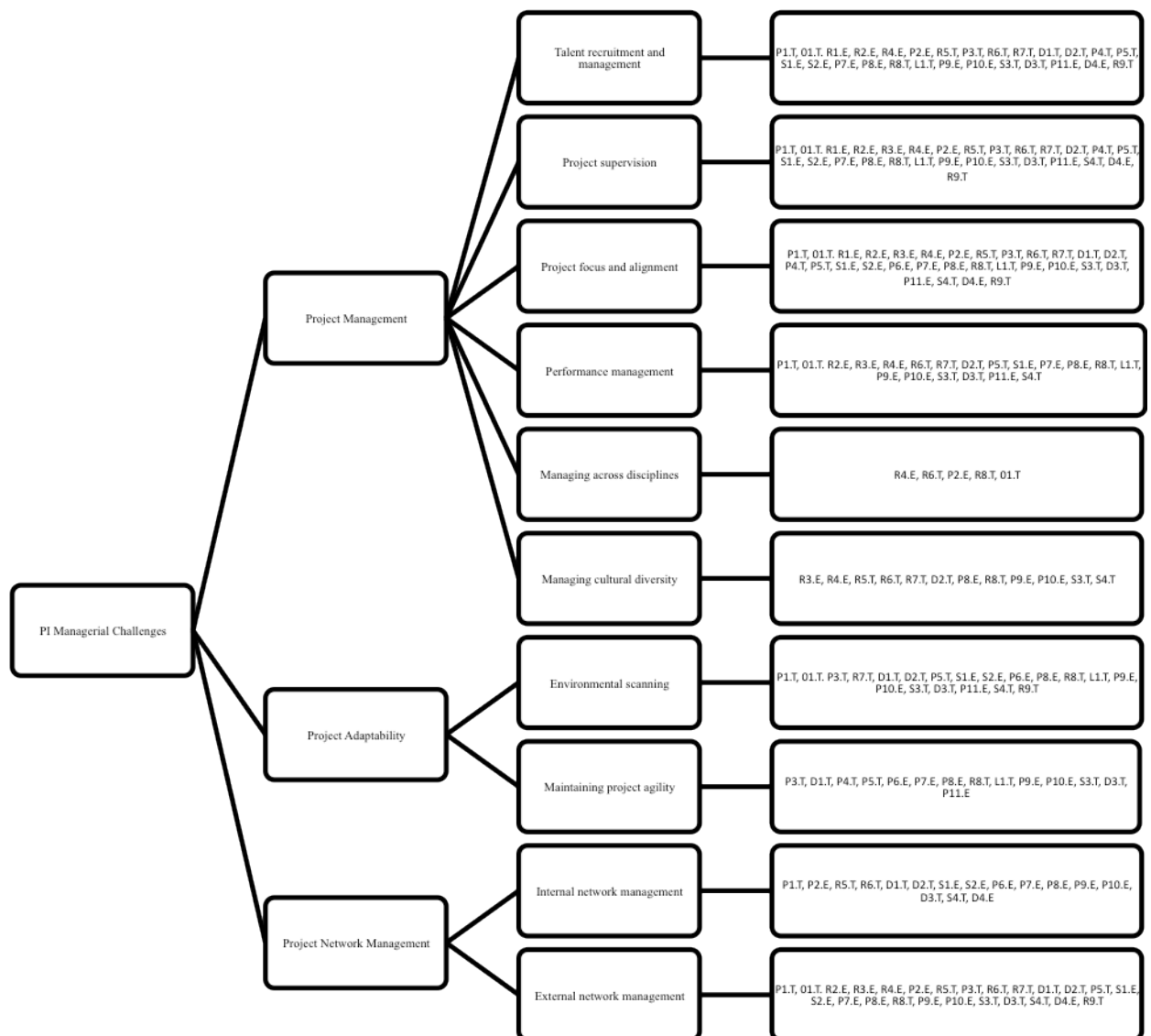


Table 1 Sample funding agencies descriptions

Funding agency	Key elements of PI description	Description emphasis
National Science Foundation (NSF)¹ - USA	<ul style="list-style-type: none"> • Individual designated by the grantee, and approved by NSF. • Responsible for the scientific or technical direction of the project. 	Organisational support with the necessary scientific, research management and leadership
National Institute of Health (NIH)² -USA	<ul style="list-style-type: none"> • Judged by the applicant organisation to have the appropriate level of authority and responsibility to direct the project or program supported by the grant. 	Organisational support and the necessary scientific, research management and leadership
National Aeronautics & Space Administration (NASA)³ -USA	<ul style="list-style-type: none"> • A research organization designates as having an appropriate level of authority and responsibility for the proper conduct of the research, • Appropriate use of funds and administrative requirements such as the submission of scientific progress reports to the agency. 	Organisational support and the necessary scientific, research management and leadership. Particular emphasis on the research management and reporting
European Research Council (ERC)⁴ – European	<ul style="list-style-type: none"> • The individual that may assemble a team to carry out the project under his/her scientific guidance. 	Loose definition lead by an individual that can lead a team with scientific credentials
European Medicines Agency (EMA)⁵ European	<ul style="list-style-type: none"> • The individual with responsibility for the coordination of investigators at different centres participating in a multicentre trial, • Or the leading investigator of a monocentre trial, • Or the coordinating (principal) investigator signing the clinical study report. 	Loose definition focusing on the co-ordination across different organizations. No explicit focus on scientific or managerial leadership.
Economic and Social Research Council (ESRC)⁶ European -UK	<ul style="list-style-type: none"> • Individual who takes responsibility for the intellectual leadership of the research project and for the overall management of the research. • He/She will be the Council's main contact for the proposal. • The nature of the role includes making a significant contribution to the design, project management, scientific leadership, impact activities, and overall supervision of staff conduct/responsibilities. 	Focus on intellectual leadership, key contact point and all aspects of research project management
Science Foundation Ireland (SFI)⁷ European- Ireland	<ul style="list-style-type: none"> • The lead applicant responsible for the scientific and technical direction of the research programme and the submission of reports to SFI. • Primary contact point and have primary fiduciary responsibility and accountability for carrying out the research within the funding limits awarded and in accordance with the terms and conditions Science Foundation Ireland (SFI). 	Focus on scientific leadership and all aspects of research project management.
National Development Plan (NDP)⁸ European- Ireland	<ul style="list-style-type: none"> • Individual who co-ordinates the research and drives the overall objectives. • They must ensure that all reports are submitted on time and that they are of a satisfactory standard that clearly details 	Focus on research leadership, project delivery and research management

progress on the project.

¹. <http://www.nsf.gov/pubs/2002/nsf02151/gpm2.jsp#210>

². enhancing-peer-review.nih.gov/.../Tab_6b-Applicant_Survey_Version_B.pdf

³. www.hq.nasa.gov/office/procurement/nraguidebook/proposer2010.doc

⁴. Provided by EUROPE DIRECT Contact Centre/ Research Enquiry Service

⁵. www.ema.europa.eu/docs/en_GB/document.../10/WC500097905.pdf

⁶. Provided by ESRC RTD Enquiries Service

⁷. <http://www.sfi.ie/funding/grant-policies/sfi-investigator-titles/>

⁸. www.epa.ie/.../research/researchtcandguides/cgpp4%20guide%20for%20grantees.pdf

Table 2 Ivy League descriptions of principal investigators

Funding agency	Key elements of PI description	Description emphasis
University of Pennsylvania¹	<ul style="list-style-type: none"> Individual designated by the University and approved by the sponsor to direct a project funded by an external sponsor. S/he is responsible and accountable to the University and sponsor for the proper programmatic, scientific, or technical conduct of the project and its financial management. 	<p>An individual with total responsibility for all aspects of project delivery.</p> <p>Internal Management Focus.</p>
Dartmouth University²	<ul style="list-style-type: none"> Primary responsibility for achieving the technical success of the project, while also complying with the financial and administrative policies and regulations associated with the award. Although Principal Investigator's may have administrative staff to assist them with the management of project funds, the ultimate responsibility for the management of the sponsored research award rests with the Principal Investigator. 	<p>An individual with total responsibility for all aspects of project delivery irrespective of the administrative support.</p> <p>Internal management focus.</p>
Columbia University³	<ul style="list-style-type: none"> The full administrative, fiscal and scientific responsibility for the management of a sponsored project resides with the Principal Investigator named in the award. 	<p>An individual with total responsibility for all aspects of project delivery.</p> <p>Internal management focus</p>
Brown University⁴	<ul style="list-style-type: none"> The individual responsible for all scientific or technical aspects of the project and for the overall day-to-day management of the project or program. This person may be any member of the Brown faculty, or, with special permission and the signature of the senior officer for their division, a graduate student, medical student, or an exempt staff member. 	<p>An individual member of the institutional community with total responsibility for all aspects of project delivery.</p> <p>Internal management focus</p>
Cornell University⁵	<ul style="list-style-type: none"> Individual responsible for the conduct of the project. This responsibility includes the intellectual conduct of the project, fiscal accountability, administrative aspects, and the project's adherence to relevant policies and regulations. A project may have multiple individuals as PIs who share the authority and responsibility for leading and directing the project, intellectually and logistically. 	<p>An individual or number of individuals with total responsibility for all aspects of project delivery. .</p> <p>Internal management focus</p>
Princeton University⁶	<ul style="list-style-type: none"> Individual judged by the University to 	<p>An individual or a number of</p>

	<p>have the appropriate level of authority, expertise, and responsibility to direct a research project or program supported by a grant.</p> <ul style="list-style-type: none"> • There also may be multiple individuals serving as co-PIs who share the authority and responsibility for leading and directing the project, intellectually and logistically. • Each PI/co-PI is responsible and accountable to the University for the proper conduct of the project or program. PIs are responsible for mentoring students involved in the project. They are also responsible for fulfilling the programmatic, management, and other requirements of the sponsoring organisation. 	<p>individuals <u>all</u> with total responsibility for all aspects of project delivery.</p> <p>Internal management focus</p>
Harvard University ⁷	<ul style="list-style-type: none"> • Project director of a research grant or contract responsible for seeing that the work is carried out according to the terms, conditions, and policies of both the sponsor and the university. • The principal investigator is solely responsible for the intellectual integrity of the work. Normally, a principal investigator must hold a full-time academic ladder appointment. 	<p>An individual with total responsibility for all aspects of project delivery. Normally full time academic</p> <p>Internal management focus</p>
Yale University ⁸	<ul style="list-style-type: none"> • Designated by the University and approved by the sponsor to direct a project funded by an external sponsor. • S/he is directly responsible and accountable to the University and sponsor for the proper programmatic, scientific or technical conduct of the project, and its financial and day-to-day management. • The principal investigator is a critical member of the sponsored project team responsible for ensuring compliance with the financial and administrative aspects of the award. • It is expected that the principal investigator will maintain contact with the appropriate sponsor representative with respect to the scientific aspects of the project and the business and administrative aspects of the award. 	<p>An individual approved by the <u>university</u> with total responsibility for all aspects of project delivery. Clear expectations set in terms of accountability, co-ordination and accountability.</p> <p>Internal management focus</p> <p>External engagement focus</p>

¹. www.upenn.edu/researchservices/faq.html

². <http://www.dartmouth.edu/~osp/resources/manual/post-award/pirole.html>

³. www.columbia.edu/cu/compliance/pdfs/PI_Quick_Guide.pdf

⁴. research.brown.edu/pdf/PSAF_Guide.pdf

⁵. www.research.cornell.edu/VPR/Policies/PI-policy.html

⁶. www.princeton.edu/.../PI%20Request%20for%20Website%20-%20Final.pdf

⁷. http://www.gsd.harvard.edu/academic/faculty_resources/faculty_handbook/chapter_three.htm

⁸. www.yale.edu/ppdev/policy/1310/1310.pdf