Chapter 3
Publicly Funded Principal Investigators as Transformative Agents of Public Sector Entrepreneurship

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3.1 Introduction

National governments consistently implement an array of public sector entrepreneurship policies and activities, seeking to generate further economic activity and create new networks and market opportunities that reduce market risks and uncertainties for market-based technology exploiters. This means that scientists taking on the role of being a publicly funded principal investigator (PI) is at the nexus of science, government and industry, and can have a significant influence and impact on shaping and delivering outcomes of public sector entrepreneurship policies and activities. Within the emerging public sector entrepreneurship literature (see Leyden and Link 2015; Link and Link 2009), we argue that publicly funded PIs as key public sector entrepreneurship transformative agents, through scientific novelty and originality involving some creative and innovative processes that can be exploited for opportunities with good market or societal potential. Publicly funded PIs are key agents of what Leyden and Link (2015:14) define as public sector entrepreneurship:

> Innovative public policy initiatives that generate greater economic prosperity by transforming a status-quo economic environment into one that is more conducive to economic units engaging in creative activities in the face of uncertainty.

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For innovative science technology and entrepreneurship-orientated public policy initiatives, publicly funded PIs are key assets, and the combination of their novel efforts and their capability to meet the expanding PI role means that they are a core and critical player in transforming scientific, economic and societal environments.

The implementation of public sector entrepreneurship policy agendas supporting basic and applied research has seen publicly funded PIs becoming the linchpin of this transformation process, as they shape novel research avenues, articulate and coordinate players within scientific programmes and bridge academia and industry. They play a specific role in the new governance of research and design novel scientific research programmes and projects in response to public sector entrepreneurship research funding opportunities and initiatives. When successful, they manage the implementation of these typically large-scale, publicly funded research programmes. While policymakers and funding agencies specify and prioritise scientific targets, publicly funded PIs interpret public policies and programmes; they articulate scientific research avenues, scientific programmes and priorities, firms' expectations and their own anticipation of where science is going. This can involve the mobilisation of scientific and industry networks nationally and internationally to create consortia that can compete to secure funding by means of scientific and increasingly now also commercial peer review processes.

Being an excellent scientist is only one aspect of the publicly funded PI role, which has now become multidimensional. The role has evolved from providing research leadership to research management. Some key tasks of publicly funded PIs include leading a research programme, overseeing the day-to-day management of the project, supervising and mentoring staff conduct, signing off on the budgets and financial management, ensuring that all deliverables and deadlines are met and submitting technical documentation and progress reports. The multidimensional publicly funded PI role also now involves coordinating with multiple organisations, including industry partners, scientific partners, technology transfer (TT) specialists, lawyers and innovation specialists. Publicly funded PIs need to be constantly spanning boundaries in their dealings with a wide variety of stakeholders inside and outside their institution. They also operate within the dual sets of control mechanisms and bureaucracies prescribed by their own institution and that of the public funding agency. Moreover, the role of publicly funded PIs is more important and policy-relevant with regard to the development, implementation and delivery of public sector entrepreneurship policy.

For most academic researchers, taking on the role of lead researcher on a research project as PI represents an important landmark in their research career. From the researcher's perspective, it marks a point in their career at which they have assumed intellectual leadership of their research efforts and are providing leadership for others in this endeavour. From a research system perspective, it also identifies a point in time when the academic researcher can be entrusted to successfully deliver a funded research project on behalf of the funding agent. Responding to public sector entrepreneurship policies through open funding calls requires scientists to strategise and develop novel scientific research programmes that meet and exceed the expectations of relevant stakeholders and 'that generate greater economic

prosperity' (Leyden and Link 2015:14). Inherent in this PI strategising is transformative intent with regard to different environments—scientific, industry, regulatory, etc. Despite the importance of publicly funded PIs, little is understood about the various aspects of the role and activities.

We begin our chapter by examining definitions of PIs that attempt to illuminate the various facets and responsibilities of the role. We then consider as agents of public sector entrepreneurship policies that PIs need to become ambidextrous and boundary-spanning in their activities and this creates new challenges and tensions. While our research into publicly funded PIs has focused on many themes, for the purposes of this chapter we concentrate on three: the publicly funded PI as research strategists, as managers and as agents of technology and knowledge transfer. Implicitly inherent in each of these PI activities is the intentional transformation of different environments. We conclude the chapter with reflections and recommendations in addition to suggestions for future research, integrating emerging research into public sector entrepreneurship and publicly funded PIs.

3.2 A Question of Definition: A Scientist, Administrator, Manager or Research Leader?

The term "principal investigator" is commonly used within academia and has different institutional interpretations. Despite the common use of PI among researchers and in the organisational arrangements for public research, the term itself has limited usage in the academic literature on research management. There does not appear to be a universal definition of the role and responsibilities of a PI. However, the term is commonly used in the research policies of universities and publicly funded institutions. It is a role with responsibilities in addition to those that researchers already hold. Academic institutions can prescribe the role and responsibilities. In their standard contractual requirements from host institutions and the lead scientist—the principal investigator— the funding agencies may outline very specific roles, responsibilities and requirements. For example, funding agencies can contractually require the PI to devote a certain percentage of his or her time to the funded project.

In the absence of a universal definition of PIs, we conducted a small review of US Ivy League research policies in search of PI role definitions. From this small review there was a universal commonality with regard to these descriptions. They all agree that the PI has total responsibility for all aspects of a funded project. For example, the University of Pennsylvania[1] defines the PI as follows:

> The principal investigator is an individual designated by the University and approved by the sponsor to direct a project funded by an external sponsor.

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

Columbia University's[2] definition is simple:

> The full administrative, fiscal and scientific responsibility for the management of a sponsored project resides with the Principal Investigator named in the award.

Princeton University's[3] definition is broader and includes a number of individuals as co-PIs:

> The principal investigator is an individual judged by the University to have the appropriate level of authority, expertise, and responsibility to direct a research project or program supported by a grant. 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 organization.

Stanford University's research policy notes that the PI plays a privileged role with limited availability and that the post-holder is:

> Responsible for determining the intellectual direction of the research and scholarship, and for the training of graduate students.

We found that the predominant managerial focus of the Ivy League PI role descriptions we reviewed was internal. Various aspects of managerial planning, organising, leading and controlling formed part of this internal managerial focus.

Funding agencies are the other institutional bodies that have provided definitions of PIs. A review of the main research funding agencies in the USA, Europe and Ireland highlights a more expansive interpretation of the PI role. These definitions emphasised different aspects of scientific research management and leadership. We found from reviewing these funding agency descriptions that they clearly laid out the primary fiduciary responsibilities of PIs and ensured that they strictly adhered to the terms and conditions of their grant award. For example, the Economic Social Research Council[4] in the UK gives the following definition:

> The principal investigator is the 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.

The European Research Council[5] simply defines the role as follows:

> The Principal Investigator is the individual that may assemble a team to carry out the project under his/her scientific guidance

[2] www.columbia.edu/cu/compliance/pdfs/PI_Quick_Guide.pdf

[3] www.princeton.edu/…/PI%20Request%20for%20Website%20-%20Final.pdf

[4] See ESRC RTD Enquiries Service.

[5] See EUROPE DIRECT Contact Centre/Research Enquiry Service.

However, the National Science Foundation[6] in the USA defines the PI role as:

> The individual designated by the grantee, and approved by NSF. Responsible for the scientific or technical direction of the project for carrying out the research within the funding limits awarded and in accordance with the terms and conditions of the award.

Other responsibilities enshrined in the PI role by the funding agencies include:

- Acting as the primary conduit between the project organisation or team and the funder
- Leading the scientific and technical direction of the project
- Ensuring compliance with the intellectual property requirements of the award
- Maintaining proper conduct on the project and the appropriate use of funds
- Assembling and coordinating the project team
- Designing project management structures

In general, the definitions used by universities and funding agencies to explain the role and responsibilities of PIs do little to appreciate the full extent of the expanded responsibilities and practices embodied in it. These definitions tend to be designed from a contractual perspective with an emphasis on project management, administration and fiduciary responsibilities—scientific and financial. They do little to reflect the complexity and strategic importance of the role in the context of the implementation of public sector entrepreneurship policies that are carried out in a multilayered institutional setting, and that involve industrial partners across international research systems. The reality for publicly funded PIs is they are expected to be the agents for implementing public sector entrepreneurship policies, programmes and initiatives. This involves overseeing the day-to-day management of a research project or research programme, supervising and mentoring researchers, conducting and signing off on the financial arrangements of the research project, ensuring that all deliverables and deadlines are met and submitting technical documentation and progress reports to both the funding agency and their own institution.

Given the expanding array of activities and responsibilities of publicly funded PIs, they are expected to take on more significant management roles, including designing and scheduling the research project, coordinating and directing a research team, liaising with stakeholders and acting as a primary contact point for the funding agency and flagging and responding to institutional or project issues. Significantly, however, the responsibilities associated with the position of PI are somewhat heightened, with the added expectations that they develop and maintain their own status and expertise in the field, demonstrate intellectual leadership, set the scientific direction, deliver technical success and oversee the project's impact activities following completion. In addition to these conditions, there is also the increased imperative for publicly funded PIs to incorporate industry partners into their research, to meet the expectations of these partners and to contribute towards TT targets set by funding agencies. All of this is to be achieved within as many as three layers of control mechanisms, including their own institution, the public funding agency and the project-specific controls.

[6] http://www.nsf.gov/pubs/2002/nsf02151/gpm2.jsp#210

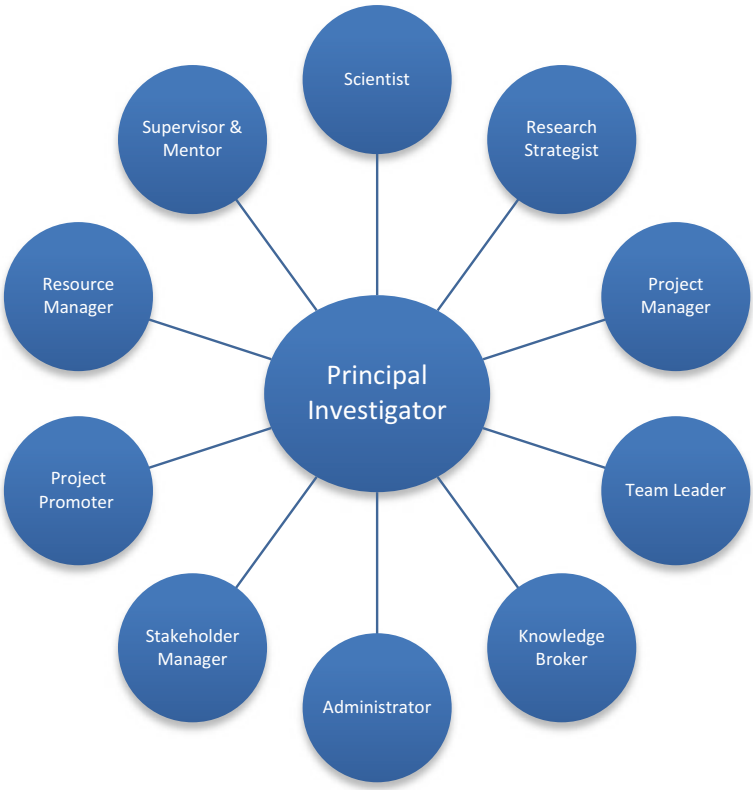

Fig. 3.1 Key responsibilities of publicly funded principal investigators (PIs)

By considering the different definitions of the PI role, we define PIs as scientists who orchestrate new research projects, combine resources and competencies, deepen existing scientific trajectories or shape new ones that are transformative in intent, nature and outcome, and that can be exploited for commercial ends and/or for the common good of society. We have identified and mapped ten core responsibilities of public funded PIs (Fig. 3.1).

3.2.1 From an Agent of Science to an Agent of Economic Transformation: The Ambidextrous PI

In Europe over the last 15 years there has been an increasing emphasis on the generation of commercial outcomes from publicly funded research, although until recently, research commercialisation or TT was not a mainstream activity for research and publicly funded PIs. Public sector entrepreneurship research programmes seeking to generate economic activities are now requiring publicly funded

PIs and their host institutions to deliver a research impact, including technology and knowledge transfer that will have a tangible impact on local, regional and national economies. This research system objective presents challenges at various levels. Universities and public research institutions are undergoing a significant transformation in terms of how research is managed at an institutional level (see Kang 2004; Park et al. 2010). Universities have responded to these changes by investing in signature research centres, thereby concentrating research and scientific activities and resources on supporting transformation- and impact-orientated research. Technology transfer offices (TTOs) have seen their mission, role and influence expanded beyond protecting intellectual property of the university (see Fitzgerald and Cunningham 2015; Gubitta et al. 2015). TTOs are involved in the marketing and promoting of technology, supporting the creation of start-up and spin-off firms and encouraging the faculty to exploit technology (see Friedman and Silberman 2003; Muscio 2010). This has meant that TTOs have had to develop and shape dual identities—scientific and business—and building such legitimacy for TTOs can be challenging for academics (O'Kane et al. 2015). Funding agencies and governments are expecting greater returns for their research investment (see Bessette 2003; Hertzfeld 2002; Link and Scott 2004). They now need to demonstrate to society the economic value of public investment in science, innovation and technology.

These contextual drivers and changes have had significant implications for publicly funded PIs as they seek to develop research programmes that exploit public sector entrepreneurship transformation programmes seeking to generate economic prosperity. Therefore, scientists taking on a publicly funded PI role need to have an ambidextrous mindset to move between scientific and commercial environments and the capabilities that convert transformative intent to action and measureable outcomes. Ambos et al. (2008:1425) describe this as something of an extraordinary challenge where researchers are:

> Not simply required to switch from one (single-handed) activity to another, but to develop the simultaneous capacity for two activities (academic rigour and commercialisation).

They also note that few studies have examined the capacity of researchers to handle what they describe as conflicting demands and the tensions created by this requirement. For many scientists there is a firm conviction that academic research and commercial research are fundamentally different. Some highlight the notion that engagement in TT is insufficiently valued in their institutions, particularly in relation to scientific publishing activity (Markman et al. 2005b). Indeed, there may even be reluctance on the part of some senior faculty to alter a system that has provided the basis for their own success. Other scientists simply lack the competence to undertake commercial activities or engage in TT initiatives (Clarysse and Moray 2004). For publicly funded PIs the new paradigm is that they are transformative scientific and economic agents for public sector entrepreneurship policy programmes. This requires an ambidexterity and effective boundary-spanning abilities to influence and shape scientific and economic directions that generate economic prosperity.

The boundary-spanning perspective is particularly important as it introduces key dimensions to the role. First of all, as boundary-spanners, publicly funded PIs are bridging different areas, from academia and higher education to policymakers and

enterprises. They play a role in articulating different objectives, time frames, logics and cultures. They also play a role within academia in creating a dialogue between disciplines, shaping research avenues and combining different approaches and instruments to propose solutions. Finally, emphasising the boundary spanner role obliges scholars of research management to reconsider the definition of publicly funded PIs and their characteristics, and to question their role in academic science, not only in the light of their productivity, but also taking into account their ability to implement multi-environment transformative visions and to share expectations, particularly as agents of public sector entrepreneurship policies.

3.2.2 Some Challenges and Tensions Facing Publicly Funded PIs

From the definitions and role descriptions proffered by funding agencies and universities, our understanding of the activities and practices of PIs has emphasised their role as project managers and administrators (Birnbaum-More et al. 1990; Frestedt 2008). More recently, the role of research leaders as boundary-spanners taking on different points of view and logics to solve problems has been considered (see Alder et al. 2009; Comacchio et al. 2012; Jain et al. 2009). These changes have created new challenges and tensions for publicly funded PIs. Ambiguities regarding the definition of the role of PIs reflect these tensions and include:

Scientific versus Economic Activities and Impact: Scientist formation and training predominantly focuses on being trained to be an excellent researcher, to write academic papers, to participate in international scientific communities and to learn how to mentor and support. The publicly funded PI role means that they now have to act as a transformative conduit between science and industry. This involves PIs becoming knowledge brokers, playing a role that was not common in decades past. For this role they typically receive little professional training and learn on the job. Moreover, as part of securing public funding, PIs are required to elaborate on the economic impact of their research proposal, such as the number of jobs created etc. The proposal needs to be transformative in intent. Again, PIs receive little formal professional support and rely on the professional support within their network and in their institution to meet these growing demands. As research projects evolve and mature, the competing scientific and commercial agendas create more tensions for the PI between economic and scientific activities.

Governance and Fiduciary Responsibilities: The governance requirements and broader fiduciary responsibilities that publicly funded PIs now face are growing. Most publicly funded PIs at least have to deal with institutional and funding control mechanisms. Moreover, funding agencies require even more of an overview regarding the scientific progress of funded projects, and with regard to financial and project management. These additional requirements can be demanding for publicly funded PIs and their institutions. The real challenge and tension created for publicly funded PIs is achieving the appropriate balance between research leadership and research

management. Thus, for public sector entrepreneurship policies, the overall challenge is to achieve the appropriate balance between loose and tight administrative controls that enables them to realise transformational intent in multiple environments.

Market-Shaping Expectations: Public funding agencies are increasingly requiring scientists to articulate the commercial and economic impact of their proposed scientific proposals that have the potential to be market-shaping. Such an articulation may include outlining a clear technology management and transfer strategy, forecasts such as the potential size of market opportunities and supported market research and analysis that further validate the economic and financial case for the proposed project. The challenge for the PI is how they form these projections and expectations, while allowing for manoeuvrable change, if, for example, anticipated market opportunities change or if the scientific progress is not achieved. Furthermore, another challenge is making credible linkages and claims between the anticipated scientific programme and potential market opportunities that is substantially transformative, to secure funding through public sector entrepreneurship programmes and subsequent market support.

Taken together, these tensions provide a framework for studying the role of the PI. We observe that the effective publicly funded PI is required to have the ambidextrous qualities that enable them to lead highly complex and technically advanced research programmes, while having the dexterity to simultaneously manage a set of relationships that extends to their institution, industry partners, research funders, government agencies and research team members. Setting aside the obvious scientific competencies required to lead research efforts, they must also be:

A *research strategist*, where they envision transformative scientific trajectories and design scientific programmes
A *manager*, where they lead a research team and manage a diverse stakeholder network to realise transformation intent in multiple environments
A *TT agent*, where they create a bridge between science and industry and support the knowledge transfer and application of their research outputs

3.3 Study Framework

Given that there is little empirical focus on scientists in the publicly funded PI role with the support of funding from the Irish Research Council,[7] the research team, comprising researchers from NUI Galway, the Dublin Institute of Technology, the University of Otago in New Zealand and Grenoble Ecole de Management in France, undertook quantitative and qualitative investigations and analysis of a range of issues with regard to publicly funded PIs in science, engineering and technology. Our data collection had two elements—a large-scale survey of publicly funded PIs and in-depth interviews and documentary analysis.

[7] Formerly known as the Irish Research Council for Humanities and Social Science

3.3.1 Large-Scale Survey

We undertook a full population survey of publicly funded PIs in science, engineering and technology in Ireland. This included publicly funded PIs from public funding agencies such as Science Foundation Ireland, Enterprise Ireland, the Health Research Board, the Programme for Research in Third-Level Institutions (PRTLI), Food Institution Research Measure, SafeFood, the Environmental Protection Agency and EU Framework Programmes. Across these programmes, a dataset comprising 1,391 individual publicly funded PIs was compiled and surveyed. Our survey response rate was 32 %. The survey had a project focus and addressed PI issues such as activities and practices as they designed, led and managed publicly funded research projects. Areas of activity surveyed included project design, project management, collaboration strategies, stakeholder management and TT activities. Some 82 % of the respondents were based in universities, 9 % were based in public research organisation (PROs) and the remainder at institutes of technology (IoTs).[8]

3.3.2 In-Depth Interviews

Thirty case studies of publicly funded PIs were undertaken using in-depth interviews and documentary analysis. The selection criteria required case subjects to have been the publicly funded PI for multi-annual and collaborative (preferably with industry) research projects with a minimum funding value of €250,000. The final sample was refined to include an appropriate diversity of discipline areas, genders, age and stage of career of the PI. It was also refined to suitably reflect the host research institutions in Ireland (i.e. universities, PROs and IoTs. Thirty semi-structured interviews of approximately 90 min each were undertaken (amounting to just over 400 pages of transcripts). A second phase of data collection included an analysis of documentation collected before, during and after the interview that was relevant to both the project and the CV of the PI.

3.3.3 Our Focus

Our data collection focused on a variety of themes, given the dearth of empirical research on publicly funded PIs. In the findings section of this chapter, we focus and report on three themes of the publicly funded PI as a strategist, a manager and a knowledge and TT agent based on the research we have undertaken to date. Publicly funded PIs are transformational agents of public sector entrepreneurship; thus, there is a need to understand their strategic behaviours, their managerial challenges and

[8] For more information about the project and other large-scale survey findings, see www.topik.ie

what barriers or stimuli they face with regard to technology and knowledge transfer given their central role in designing, leading and delivering publicly funded programmes in science, innovation and technology.

3.4 Findings

3.4.1 The Publicly Funded PI as Research Strategist

Within the evolving research environment, PIs are key strategic and transformational players. As scientists, they design and orchestrate new research projects, which involves combining resources and competencies with other researchers, research organisations and enterprise partners (Kidwell 2014). To varying degrees they seek to deepen scientific trajectories and shape new areas (Casati and Genet 2014). Despite this important strategic aspect to their roles, surprisingly little is understood regarding the strategic orientation of researchers or indeed their approach to strategising in relation to their role as leaders in national and international research systems.

3.4.1.1 Strategic Behaviours of Publicly Funded PIs

To examine the strategic behaviours that underpin the research activities of publicly funded PIs, we identified two key constructs that inform their strategic behaviours and applied them to 30 case studies of publicly funded PIs (see O'Kane et al. 2015). First, we drew on the theory of exploration and exploitation in organisational adaptation and learning to describe the strategic posture of PIs as being more 'reactive' or 'proactive'. Second, we explored the effects of strategic conformance on PI research development trajectories. We grounded conformance in funding applications in literature detailing the influence of peer review funding on research creativity and originality. Together, our constructs reflect how choice of research line in science must balance curiosity and opportunity boundaries (see Bozeman and Mangematin 2004; Fisher 2005; Franzoni 2009; Porac et al. 2004).

After examining the strategic posture of publicly funded PIs and how they are more proactive or reactive, and mapping that against their level of conformance in funding applications, four distinct categories of PI strategic behaviours became apparent—*research designers*, *research adapters*, *research supporters* and *research pursuers*.

Research Designer: These publicly funded PIs are highly purposeful, passionate and committed, with clearly focused and novel research agendas. They have challenging ambitions and long-term intentions and combine projects to build their own trajectory, shaping the scientific field. These publicly funded PIs do not attain their deliberate planned objectives through single stand-alone projects and are highly selective when choosing public funding opportunities to pursue. Moreover, they are more driven by the originality of their research and how funding opportunities are compatible with their broader research objectives.

Research Adapters: These publicly funded PIs have a broad research focus, are not overly committed to a focused or long-term research agenda, take a reactive and broad focus so that they maintain some career and research competitiveness, and being in a position to respond to the emerging opportunities. Like the research designer, they are less conformist in relation to funding applications and have the confidence to convey to funding bodies their research intentions. We found this category of PI to have a varied professional ranking and that they are constantly adapting their research trajectory and activities to fit their external environment.

Research Supporters: These publicly funded PIs are deliberate planners and have a clearly defined long-term research focus that they proactively pursue, and build upon existing scientific trajectories rather than opening up new ones. They are less of a risk-taker when it comes to pursuing their research objectives, are heavily reliant on funding and concentrate on conformity.

Research Pursuers: This type of publicly funded PI is in the short term focused on a poorly defined or absent research agenda and is less reliant on original research. Research pursuers are highly tactical and build on existing research by making adjustments to meet the threshold expectations of funding opportunities. They also have a reactive research posture, a broad research focus and short-term and fluid research intentions. They are less focused on building originality and more concerned with meeting the expectations of the funding body.

3.4.2 PIs as Managers

Our review of the definitions of PIs demonstrated both implicit and explicit notions that the scientist, in taking on the publicly funded PI role, accepts managerial responsibility. In becoming a publicly funded PI, an individual scientist assumes managerial responsibilities that are associated with the successful delivery of the project. The publicly funded PI has to manage the budget, select and recruit the research team, set up the management structure for the project, engage with stakeholders and provide leadership for the whole project team. For large-scale multi-partner projects, management and leadership by the publicly funded PI is significantly complex. We examined the managerial nature of the publicly funded PI role, as there has been little empirical focus on this topic.

3.4.2.1 The Managerial Nature of the PI Role

Publicly funded PIs have to ensure that the work programme articulated in their successful proposal is implemented. They have to ensure that the project is effectively coordinated to ensure delivery of project objectives. Effective organisation and allocation of resources is essential to meet the needs of the different work packages within a project. The project team, partners and funders require the scientist

in the role of PI to lead, to deal with unanticipated events and to adhere to his or her own institutional policies and the terms and conditions of the funding agency.

The PI has to balance project leadership and management responsibilities with other teaching and service demands, and they need to manage their time effectively (Link et al. 2008). In addition to their scientific excellence, PIs have to be effective managers to deliver multi-environment transformation. Acquiring managerial skills for PIs is learnt on the job (Kidwell 2013). One recent study of research centres established by the US National Science Foundation found that some PIs demonstrated managerial capabilities and some did not (Boardman and Ponomariov 2014). Boardman and Ponomariov (2014) suggested that managerial capabilities matter with regard to how research gets done effectively. Managerial capabilities are also essential for dealing with inter-organisational relationships, such as industry collaborators (Boehm and Hogan 2014).

3.4.2.2 Managerial Challenges

Addressing the deficit of empirical studies on managerial issues facing PIs, from the qualitative phase of our study, we focused on the managerial challenges experienced by publicly funded PIs. We found three main categories of managerial challenges—*project management, project adaptability and project network management* (see Cunningham et al. 2015).

3.4.2.2.1 Project Management

The managerial challenges experienced by PIs in our study demonstrate a focus on operational tasks.

Talent Recruitment and Management: How to attract, recruit and manage the best research team for a funded project was the most significant management task for publicly funded PIs. Developing a productive work environment was essential in maintaining the research team and ultimately in delivering against expected project outcomes.

Supervision: How best to supervise research teams, ensuring scientific quality and monitoring any project partner delivery were key managerial challenges for publicly funded PIs. The key challenge for publicly funded PIs is balancing operational day-to-day activities with the strategic responsibilities of delivering project objectives against the conditions of the funding agency.

Maintaining Project Focus and Alignment: How to balance a shared vision for the overall project with all project participants against individual partner objectives that could be in conflict with the overall project objectives. This requires publicly funded PIs to build effective relationships with project partners and with internal and external stakeholders to maintain project focus and alignment.

Managing Across Disciplines: How to create a common project language, vision and objectives when dealing with cross-disciplinary teams to ensure project delivery. Managing across disciplines can be an on-going managerial challenge for publicly funded PIs; therefore, having open dialogue and garnering shared ideas among the project partners can be effective management mechanisms.

Managing Cultural Diversity: There is cross-cultural diversity within publicly funded project teams. How best to manage this cultural diversity against different layers of institutional and funding agency control is managerially challenging. Publicly funded PIs need to have an understanding and appreciation of cross-cultural and institutional differences to manage effectively for the duration of the project.

Performance Management: How best to deal with project partners who do not deliver is a key managerial challenge and concern for publicly funded PIs. Reported responses in dealing with non-performance included, individual meetings, exposure of underperformers or project partner removal.

3.4.2.2.2 Project Adaptability

We found another significant set of managerial challenges centred on project relevance that we termed "project adaptability". A constant concern for the publicly funded PI was to ensure that their funded project had temporal relevance and if it did not, how it could be shaped to achieve this.

Environmental Scanning: How best to balance scientific and market perspectives to ensure consistent relevance of the project. For example, during the course of a publicly funded project, external market changes and external scientific breakthroughs may occur that may lessen the potential market attractiveness of projects. To deal with this managerial challenge, if possible, the publicly funded PIs used a dedicated work package on environmental scanning or building to report processes to have consistent market intelligence within the project to ensure temporal relevance.

Maintaining Project Agility: The focus of markets and funding agencies can shift; thus, the key managerial challenge for PIs is to adapt project activities and outcomes to reflect these changes. The shift towards economic and social outcome for projects is an on-going managerial challenge.

3.4.2.2.3 Project Network Management

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

Internal Network Management: How do deal with control systems, bureaucracy and host institutional units such as TTOs can be a difficult managerial challenge for publicly funded PIs. We found that publicly funded PIs of large-scale research programmes tended to have a structured relationship with TTOs to deal with or overcome any difficulties effectively. For publicly funded PIs early in their career, a

major challenge is balancing publishing against initial invention disclosures, as required by host institutions and TTOs.

External Network Management: As publicly funded PIs, boundary-spanning activities are expanding; they are engaging with industry, regulatory bodies, research funders and governments as key external stakeholders. The managerial challenge is balancing this external networking effectively against the other demands and responsibilities of the PI role.

3.4.3 PIs as Agents of Technology and Knowledge Transfer

When taking on the role of PI for a publicly funded project means that a scientist becomes an agent of technology and knowledge transfer. Nearly all publicly funded research programmes require PIs to proactively disseminate their project outcomes through traditional knowledge transfer mechanisms, such as scientific papers, conferences etc. They now also require PIs to be actively involved in TT based on project outcomes through licensing, material transfer agreements and spin-out and spin-in companies. The PI has become an agent of technology and knowledge transfer. In essence, they have to contribute to scientific and economic environments and where appropriate, society. When considering these issues, we first assess more general demands and some of the conditions for TT before presenting our study findings in relation to prevalent technology and knowledge transfer activities, and factors inhibiting and stimulating TT.

3.4.3.1 Demands and Some Conditions for TT

An increasing feature of national and international publicly funded programmes is a requirement for projects to transfer technology and knowledge to external stakeholders that can be exploited by firms and/or have public good outcomes. Publicly funded programmes may also require engagement with citizens with regard to building up their awareness and knowledge of different aspects of science and technology.

This growing demand is being shaped by the way in which the key stakeholders of business, academia and government in many domains are collaborating and co-creating together in advanced scientific programmes. Transformative innovation and research development that can be exploited in markets now require multiple players. In addition, many businesses are using open innovation strategies to expand their research and development capabilities. Rapid advances in ICT have meant that open economies and R&D activities can be undertaken in multiple locations across the globe (see Cunningham and Harney 2006:7–9). Other factors increasing the demand for public research commercialisation include increasing national competitiveness, scientific costs and budgetary pressures, competition for human resources and funding, and open access and open research data.

Increasing numbers of universities have adopted third mission activities focused on technology and knowledge transfer. This has led to the creation of the TTOs within universities to protect, manage and exploit university intellectual property. US University TTOs have become the model for many institutions worldwide

(Grimaldi et al. 2011). Some universities are adopting the characteristics of an entrepreneurial university where the culture of institutions means that ideas can be explored and exploited for economic and social return through engagement in a wide range of university networks and relationships (Guerrero and Urbano 2012; Guerrero et al. 2014). The easier the access between businesses and universities, the easier it will be to foster university–business R&D collaborations. The conditions for effective technology have been the focus of much empirical study. The research quality of the affiliate university increases the likelihood of researchers participating in commercialisation (see Di Gregorio and Shane 2003; O'Shea et al. 2005). The presence of formal TT mechanisms is generally positively related to commercialisation (see Markman et al. 2005a, b; Phan and Siegel 2006). Research has also found local peer effects, which means that academics are more likely to be entrepreneurial if departmental colleagues of the same rank are entrepreneurial (Bercovitz and Feldman 2008), and disciplinary affiliation, which is an important variable informing engagement with industry. Scientific disciplines affect the selection of knowledge transfer channels from university to firms (Bekkers and Bodas Freitas 2008). For example, for biomedical and chemical engineering the most important channels are patents and licensing, scientific output, student placements, informal contacts and contract research. For researchers in computer science, patents and licenses do not seem a relevant transfer channel, whereas they are very important for material scientists. The scientist in the role of PI is a central player in technology and knowledge transfer.

3.4.3.2 Prevalent Technology and Knowledge Transfer Activities

The most prevalent TT activities among publicly funded PIs in our study are peer publications, research symposiums, end-of-project reports, collaborative research with industry and industry workshops (Fig. 3.2). Notably, all of the commercially orientated activities (licensing, spin-offs, consulting and contractual research) are less prevalent than the other TT activities. Peer publication (48 %), research symposiums and colloquiums (17 %) and end of project reports (12 %) are the top three dissemination and TT activities reported by publicly funded PIs in our survey.

Technology transfer activities in their order of prevalence, broken down by institution type, show that collaborative research with industry, licensing of intellectual property and consulting are more likely to take place at universities (Table 3.1); industry workshops and contractual research are more likely to take place at both universities and PROs; and spin-off enterprise is more likely to take place at IoTs, and even more frequently at universities.

Table 3.2 shows the TT activities in order of prevalence, broken down by the size of the project budget. Peer publications dominate as the main mechanism for knowledge and TT. For projects with a budget of less than €500,000 collaborative research with industry, industry workshops and research symposiums were the predominant mechanisms reported by publicly funded PIs in our survey. On the other hand, for projects with budgets greater that €500,000, research symposiums and colloquiums and end-of-project reports have been used.

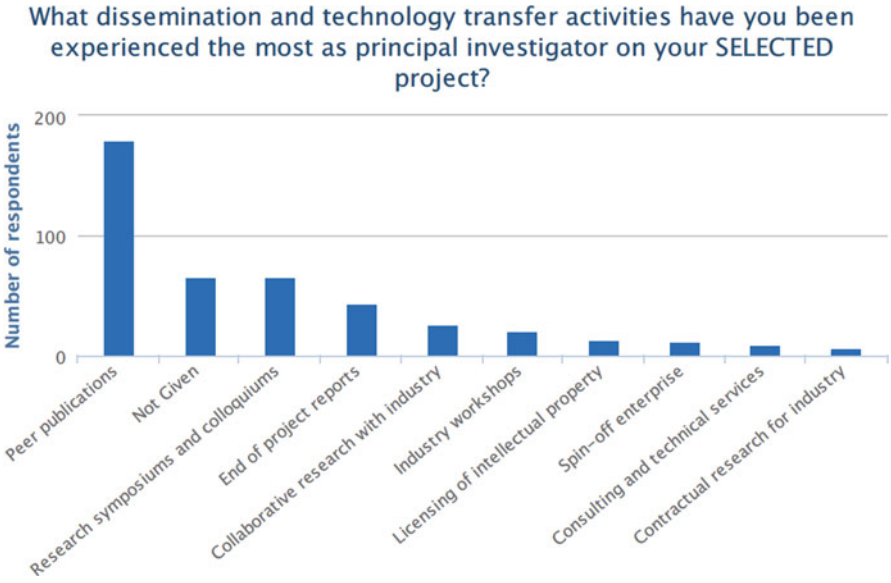

Fig. 3.2 Publicly funded PI dissemination and technology transfer activities

Table 3.1 Knowledge and technology transfer (TT) by institution type

Knowledge and TT by institution	University *n*	Public research organisation *n*	Institute of technology *n*
Peer publications	158	9	13
Research symposiums and colloquiums	55	7	2
End of project reports	35	4	4
Collaborative research with industry	23	1	2
Industry workshops	7	10	3
Licensing of intellectual property	10	1	2
Spin-off enterprise	8	0	3
Consulting and technical services	8	0	0
Contractual research for industry	4	3	0

3.4.3.3 Factors Inhibiting TT

The top factors that inhibit TT are lack of funding for bringing research to market (24.14 %), lack of commercialisation opportunities, lack of available time, weak links with industry and lack of personal motivation. From our analysis of our qualitative data, we found inhibiting factors that were directly or indirectly related to TT. Overall, we found three main inhibiting factors: political and environmental, institutional and project-based (see Cunningham et al. 2014).

Table 3.2 Knowledge and TT by size of the project budget

	Budget value	
Knowledge and TT mechanism	<€500,000	€500,000+
Peer publications	37	143
Research symposiums and colloquiums	12	53
End of project reports	8	36
Collaborative research with industry	17	9
Industry workshops	13	8
Licensing of intellectual property	7	6
Spin-off enterprise	5	6
Consulting and technical services	4	5
Contractual research for industry	4	3

- *Political and Environmental Factors*: These factors relate to TT policy, particularly in relation to project direction and focus, stakeholder demands and IP valuation.
- *Institutional Inhibitors*: These factors relate to TT support, tailored support for the PI role and human capital support. It should be noted that all the organisations of the PIs in our study had centralised administration services, such as finance, human resources and TT.
- *Project Inhibitors*: We found several project level inhibitors that had an impact on publicly funded PIs and their projects, the most significant among all PIs in our study being administration, lack of dedicated professional development support for publicly funded PI roles and the power of industry partners.

3.4.3.4 Factors Stimulating TT

Institutional provision of TT activities, strong links with industry and clearly defined commercialisation opportunities are the top three factors that stimulate TT among the publicly funded PIs in our study (Table 3.3). When factors that stimulate TT are broken down by institution, the order of prevalence is somewhat different for universities, with institutional provision of TT services, strong industry links and accessibility of support being the top three factors among publicly funded PI respondents.

For PROs the top three factors that simulate TT reported by publicly funded PI respondents are strong links with industry, institutional provision of TT services and facilitation of researcher involvement in the process.

For publicly funded PIs in IoTs strong industry links, institutional provision of TT services, facilitation of researcher involvement in the process and clearly defined commercialisation opportunities (ranked joint third) are the top three factors that stimulate TT. When examining stimulants by project budget the top stimulating factor for project budgets of less than €500,000 is institutional provision of TT support, but for project budgets of more than €500,000 strong links with industry are most important.

Table 3.3 Ranking of factors that stimulate TT among publicly funded principal investigators (PIs)

Stimulating factor	% of Respondents
Institutional provision of TT activities	16.46
Strong linkages with industry	14.64
Clearly defined commercialisation opportunities	11.60
Accessibility of TT office support	11.60
Own department leadership and commitment	10.09
Facilitation of researcher involvement TT	9.90
Realistic expectations of commercial returns from TT	7.35
Professional development initiatives to enhance TT	5.47
Financial rewards for researchers	4.68
Positive experience in relation to TT	4.50
Clearly defined and documentedTT policies	3.71

3.5 Discussions and Implications

3.5.1 Publicly Funded PI Strategic Behaviour

Our research found that the strategic behaviours of publicly funded PIs fall into four categories—research designer, research adapter, research supporter and research pursuer—and that these categories are influenced by strategic posture and conformance. How these agents respond and the capabilities they possess do matter in the delivery of public sector entrepreneurship policies. This has implications for practising PIs, policy-makers, research funding agencies and research organisations as scientists in the publicly funded PI roles are transformation agents in multiple environments progressing from intent to action.

We found that proactive publicly funded PIs seek to enact their environment whereas reactive PIs respond to research funding opportunities that arise. We suggest that proactive publicly funded PIs with the appropriate institutional support and research environment might have the capability to deliver transformative research that has the potential to enable direct and indirect economic spillovers of public sector entrepreneurship policies. Such publicly funded PIs promise to shape scientific direction and market opportunities that can be transformational in both environments. This requires publicly funded PIs to reflect on what strategic posture is best aligned to their long-term research ambitions.

For funding bodies and policymakers devising and implementing public sector entrepreneurship policies and initiatives greater consideration needs to be given as to the type of publicly funded PIs that are truly transformational agents and that have the potential to contribute to greater economic wealth. The strategic behaviour of

publicly funded PIs contributes to the success of public sector entrepreneurship policies. Selecting the appropriate mix of PIs is necessary so that they are enabled to be transformational with regard to scientific endeavours and in creating potentially sustainable market opportunities. Moreover, funding agencies need to recognise that the selection mechanisms of research strategies are interwoven with the pro-reactive posture of strategic players and conformance. When the publicly funded PI selection programmes and processes are based on conformance, it discourages proactive exploration strategies and encourages conformity. Resource allocation must promote an appropriate balance of research exploration and research exploitation activities, hence the need for the different strategic behaviours of publicly funded PIs in a research system to realise economic potential, which is transformational.

For research organisations such as universities, IoTs and PROs, which provide the environment in which publicly funded research is carried out, their institutional strategies and policies (HR and IPR) and their organisational cultures have an important influence on the strategic behaviours of publicly funded PIs. To deliver on their missions relating to research exploration and exploitation, it is necessary for these institutions to have an awareness of the strategy postures of their publicly funded PIs and to maintain appropriate research environments that support the strategic behaviours of publicly funded PIs.

3.5.2 Managerial Responsibilities of Publicly Funded PIs

Our study has found that publicly funded PIs are heavily involved in the operational management of their project and active in the project compliance of their funding awards. It also highlights the totality of the managerial burden and extent of the managerial work that publicly funded PIs have to deal with in the role. It is more extensive and has a compliance focus. The publicly funded PI role endows scientists and their institution with a certain prestige; however, the role involves greater managerial responsibilities than anticipated or estimated by the publicly funded PIs in our study. The managerial role has a low status among publicly funded PIs, but it remains an intensive part of their engagement with research.

The PIs are involved in all managerial functions (planning, leading, organising and controlling), which are challenging and complex. We suggest that the ability of publicly funded PIs to effectively manage and lead in multiple environments might ultimately determine the extent of economic and transformational outcomes of public sector entrepreneurship policies. This issue requires more empirical investigation to assess how critical the managerial capabilities of publicly funded PIs are in delivering large-scale, multi-partner, multi-impact, cross-discipline, publicly funded research programmes.

Our research indicates that publicly funded PIs learn the PI role on the job. They face multiple and contradictory demands and expectations, particularly in dealing with the project focus, cross-cultural, cross-disciplinary and under-performance aspects. In responding to these managerial challenges they use a variety of managerial approaches (see Cunningham et al. 2015). More empirical research is required to

understand the managerial approaches used by publicly funded PIs in different organisational contexts and the hybrid role identities—scientific, managerial, economic—they adopt in different environments in the role of a publicly funded PI.

In designing public sector entrepreneurship programmes policymakers need to consider the managerial burden that is actually being placed on the publicly funded PIs and the real institutional supports that are available to them. If they are over burdened with managerial responsibility and do not have appropriate organisational support, this has implications regarding whether such public sector entrepreneurship programmes are sufficiently attractive to secure the right mix of publicly funded PIs engaged in programmes that seek to generate economic prosperity and be transformational in nature.

3.5.3 Knowledge and TT

There is a clear need for all publicly funded PIs to have the knowledge and developing expertise to effectively undertake knowledge and TT activities. The demands for TT from all national and international public research programmes are growing and therefore scientists need to hone their own knowledge and skills so that they can implement them in a PI role.

Research quality and excellence is the basis for effective knowledge and TT. Consequently, publicly funded PIs need to ensure that within projects research quality is maintained and that a strategic relationship with TTOs is developed to ensure that the appropriate knowledge and TT strategy is in place to maximise the impact of the public research programme.

Within institutions, having role models, a culture of academic entrepreneurship and good provision of TT support is essential if publicly funded PIs are to be supported as agents for technology and knowledge transfer in public sector entrepreneurship programmes. Also, institutions need to customise their provision of TT for different scientific domains.

In designing public sector entrepreneurship programmes, policymakers and funding agencies can shape the desired knowledge and TT outcome that have the potential to contribute to economic prosperity and underpin the development of new sustainable market opportunities that can be exploited by the relevant players.

3.6 Recommendations and Final Reflections

Our research on the PI role and the experiences of scientists as publicly funded PIs highlights increasing levels of complexity and the need for further empirical research. We conclude with some key reflections and recommendations for PIs, host institutions, funding agencies and government policymakers. In summary, publicly funded PIs are the linchpins of the public sector entrepreneurship programme-based

organisation of science and technology policies. This needs to be more widely recognised. PIs are not only instruments but also facilitators of the public sector entrepreneurship policy.

3.6.1 Publicly Funded PIs: Strategising, Competencies and Skill Mix

3.6.1.1 Strategising

The PIs have a vision of what should be done, and they have their own goals and expectations about how to leave a footprint in academia. They strategise their action, they resource their strategy and they shape organisations to reach their goals. For the individual scientist, our research highlights the need to have a clear scientific vision that has transformational intentions and to use a resourcing strategy to secure resources and collaborations. Publicly funded PIs are strategising themselves and using the program-based organisation of science and technology to resource and nurture their own strategy. PIs need to be proactive and selective about their resourcing strategy and consistently strategise about realising their scientific vision. Resourcing means convincing colleagues to collaborate with them and funding bodies to fund them, building alliances with other teams or researchers and investing in academic and/or industrial communities.

3.6.1.2 PI Competencies and Skill Mix

The skills a PI requires to be effective encompass managerial, leadership and strategic skills. Being an excellent scientist is just one competency that a PI requires. Effective boundary-spanning skills and being able to network effectively with a wide variety of stakeholders are essential and critical. PIs should look at ways of developing their managerial skills of planning, leading, organising and controlling that compliment their scientific skills. The combination of scientific and managerial skills and the knowledge of markets is necessary for publicly funded PIs to devise and implement public sector entrepreneurship policies.

3.6.2 Role Supports

3.6.2.1 Recognition of the Managerial Nature of the Publicly Funded PI Role

Among funding agencies and host institutions there needs to be a greater recognition of the managerial nature of the publicly funded PI role in the allocation of workloads, additional resources and for project evaluations. For scientists, the

publicly funded PI role involves consistently acknowledging and highlighting the extent of the managerial tasks and challenges that they face within their own institution and to funding agencies. Also, scientists in the submission phase of competitive project proposals need to be realistic and understand the management challenges they will face and factor the necessary supports into project proposals. Moreover, they need to be unafraid to articulate credible transformative project ideas because of the more pervasive managerial constraints imposed by host institutions and funding agencies.

3.6.2.2 Structured PI Professional Development

To deal with the growing managerial demands of the publicly funded PI role, scientists require more structured and customised training and must be able to operate effectively in multiple environments. Such structured training with regard to business, entrepreneurship, knowledge and TT should also be a consistent feature of the educational transformation from undergraduate to doctoral level. Moreover, scientific training is mostly on the job and through companionship with mentors and senior scientists. Better identifying other practices and connecting these to personal scientific strategies contribute to the recognition of PIs as a transformational agent of public sector entrepreneurship within academia. Moreover, it ensures that as agents of public sector entrepreneurship, they can respond to and have the necessary tools to be effective in the realisation of outcomes.

3.6.2.3 Research Administration and Support

Recognising the necessity for project administration, greater consideration should be given by funding agencies and host institutions with regard to reporting templates, information needs, timing, etc. and having in place dedicated research support as part of projects. Publicly funded PIs are focused on complying with funder requirements; however, the rationale for transforming scientists into administrators is not obvious. To realise the potential of public sector entrepreneurship policies publicly funded PIs need appropriate levels of research support. Less optimal levels of research support have the potential to diminish project outcomes—scientific and economic and the potential common benefits for society.

3.6.2.4 Organisational Flexibility

The challenge for universities and other host institutions is how best to support high-performing and high-potential publicly funded PIs. How does an institution provide sufficient flexibility to publicly funded PIs to conduct their research projects and to implement their research programmes, while at the same time trying to implement its own scientific policy or to cope with accountability concerns.

While we talk about the craft of research management and leadership for the publicly funded PI, there may also be a craft to research management and administration for university research support professionals. This craft is required to manage the tensions between conformance and administration commitments, while maintaining a flexible university or institutional research environment. Further exploration of the characteristics that contribute to this craft is required.

3.6.3 Knowledge and TT

3.6.3.1 Effective TT Support

Publicly funded PIs need effective access to appropriate knowledge TT support. This access aids TT support. Without adequate and appropriate provision of TT services, publicly funded PIs can be significantly hindered in fulfilling their knowledge and TT project objectives that are necessary in realising potential economic prosperity.

3.6.3.2 Industry Links

Before taking on the role of PI, scientists should be encouraged to build local, national and international relationships with industry and this should be recognised in workload, career planning and promotion. In the mobilising of players to respond to public sector entrepreneurship policies, PIs are enabled to create scientific and industry networks that can effect potential economic prosperity and realise new sustainable market opportunities.

3.6.3.3 Resources for TT

Time and funding are the two major inhibitors of TT for PIs. Institutions can mitigate the time factor by providing publicly funded PIs with, for example, better levels of research support and allocations of workload. In terms of funding, systematic analysis should be undertaken to identify funding opportunities at the beginning of projects for publicly funded PIs. Also, it is necessary to identify appropriate public sector entrepreneurship instruments that will financially support different forms of knowledge and TT.

3.6.4 Funders and Policymakers

For policymakers the diversity of publicly funded PIs and their role in the implementation of public sector entrepreneurship science and technology policy objectives calls for ex ante differentiation of supporting schemes. It is important to

design public sector entrepreneurship programmes where there are targeted research projects. Such programs may explore scientific bottlenecks, technological conditions to innovate, or methodological advances that benefit the whole community. It is also critical in the design of public sector entrepreneurship programmes to leave space for publicly funded PIs to take risks, to propose and discuss ambitious research programmes and to support unconventional ideas. This also involves high levels of risk and uncertainty, but also great transformational potential. Encouraging, developing, leveraging and managing such unconventional and original thinking from publicly funded PIs should further influence public sector entrepreneurship policy direction setting. This may require a new way of engaging with stakeholders collectively about the direction setting of public sector entrepreneurship programmes. As critical agents of public sector entrepreneurship, the voice and input of publicly funded PIs are vital. Each publicly funded PI has the potential to realise many of the desired outcomes of public sector entrepreneurship expected by funders and policymakers. We suggest that they need to be allowed and provided with more systematic means and consistent opportunities to become co-designers of public sector entrepreneurship programmes. They are the agents upon whose scientific originality public sector entrepreneurship programmes consistently rely, and have the potential to provide a sufficient transformational basis that can contribute to economic prosperity. Furthermore, in encouraging publicly funded PIs to develop their projects for different environments (scientific, TT, training, etc.), it is important to support publicly funded PIs to lead research teams with additional personnel to manage and administer projects effectively, delivering or exceeding expectations.

3.6.5 Opportunities for Future Research

We see that combining the emerging fields of research on public sector entrepreneurship and PIs holds great promise in unearthing a new understanding of publicly funded PIs as transformative agents of public sector entrepreneurship. More research is necessary into the themes explored in this chapter on publicly funded PIs—strategic behaviours, managerial challenges and knowledge and TT. Future research that focuses on what influences and shapes the thinking of public sector entrepreneurship policymakers in the areas of science, innovation, technology, enterprise and education is warranted and cross-country studies to examine the extent of the replication of "successful" public sector entrepreneurship policies, such as the SBIR programme from the USA. Furthermore, taking established research themes from the fields of strategic management and entrepreneurship such as entrepreneurial effectuation, entrepreneurial orientation, value creation, business models, strategic leadership, and applying these to emerging fields, public sector entrepreneurship and PIs have real potential in yielding new theoretical and empirical insights, and providing evidence that policymakers, PIs and supporting institutions can use in supporting scientists in the PI role who are shaping, influencing and implementing public sector entrepreneurship. Moreover, further research on how PIs scan in

multi-environmental settings and what factors influence their transformational intent, activities and actions is necessary. We suggest that taking PIs as a unit of analysis for future studies might be an integral part of the development of empirical studies of public sector entrepreneurship.

Finally, in their concluding observations on public sector entrepreneurship Leyden and Link (2015:206) cite Vanneaver Bush (1945:2) with regard to scientific progress and pioneers:

> Science offers a largely unexplored hinterland for the pioneer who has the tools for his task.

Viewing publicly funded PIs as the contemporary pioneers suggests that more empirical research might be required to really understand if they have the "tools", as Bush describes, as transformational agents to realise fully the potential of public sector entrepreneurship programmes. Further empirical research on the impact of public sector entrepreneurship will provide a better understanding of how it influences the PIs as "pioneers" and the "tasks" they undertake as transformational agents of public sector entrepreneurship.

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