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Value capture mechanisms in publicly funded research

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Abstract

There is increasing pressure on academic scientists to acquire research funding and to produce impactful research that stakeholders external to the research can capture value from. However, our understanding of the mechanisms by which funded scientists do this remain unclear. We conceptualize a two stage process of value capture in publicly funded research, the first being resource exchange and knowledge exploration and the second, exploiting the funded research to expand its use. Based on this framing we ask, what are the mechanisms through which value in use is captured in publicly funded research? We draw on interviews with 41 health science principal investigators (PIs) in New Zealand along with related secondary material. Our findings identify two value capture in use mechanisms – boundary spanning and brokering – that PIs employ to extend the use of their funded research to a diverse range of ecosystem actors. While boundary spanning facilitates efficient and deep value capture with select ecosystem actors, brokering allows for wider value capture by identifying, combining and balancing multiple ecosystem interests simultaneously. Our research shows that PIs are not only at the nexus of science to business interactions, their influence surpasses industry to incorporate much broader ecosystem engagement.

Keywords: Principal investigators; public research funding; value capture; science-to-business; qualitative research

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Value capture mechanisms in publicly funded research

> "When a company has a good idea that they want to develop or evaluate, they don't know where to go to in a hospital and they don't know where to go to in a university. There is not obvious receptor site for them to dock. The result is that there is a huge lost opportunity for universities, with this huge resource pool and for hospitals too that provide this wonderful test bed in which we can evaluate products and processes. It doesn't happen like it should. The HRC (Funder) is talking about how this is a good idea but how are they going to help us do that? I just don't quite see it. There's still a huge gulf between companies and hospitals and universities. There's more stuff that needs to be in place at the interface to actually help us move forward and achieve economic benefit" (Funded scientist research informant)

1. Introduction

A recent editorial in this journal highlighted the increasing pressures on and competition among academic scientists to acquire external research funding (Lindgreen et al., 2019). In line with a growing interest on value creation in science to business (S2B) interactions (Boehm and Hogan, 2013; Baraldi et al., 2014; Canhoto et al., 2016; Clauss and Kesting, 2017; Winkelbach and Walter, 2015), the same editorial emphasizes that undertaking funded research and appropriately disseminating the results poses separate challenges that are often underestimated: "really, receiving a research grant is only the beginning. The research project needs to be completed successfully" (Lindgreen et al., 2019, p.238). A primary completion challenge relates to the expectation that publicly funded scientists will "successfully" close the research-relevance gap, producing impactful research from which stakeholders external to the research can capture value (Blume-Kohout, Kumar and Sood, 2014; Lindgreen et al., 2019). However, our understanding of how funded scientists do this remains unclear. Indeed, as illustrated in the opening research informant quote, publicly funded science often suffers from value slippage (Lepak, Smith and Taylor, 2007), whereby the potential value capture within the public funding research ecosystem remains unfulfilled.

Value capture refers to the process in which actors appropriate a portion of value jointly created in a relationship (Brandenburger and Stuart, 1996). According to Chesbrough et al. (2018), we can distinguish between two forms of value capture, value capture through resource exchange and value capture through use of an innovation (Chesbrough et al., 2018). Drawing on these insights, in the context of publicly funded science, value capture can be represented by two stages, first scientists' search for and acquisition of research funding to undertake research (value capture in exchange) and then the subsequent dissemination and translation of the research outcomes (value capture in use). While the first stage of value capture is reasonably well accepted and understood, the second stage is much less clear. That is, it remains unclear how funded scientists set about ensuring other actors secure a share of

the value captured through their funded research. This is problematic as expectations continue to rise with respect to how publicly funded research serves societal, commercial and other interests beyond science advancement (Bozeman and Sarewitz, 2011; Bornmann 2013; D'Este et al., 2018, Fini et al., 2018). To this end, in this research we ask, what are the mechanisms through which value in use is captured in publicly funded research?

To address this question, we employ the exploration-exploitation framework (March, 1991) to theorise two distinct but interdependent stages of value capture: value capture in exchange through exploration and value capture in use through exploitation. This exploration-exploitation lens is important because it can provide new insights on how narrow value capture through exploration is enlarged through exploitation. More specifically, we argue that the initial stage of value capture in publicly funded research is through a negotiated resource exchange (Chesbrough et al., 2018; Frow et al., 2014; Vargo et al., 2008) between the science community and funding bodies in which, in return for their research proposal and associated expertise, scientists receive funding and then capture value through the exploration and generation of new knowledge. Following successful resource exchange, the value capture process turns to exploitation, which forms the central focus of our research, to translate and expand the use and development of the knowledge generated through the funded research. Ultimately, exploitation enables scientists to enlarge the value capture of publicly funded research. This research focus therefore addresses an unanswered and important issue in that, although the literature has highlighted how hybridising the logic of academic science enhances its innovation and value capture potential through the integration of exploration and exploitation (D'Este and Perkmann, 2011; Murray, 2010; Owen-Smith, 2003; Perkmann et al., 2019; Petruzzelli and Rotolo 2015), how this occurs in the context of publicly funded projects and programmes has not yet been examined.

This research draws on interviews with 41 health science funded principal investigators (PIs) in New Zealand (NZ) along with related secondary material. Studying PIs to address our research question is appropriate as they are the actors that, on the one hand formulate and lead successfully funded projects and programmes (Mangematin et al., 2014; O'Kane et al., 2015), and on the other hand have responsibility for facilitating value capture across a multitude of ecosystem actors (Cunningham, et al. 2018; Cunningham et al., 2019). Therefore, as the bridge between value capture in exchange and value capture in use in publicly funded research, PIs must proficiently pursue both exploration and exploitation to optimise value capture.

Our research provides a number of novel insights relating to the value capture perspective. Specifically, in conceptualizing a two stage process of value capture, we identify and propose two PI value capture in use mechanisms – boundary spanning and brokering – that serve to exploit and widen the impact and reach of funded research. We show that PIs span boundaries beyond those associated with commercial interests and propose that this boundary spanning mechanism facilitates efficient and deep engagement with ecosystem actors. We also show that brokering integrates and balances various combinations of ecosystem actors' interests identified among policy makers, funding bodies, industry, community end-users and universities. We further propose that brokering has some benefits that are less accessible through boundary crossing. Specifically, although more complex, when done effectively brokering avoids excessive stakeholder salience in terms of the value captured, and simultaneously provides the opportunity to significantly widen the overall reach of the value in use captured from publicly funded research. In essence, wide search and effective brokering presents PIs with the chance to identify a greater number of 'interest' recombination opportunities across various ecosystem actors for exploitation through their research. Finally, our research shows that publicly funded PIs are not only at the nexus of S2B interactions, their influence and visibility surpasses business to stimulate and synthesize broader engagement, making them key entrepreneurial agents within the public funding research ecosystem.

The remainder of this paper is structured as follows. Next in Section 2, we theorise around the interplay between the search for public research funding and value capture, and in so doing develop a conceptual framework for our research. We then outline the empirical setting for the study, namely publicly funded PIs, and we also speculate on some value capturing mechanisms they may employ. Section 3 presents the study's research design. In Section 4 we present our findings and in Section 5 we discuss the theoretical and practical implications of these. Section 6 outlines some concluding comments and areas for future research.

2. Value capture in the search for public research funding

Value capture refers to the process in which actors appropriate a portion of value jointly created in a relationship (Brandenburger and Stuart, 1996). While the type and pattern of value captured by individual actors varies across actor groups and institutional contexts, in general we can distinguish between two stages of value capture, namely value capture through resource exchange with other actors and through use of an innovation (Chesbrough et

al., 2018). These two stages of value capture can be understood as a sequential process, with value in exchange first resulting in value creation and capture during resource acquisition, and then subsequent value capture occurring through resource utilization (Eggert et al., 2018), at which point the embedded value potential is released (Chesbrough et al., 2018). These ideas help to conceptualise the mutually dependent stages of value capture in publicly funded research, namely scientists' initial search for research funding and the subsequent undertaking and dissemination/translation of the research. To more clearly explain the interplay between value capture and research funding, we employ the exploration-exploitation framework (March, 1991) to theorise two distinct stages of value capture: value capture in exchange through exploration and value capture in use through exploitation.

2.1 Value capture in exchange through exploration

One perspective on value capture is that it takes place through co-creation, a process of joint production between actors (Prahalad et al., 2004; Vargo and Lusch, 2004) in which they collaborate and combine complementary resources (Frow et al. 2016; Gronroos, 2008). Resource exchange and integration is initiated because actors lack the resources necessary to achieve their objectives alone (Frow et al. 2014). Actors evaluate resource gaps and address these through engagements that will provide access to needed resources (Frow et al. 2016; Frow et al. 2014). Chesbrough et al. (2018, p.934) describe a process of value negotiation to explain how value capture occurs though value in exchange, with actors 'negotiating access to and or ownership over resources in return for the provision of value to an exchange partner'. The value propositions that actors respectively hold are often themselves co-created through dialogue, knowledge sharing and negotiation for resources (Frow et al., 2014).

Applying this logic to the public funding of research, on the one hand members of the research community hold particular research expertise but also have scholarly objectives and resource gaps related to achieving these. To address these resource gaps, they apply for funding but how they present their objectives within grant proposals is heavily influenced by the criteria of the funding call (O'Kane et al., 2015). On the other hand, funding bodies, who seek new knowledge and evidence to support/inform policy priorities, possess research funds within a range of funding calls, many of which are influenced by bottom-up or extant insights from the research community. Thus, a continuing negotiation exists as the respective value propositions are formed and interact. Just as firms, in the absence of actually integrating stakeholders' insights and knowledge, are restricted to proposing value (Vargo et al., 2008; Vargo et al., 2004), researchers and funding bodies do not capture value until they exchange

resources through productive interaction, namely a programme or project grant proposal is funded. Once successfully funded, projects and programmes represent a boundary object at the interface or 'joint sphere of the interaction' (Marcos-Cuevas et al., 2016) between the respective value propositions of the research community and funding bodies.

The value captured through this exchange can be conceptualized as knowledge exploration, of which the essence is "experimentation with new alternatives" (March, 1991, p85). In comparison to privately funded research which often results in less novelty, shorter time frames and more incremental innovation (Sauermann and Stephan, 2012), publicly funded research typically mobilizes science teams around longer-term activities with high outcome uncertainty. With the expectation from public funders that new knowledge will be generated, original knowledge trajectories and innovative ideas are proposed, explored and discovered through wide search, experimentation and risk taking (March, 1991; Levinthal and March, 1993). A number of scholars highlight how important it is that funding bodies support such explorative research endeavours (Heinze et al., 2009; Azoulay et al., 2011 and Laudel, 2006). Value capture in exchange through exploration is also underpinned by an academic science logic. This logic prioritises wide dissemination of newly created knowledge through publication, rather than practical application (Nelson, 1959), to maximise impact (Dasgupta and David, 1994). Career satisfaction is most associated with the scientific priority (Merton, 1957) and status (Latour and Woolgar, 1979) that arises through this knowledge generation and dissemination.

However, there is pressure for value capture from publicly funded research to expand beyond value in exchange through exploration and scholarly achievement. Indeed, evaluations of research quality in publicly funded research are increasingly incorporating societal outcomes and commercial impact as well as scientific results (Bozeman and Sarewitz, 2011; Bornmann 2013; D'Este et al., 2018). In particular, D'Este et al. (2018, p.1) emphasize that while science impact prioritises recognition among knowledge producers, societal contributions need to resonate with audiences outside of academia including those interested in "current and/or future social, environmental, economic, and other needs". Furthermore, Fini et al. (2018) point out that impact through science must be relevant to market audiences while societal impact, which incorporates a "change or benefit to the economy, society, culture, public policy or services, health, the environment, or quality of life from new or improved products or services based on scientific knowledge" (p.8), should be relevant to a wide range of stakeholder audiences. Thus, to maximise value capture, exploration must generate demands for new knowledge that can be further refined and

extended (March, 1991). This can ensure the beneficiaries of publicly funded research expand beyond the science community and funding bodies. To this end, we next theorise a second stage of value capture, namely value capture in use through exploitation.

2.2 Value capture in use through exploitation

After value in exchange has been achieved further value capture can occur through value in use (Ballantyne and Varey, 2006; Macdonald et al., 2011). Chesbrough et al. (2018) describe a process of value partake which emphasizes how value capture occurs when one actor secures a share of another actor's value creation activities from using or applying the focal actor's resources or value offering. Thus once funded, scientists and their teams can achieve further value capture by leveraging other stakeholders' benefits from engagement with their research. This can be understood as value capture in use through exploitation. Knowledge exploitation refers to "the use and development" of existing knowledge (Levinthal and March, 1993, p105). With greater certainty around research outcomes, value capture through exploitation provides a means of heightening the use of and return from research results. It widens the application and reach of new knowledge explored, to benefit and meet the needs of a wider span of audiences.

To exploit their research which has been explored at the early stage, academic scientists must diversify the logics associated with their work (Greenwood et al., 2011; Kraatz and Block, 2008). The most prominent reference to this in the literature relates to the overlapping logics of academic science and commerce (Dasgupta and David 1994; Owen-Smith, 2003; Murray, 2010). While there is concern that exploiting research through commercial means damages the fabric of academic science (Blumenthal et al., 1997), the potential for complementary value capture between both logics is reasonably well established. On the one hand, engagement with industry is often undertaken with the purpose of supporting the core academic logic, or further enlarging value capture through research exploration. Specifically, engaging with industrial actors who have an interest in exploiting research outcomes provides academics with a means of progressing their exploratory research through learning, idea generation and access to funds (D'Este and Perkmann, 2011; Perkmann and Walsh, 2009). On the other hand, the benefits arising from industry engagements can be manifested in exploitative value capture through use. For example, the knowledge created through academia helps to develop capabilities and tacit knowledge within national innovation systems (O'Kane et al., 2018; Patel and Pavitt 1994), expand research networks (Malo, 2009; Rosenberg 1992), provide firms with new methodologies,

instruments and knowledge (Bishop et al., 2011; Malo, 2009; Mowery and Sampat. 2004; Roessner, 1993) and enhances firm innovation (Mansfield, 1991; Perkmann and Walsh, 2007; Zucker, Darby and Armstrong, 2002).

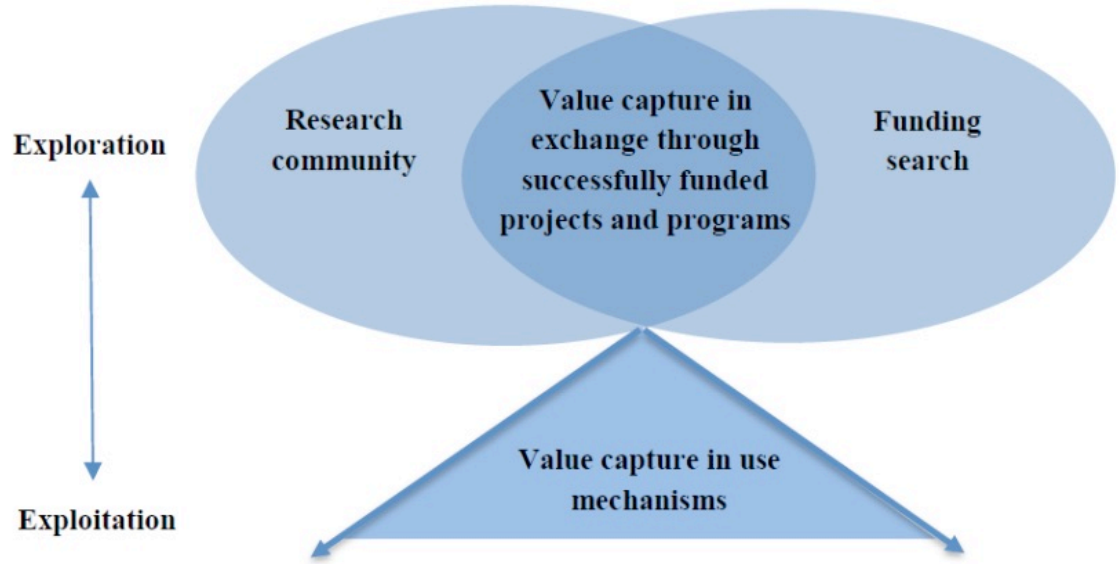
Emphasizing the importance and complementarity of both logics for value capture, Petruzzelli and Rotolo (2015) show how the deep rooted diversity that characterise academic-commercial collaborations better enable value capture as they provide a means of effectively balancing exploration and exploitation activities. Specifically, the authors show how combining academic and commercial logics in R&D serves to support and enhance innovation outcomes from science, particularly when firms utilize broad and science based search activities. Likewise, in their examination of University-Industry research centres, Perkmann et al. (2019) refer to the importance of purposefully bolstering, leveraging and hybridising the dominant logic of academic science in order to facilitate value capture through exploitation for wider minority (i.e. commercial) logics that sit outside knowledge exploration and publication.

Of course cross-boundary engagements for exploitation and value capture in use are represented by minority logics beyond commercial interests alone. For instance, Bush (1945) makes the point that science has the capacity to address a range of societal challenges related to security, economic development, disease, agriculture and wellbeing. Latour (1983) argue that in order to effectively achieve and expand value capture in use, academic scientists must overcome the natural disinterestedness present among various stakeholders external and enlist their attention in the research. When done effectively, the exploitation of the value captured through exploratory knowledge generation holds the potential "to persuade others of who they are and what they should want", thereby making their interests inseparable from the research. (Latour, 1983, p.144).

Overall, as illustrated in Figure 1, in the search for and undertaking of publicly funded research, we suggest a two-stage process of value capture beginning with knowledge exploration and being followed by knowledge exploitation. The first stage is realised through resource exchange and represented in funded projects and programmes. The second is accomplished though extending the reach and use of the research. More precisely, to optimize the value capture process, knowledge that is explored must identify opportunities for further exploitation, while knowledge that is exploited must have been generated at the early stage. However, the enabling mechanisms through which this value capture in use occurs remain poorly understood. That is, it remains unclear what mechanisms are used to exploit funded research projects and programmes in a way that widens its value capturing reach, and for

whom. Consequently, our research question asks: what are the mechanisms through which value in use is captured in publicly funded research? We next present details on the empirical setting selected to address this research question and in so doing speculate on some of the value capturing mechanisms that may be employed.

Figure 1: Conceptual model of value capture in publicly funded research



2.3 Empirical setting: Publicly funded principal investigators

This research focuses on the value capturing role of publicly funded principal investigators (PIs). Studying PIs to address our research question is appropriate as they are the actors that formulate and lead the successfully funded projects and programmes, which we conceptualize (see Figure 1) as the boundary objects linking the value propositions of the research community and funding bodies. PIs in fact are defined as "lead scientists on publicly funded large-scale research programs" (Cunningham et al., 2018: 137). It is PIs that are responsible for assembling a team to carry out a funded research project or programmes under their leadership (Melkers and Xiao, 2012).

To this end, PIs are distinct members of the research community who excel in knowledge generation and are well positioned for knowledge sharing. Such characteristics enable PIs to pursue both exploration and exploitation. PIs firstly capture value in exchange through exploration of knowledge when their grant proposals are successfully funded. The literature offers some support for this view. Mangematin, O'Reilly and Cunningham (2014)

make the case that funded PIs are a linchpin of knowledge transformation through their formulation of novel research avenues and programmes. It is also shown empirically that many PIs are exploratory in their research approach, shaping riskier, longer term and more novel knowledge trajectories when applying for funding (O'Kane et al., 2015). Kastrin et al. (2018) find that, in comparison to the average performance of active researchers, funded PIs have longer (i.e. publication span) and more productive research careers. Furthermore, Rotolo and Petruzzelli (2013) find that scientists who hold a central position in their science network, which corresponds to PIs central position in coordinating research teams, have (up to a certain point) higher scientific performance than those in less central positions as they are better able to diffuse their knowledge among science networks. Moreover, this positive impact is greater when a scientist is more exploratory in their approach, utilising diverse knowledge sources and broad search as they will then have greater "knowledge recombinant opportunities for the creation process compared with the more isolated colleagues" (Rotolo et al., 2013; p.651).

Although it is generally understood that PIs are "responsible for all activities related to the grant including budges, personnel management, data collection, periodic progress updates and submissions of findings the funding agency" (Lindgreen et al., 2019, p.238), recent scholarly attention (Cunningham et al., 2016; Cunningham et al. 2018) has begun to draw attention to the broader value creating and capturing potential of PIs beyond the acquisition and management of research funding. It is argued that PIs enact "top down triple helix policy objectives and ambitions for different industry and research domains that have economic and societal impacts" (Cunningham et al., 2016: 779). Although intriguing, to date these insights have not being supported with empirical evidence, thereby leaving the actual mechanisms and cross-boundary engagements by which they capture value in use through exploitation unaddressed. As the bridge between value capture in exchange and value capture in use in publicly funded research, PIs' responsibilities in this regard make them key knowledge gatekeepers (Burt, 2004) for the diffusion and translation of knowledge to other economic actors (Petruzzelli, 2008). Examining how they translate their research and extend its reach provides an opportunity to better understand how value is captured for use and for whom in publicly funded research. In the paragraphs that follow we draw on the emerging literature on PIs to speculate how such value capture through exploitation occurs.

2.3.1 PI value capture in use through boundary spanning

Leifer and Delbecq (1978, p. 41) describe boundary spanners as those actors that operate at the edges and who link the organisation with important elements in its environment. In a review of the boundary spanning literature, Paraponaris et al. (2015) also highlight how boundary spanners help with information exchange and with accessing key resources and expertise. The emerging literature on PIs indicates they may enact a similar boundary spanning role to capture value through exploitation of their research. For example, within the university PIs span academic boundaries to engage in proof of concept processes (McAdam et al., 2010) and spin-off formation (Del Giudice et al., 2017) to further the commercial potential of their research. O'Kane (2018) finds that PIs forward integrate and interact more collaboratively with Technology Transfer Office (TTO) executives to formulate impactful grant applications and to capture IP in their research. External to the university, a number of scholars have highlighted PIs' boundary spanning role with industry (Baglieri and Lorenzoni, 2014; Casati et al., 2014). Kidwell (2013) find that, in order to achieve their scholarly and commercial goals, PIs identify structural holes and then address these through purposeful boundary spanning activities. Boehm et al. (2013) highlight the importance of enduring S2B collaborations and how industry actors become loyal to and seek out particular PIs for science commercialisation. In a later study, the same authors show how PIs establish stakeholder networks with industry, first identifying then exploiting market needs (Boehm and Hogan, 2014). Furthermore, Baglieri et al. (2014) illustrate how PIs straddle their roles as lead academics involved in technology development and lead users operating within spin-off firms, the latter allowing PIs to operate closer to, and to better understand, relevant markets.

2.3.2 PI value capture in use through brokering

Literature on value capture also incorporates a broader network or ecosystem perspective whereby value is captured through interdependencies between multiple 'economic and social' actors (Vargo et al., 2008. p.5), as opposed to interactions between just two parties (Vargo et al., 2004). Thus, value is captured collectively among multiple stakeholders within the ecosystem (Lundberg et al., 2012; Merz and Vargo, 2009). For example, according to Reypens, Lievens, Blazevic (2016), value is co-created at the network level and then captured by individual stakeholders. More specifically, Reypens et al. (2016) argue that diverse stakeholder collaborations represent 'value spaces' and individual stakeholders can leverage value utilising their distinct position and needs within the network. In a similar way, Canhoto et al. (2016) suggest it is ultimately the 'end beneficiaries' who determine the nature of value capture. Pera, Occhiocup and Clarke (2016) also describe how value capture can occur even

when diverse stakeholders with conflicting and sometimes oppositional identities and agendas temporarily coexist. Pera et al. (2016) show how ecosystem stakeholders do not require value alignment in order to contribute to and receive value capture, instead, a negotiated ecosystem occurs in which stakeholder distinctiveness is embraced, but equally chaos and individual stakeholder dominance is avoided.

Consistent with this form of value capture, literature on knowledge brokers details how these actors act as intermediaries that transfer and recombine knowledge between two or more groups that appear otherwise disconnected (Paraponaris et al., 2015). In particular, brokers are effective in collecting and communicating information between knowledge producers and users (Howells, 2006). They generate and transfer innovative ideas and solutions when "they use their in-between vantage points to spot old ideas that can be used in new places, new ways, and new combinations" (Hargadon, 1998; Hargadon and Sutton, 1997, p.158; Kirkels and Duysters, 2010). What is key to the effective recombination and transfer of this knowledge is brokers' ability to translate it in a meaningful way to various users (Boari and Riboldazzi, 2014; Hargadon et al., 1997). As explained in social capital literature (Granovetter, 1973), it is one thing to have links with different disconnected groups in a network, however, it is another thing to be able to repackage and transfer knowledge from the diverse sources of ideas and know-how at hand in a way that is valuable to others in the network. Thus, while boundary spanning helps to address structural holes with particular external groups, brokering is more suitable for understanding how this is done within a network or ecosystem.

Once again, the emerging literature on PIs indicates they may enact a similar brokering role to capture value through exploitation of their research. Conceptually, Cunningham et al. (2018) make the case that PIs utilize simmelian ties to generate, co-create and capture value for multiple stakeholders (e.g. users, regulators, firms, government). Value destruction and loss of public good impact, features which can arise through excessive individual stakeholder dominance and self-interest, are proposed to be minimised by balancing individual stakeholder value motives against collective value motives. More recently, Cunningham et al. (2019) present a PI centred governance framework highlighting how PIs broker value creation for multiple stakeholders, thereby highlighting PIs pivotal role in developing and growing entrepreneurial ecosystems through their research. Specifically, the authors map out the value creation indicators (i.e. economic and non-economic benefits) for multiple entrepreneurial ecosystem actors and institutions together with the problem categories (i.e. costs) and relevant solving mechanisms or governing capabilities PIs have for

navigating and adjudicating tensions that arise. Empirically, Kastrin et al. (2018) find that PIs are the bedrock of high performing co-authorship networks in science and when the PI is omitted, the network becomes fragmented. In a related study on the Directors of National Science Foundation organized research centres, Daniel, Hempel and Srinivasan (2003) show how these actors must develop and implement innovative programmes that simultaneously satisfy the needs of the centre, funder and industry. Finally, albeit not focusing specifically on PIs, Rotolo et al., (2013) find that establishing cross boundary ties helps scientists to better exploit the social capital available from their central position within their network, thereby increasing the diffusion and impact of their research across multiple communities. We next present the study's research method.

3. Research design

3.1 Research Setting

This study focuses on New Zealand (NZ) Health Research Council (HRC) funded PIs. The HRC was created in 1990, taking over from the Medical Research Council that had been in place since 1951, technically making the HRC the oldest specialist research-purchasing agency in New Zealand (HRC, 2011). The HRC is the primary government funder of NZ health research. As stated in the HRC's 2018 Annual Report (p.6) "we are required to give effect to the general policy of the Government in relation to health research when performing our role". In 2019/2020 the HRC funded $123 million in health research, an increase of $97 million since 2016 (NZ Health Research Strategy 2017-2027). The annual funding round uses stringent peer review processes, involving 240 expert committee members, 450-500 national and international experts and taking about nine months in total to complete (HRC Annual Report, 2017). Examining HRC funded PIs in NZ to address our research question - "what are the mechanisms through which value in use is captured in publicly funded research" - is appropriate for a number reasons.

First, in terms of knowledge generation, NZ has a vibrant research, science and innovation ecosystem. NZ's number of publications per researcher is approximately double the OECD average. Productivity per researcher is also high at 2.7 times the OECD average and top among the Small Advanced Economies (RSISPR, 2018). Indicators of research quality through citations are also consistently ahead of the OECD average (RSISPR, 2018; SISPR, 2016). NZ health research is particularly strong with health research contributing to more than one third of all academic outputs (MBIE, 2015) and medicine reported to be the area in which NZ scholars publish the most highly cited research (RSISPR, 2018). More

specifically, from 2011-2015 field-weighted citation impact for NZ publications in medicine was 1.72, which is significantly above the OECD average of 1.23; and publications in health professions was 1.34 compared with an OECD average of 1.16 (NZ Health Research Strategy 2017-2027). Within this, HRC funded research is highly cited internationally and outperforms other NZ funding sectors on quality and impact of publication outputs (HRC Annual Report, 2016). Thus, HRC funded research in NZ represents a promising platform of knowledge generation that aligns with the first stage of value capture in our conceptual framing, namely value capture in exchange through exploration.

Second, HRC funded research provides a promising setting to examine the focal point of our research, namely value capture in use through exploitation. At a governmental-level, the NZ Health Research Strategy 2017-2027 prioritises the need to "create a vibrant research environment in the health sector". To accomplish this, the national health strategy articulates two value capture in use pathways for "translating research findings into innovations, policy and practice". These pathways are 1) "Translating ideas from research by developing new products, processes, and approaches" and 2) "Taking up and implementing those new products, processes and approaches in policy and practice" (NZ Health Research Strategy 2017-2027). Aligned with these priorities and translation pathways set out by its chief sponsor, the HRC holds a vision of "Improved health and quality of life for all", thereby signalling that its funding will be awarded on the basis of research impact, as well as assessments of scientific quality and the track record of the science team (HRC Annual Report, 2018). Details extracted from the NZ Health Research Prioritisation Framework, which was published to assist with the implementation of the aforementioned national health strategy, provide further evidence on the appropriateness of HRC funded research for examining value capture in use through exploitation. For instance, within this prioritisation framework it is specified that health funded research should "consider building on existing excellent research to further the impact of prior investment and discoveries". Prospective PIs are encouraged to "think about how the downstream impact or uptake of research could be increased through changes in design, including co-design" and to "always consider the downstream impacts of their research on health equity in New Zealand and articulate this in funding applications". Additionally, it is recommended they "engage with next-users, end-users and communities as appropriate" (NZ Health Prioritisation Framework, 2019).

Thus overall, with a stated strategic goal of "making a difference through new knowledge with clear pathways to impact for health and economic gain" (HRC Annual Report, 2018), it is apparent that HRC funded PIs are tasked with capturing value through

both exploration and exploitation. We therefore regard the setting as relevant and appropriate for addressing our theoretically informed research question on the heretofore neglected mechanisms through which value in use is captured in publicly funded research.

3.2 Data Collection

A repository of secondary material was gathered. This included NZ health policy reports as well as HRC annual reports, application forms and supporting material for researchers including guideline documentation, FAQ sections and video clips. We compiled a dataset of all HRC funded projects, programmes, feasibility studies and emerging research grants over a two-year period. We contacted PIs from these four grant types to request an interview. In total, 110 PIs were contacted with 41 agreeing to participate. All but two of the PIs were university based, the outliers based in hospitals having recently moved from a university position. Twelve were new PIs (first successful grant) and 29 were experienced PIs (i.e., previously and/or currently held a grant). There were 23 male and 18 female PIs (see Table 1). Our sample included a range of different funding types (in terms of duration and funding amount) including projects, programmes, feasibility studies and emerging research grants This sample was conducive to gathering diverse and rounded insights on our research question.

Table 1: PI titles and project details (type, duration and value)

PI Details			Project Details		
Gender	**New/Experienced**	**PI Title**	**Project Type**	**Duration**	**Project value**
Male	E	Dr - Research Leader	Project	36 months	$750,000-$1m
Female	E	Research Professor	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Project	36 months	$1m-$1.25m
Male	E	Ass Professor	Project	24 months	$250,000-$500,000
Female	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Male	E	Research Professor	Project	36 months	$750,000-$1m
Male	E	Professor – Clinical Director	Project	18 months	$550,000-$750,000
Male	E	Research Professor	Project	24 months	$750,000-$1m
Female	E	Ass Prof - Senior Research Fellow	Project	36 months	$1m-$1.25m
Male	N	Dr – Senior Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor- Research Director	Programme	60 months	$4.25m-$4.5m
Male	E	Professor – Research Director	Project	14 months	$250,000-$500,000
Female	N	Dr – Senior research Leader	Feasibility	12 months	$0-$250,000
Female	E	Professor – Research Director	Programme	36 months	$3.5m-$3.75m
Female	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Female	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Male	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Female	E	Dr – Senior Research Fellow	Project	36 months	$500,000-$750,000
Female	N	Dr – Senior Lecturer	Emerging research grant	36 months	$0-$250,000
Male	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor – Research Director	Project	36 months	$1m-$1.25m
Female	E	Research Professor	Feasibility	12 months	$0-$250,000
Female	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor - Research Director	Programme	60 months	$3.5m-$3.75m
Male	E	Research Professor	Feasibility	12 months	$0-$250,000
Male	E	Dr – Senior Research Fellow	Project	60 months	$1m-$1.25m
Female	E	Professor- Deputy VC of Research	Project	36 months	$1m-$1.25m
Female	N	Dr – Senior Lecturer	Feasibility	12 months	$0-$250,000
Male	E	Professor – Research Director	Programme	60 months	$4.75m-$5m
Female	E	Ass Professor/Ass Dean of Research	Feasibility	12 months	$0-$250,000
Male	E	Professor – Research Director	Programme	36 moths	$4m-$4.25m
Male	E	Dr – Medical Consultant	Project	36 months	$1m-$1.25m
Male	N	Dr – Research Leader	Emerging research grant	32 months	$0-$250,000
Female	E	Dr – Research Leader	Project	30 months	$1m-$1.25m
Male	E	Dr – Clinical Specialist	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Female	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Male	N	Dr – Senior Research Fellow	Emerging research grant	24 months	$0-$250,000
Female	E	Dr – Research Director	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Female	E	Dr – Research Leader	Project	36 months	$1m-$1.25m

Semi-structured interviews lasted between 50 and 90 minutes. Interviews broadly focused on four areas: 1) competitive funding and careers, 2) research topic/novelty/impact, 3)

motivations for being a PI, and 4) PI challenges and critical success factors. While experienced PIs could draw on insights from previous funded research, all informants had ongoing funded research projects at the time of interview so problems with recollection were reduced. Before each interview, case profiles on PIs were prepared and examined from secondary material. This helped to ensure interview discussions were more in-depth and informative. To encourage open discussions, all participants were assured their anonymity would be preserved (Gioia, Corley and Hamilton, 2013). Interviews became more structured as interesting themes emerged in preliminary note taking and analysis. After 41 interviews, the occurrence of significant repetition and an absence of new insights within the data suggested a saturation point had been reached (Strauss and Corbin, 1998). 780 pages of transcripts were reviewed by two research assistants and sent back to interviewees for confirmation, and in most instances, editing. During and after primary data collection, further secondary material was collected. Table I provides an overview of data sources and use, illustrating how triangulation was incorporated in our study (Gibbert, Ruigrok and Wicki, 2008).

Table 2: Overview of sources of data collection

Data Sources	Use in Analysis
Semi-structured interviews: 41 interviews with new (12) and experienced (29) PIs amounting to 780 pages in transcripts.	Understand why being a PI is important in science careers? How do PIs position/deiver research for funding body? Identify key motivations, challenges and CSFs for PIs
Secondary data material: HRC application forms and supporting material for researchers including guideline documentation, FAQ sections and video clips.	Interview preparation – understand health research context and PI interpretations of funding body expectations. Data analysis – support and crosscheck primary data from semi-structured interviews
Personal webpages, CVs, and published university or HRC research highlights	Develop case profiles of PIs and their research careers and accomplishments ahead of interview.
General media, HRC and/or university press coverage on the research activities of PI informants	Track research developments post-interview and corroborate interpretations of primary data analysis.
HRC annual reports (2012-2017) and health policy documentation (e.g. New Zealand Health Research Strategy 2017-2027)	Track government policy and funding environment developments to gather information on the empirical context.

3.3 Data Analysis

Our analysis involved two distinct phases. First, wide ranging secondary data (e.g. annual reports, application forms, guideline documentation) from the funding body were

independently coded by two members of the research team. Guided by insights from the literature on how value can be captured for use and for whom, the purpose of this stage of coding was to identify 'expectations of value capture' within the HRC from this secondary data. Discussion and cross-checking of respective codes enabled the two researchers to eliminate duplicates or ambiguous ideas and to consolidate the most prominent and relevant codes into distinguishable themes – see Table 3 for illustrative examples on these themes relating to value capture expectations and the corresponding data.

Table 3: Illustrative coding examples on funding body value capture expectations

Themes	Illustrative secondary data from HRC annual reports and policy documents
Economic impact	"The HRC supports research that has the potential to…produce economic gain for New Zealand".
Societal health	"Research funded through New Zealand Health Delivery must have a tangible, positive impact on health delivery in the short-to-medium term (defined as within five years of the contract)".
Science impact	The HRC state within their assessment and scoring criteria that the research findings "should be original and innovative". The HRC are interested in whether the proposed work aligns with research currently being conducted either nationally or internationally or how original the approach is etc. They state "Include information that you feel is essential for the reader to better appreciate or understand why you feel your proposed research should be undertaken".
Policy/clinician/patient	"The HRC acknowledges the need to facilitate and promote the uptake and application of research findings by increasing engagement of end-users in research. This would be possible by partnering with end-users such as clinicians, planning managers and policy makers – who understand the research and its relevance. An indicator of performance is based on the "Percentage of research contracts that have clear end-user involvement"
Commercial impact	"…the HRC will support research that creates new knowledge that can be turned into products and processes that have commercial value" "(PIs') host institutions will use their best endeavours to commercialise and maximise intellectual property benefits that may arise from HRC funded contracts"
Science – collaboration	Part of the HRC's strategic goal to "Enhance the value of the organisation" includes promoting international research collaborations by participating in "beneficial international alliances". For example, for HRC Research Programmes they state that "collaboration between research groups and institutions is encouraged".
Societal/clinician/policy/ innovation	"Health outcomes are still the primary consideration although economic outcomes are also important to New Zealand. The HRC has a broad view of how health research contributes to economic gains, such as through improving the health and productivity of our population; improving the efficiency and effectiveness of our health system; and generating value through intellectual property and innovation".
Science/society/industry	"Stimulating growth with a healthy research ecosystem, people, capacity, skills and opportunities needed for a healthier, more prosperous future".

Second, interview transcripts were coded by both researchers, once again guided by themes within the literature on exploitative value capture in use, but also from the aforementioned value expectations identified in the secondary data. This was followed by an inductive round

of coding (Giola et al. 2013) to openly explore additional insights on value capture in use not identified through the aforementioned theoretically guided coding process. Here coders moved iteratively between the interview transcripts, inductive insights that were emerging, as well as those themes identified in the initial theoretically guided stage of coding. Cross-checking between the researchers again helped to refine and consolidate the final set of first order codes to emerge from this stage of the analysis. Next, using axial coding (Strauss et al., 1998), quotes relating to all codes identified in these two stages of analysis were re-evaluated by researchers with the purposes of identifying 1) their relevance as a form of PI value capture in use through exploitation for specific ecosystem actors/needs, and 2) the mechanism by which this value capture was being achieved by the PI. Illustrative evidence on this phase of analysis is presented in Table 4. Next we present our research findings from this analysis.

Table 4: Illustrative coding on PI value capture in use and relevant capture mechanism

PI value capture use: code	Illustrative primary data	Ecosystem actor/need	PI mechanism
• Community • Public funded health • Health productivity • Health quality	"Realistically the **country** can't afford to pay for enough therapy for people who have a stroke or have **Parkinson's disease**, it is just not sustainable, so one of the things about this project is looking at is a type of therapy where you get **everybody in the room** at once for their **therapy** so it is much **cheaper**. Those types of outcomes make it attractive"	PI synthesizes government, clinicians, patients	Brokering
• End users – children & community • Health quality - dental • Wellbeing	"For me it is more about the **community**, working with the **children** and getting out there and trying to improve **health outcomes** and make a shift in New Zealand for **children**. One of the things we were commended on actually was that we weren't solely looking at clinical outcomes, we were looking at **holistic outcomes like quality of life and dental anxiety**"	PI to society (children)	Boundary spanning
• Public funded health • Health care access • Patients - family • Employment • Productivity	"I think **health and economics** are so highly **interconnected** that they probably are the same thing especially because we have **publicly funded health care.** My research has implications for **society** in terms of physical **health care** but also **economically** in terms of **rates of employment** and financials because **parents** have been shown to take a lot more **days off more work**. That is a big selling point of my research"	PI synthesizes government, society (parents) and industry	Brokering
• Population inequalities • Housing • Health quality • Families	"We want to **reduce inequalities** and we decided that research aimed at improving **housing** as a means of **improving health** was the way to do this partly because housing and its **quality and safety** is so down to earth for everyone. We worked in participation with **communities** so we got into doing translational research right from the beginning and I think that has been considered one of the strengths of our group"	PI synthesizes government and society	Brokering

4. Findings

In the next section we present findings in relation to our research question on the mechanisms through which value in use is captured in publicly funded research. Our findings provide evidence on two distinct capturing mechanisms utilized by PIs, boundary spanning and brokering, to exploit and expand the value of their funded research. We also provide evidence indicating that value capture through brokering has benefits that are less accessible through boundary crossing.

4.1 PI value capture in use as boundary spanner

We find that PIs extend the reach of their research to a number of external ecosystem actors who are typically more periphery to the conduct of science. For example, we find that a significant number of PIs close the divide and interact more closely with industry. Publicly funded research provides resources but also greater exposure for PIs to generate industry engagement. Although such engagement may not always be central to the funded research, and may be an avenue through which PIs supplement research resourcing, our data indicates that funding bodies welcome PIs pursuing commercial engagement and establishing industry connections that may increase research impact through subsequent application. Together with Table 5, the following comment from a PI informant supports this point.

"We've made a deliberate strategic decision to look for commercial funds…we try and answer questions that commercial companies have and hope to bring in a bit of profit or income stream that we can then support our core funded activities in the bio-medical health sphere."

PIs also close the divide between science and end-user communities among the more general population through their research. As illustrated in Table 5, funded PIs incorporate objectives related to research translation within their research agendas in which they acknowledge the importance of transferring benefits arising from their research to society. A number of PI respondents explained how, either through their own intrinsic motivations or their conformance to the expectations of funding bodies, they commit to aligning their research with the needs of society.

"My training is clinical so my focus and everything I do concentrate on whether it would actually make a difference for a person with a XXX disorder, so if it is not going to make a difference then I don't see any point in putting in the grant. I just need to know if it will really matter"

Government represent a third ecosystem actor that PIs connect with through their research. Our results provide evidence that PIs, despite the well-recognised subsidiary type nature of government-funding body relations, look to ensure that their research which is publicly funded is explicit about how it feeds into or responds to government policy. Illustrating this

point, our findings (see Table 5) show how a number of PIs, conscious of public resource constraints, familiarise themselves with policy priorities and articulate how their research can complement these, thereby offering a bridge between science and government objectives.

Table 5: PI value capture through boundary crossing

PI boundary crossing	Illustrative evidence	Value capture
PI-Industry	"When you're trying to build the commercial side, someone has got to go around talking to these people (firms) and keep doing the ground work. We try to make sure that this doesn't affect our ability to deliver our funded research. That time is paid for by one of my grants, but you know if you don't do that, you're never going to get the business" 'One industry player is interested in contributing research funding. It's a good opportunity to pick up a wee bit of extra money. They've got certain things they want us to do that normally a funder doesn't say anything about"	The research undertaken by funded PIs generates industry interest and engagement resulting in research expansion and application.
PI-Society	"What we're doing is essentially public good translation, that's the big motivation and challenge for me. Every conference now has a stream on translation. It's become a science itself, how you get things into practice for society" "HRC's scoring is really built around how important your problem is for the health of New Zealanders although it doesn't exactly say that. But realistically, if you are talking about a very particular injury rather than a global thing like diabetes or heart conditions or something like that it's really hard to get funded so you have to accept that"	Funded PIs undertake research and produce outcomes that are translated to benefit public communities and society.
PI-Government	"You can't escape the broader government environment in terms of what the focus of research funding is and this can change regularly. I don't particularly think say that XXX, which is what I am looking at, is flavour of the month in terms of current policy priorities. But even still in applying for funding you have to try and normalise it and justify it as a valid area of research within this (policy) context" "It is really difficult and you have to follow their (HRC's) agenda closely but I also understand that New Zealand is a small country and they (Government) don't have a lot of money and they will have specific things that they want to push and want evidence for"	When successfully funded, PIs undertake research projects and programmes that are aligned with and support needs within government policy priorities.

4.2 PI value capture in use as broker

An alternative mechanism by which PIs capture value in use is as knowledge broker. Our findings provide evidence that, through the exploitation of their research, PIs identify and synthesize needs across multiple ecosystem actors in publicly funded research. More precisely, as brokers, PIs do not only cross science boundaries to engage with a diverse range of ecosystem actors, they combine and balance expectations and interests across these different actors (Table 6).

The most predominant example of this brokering mechanism to emerge in our data relates to how PIs synthesize interests across government and society (i.e. community end-users), a finding that is consistent with the health science focus of our empirical context. Virtually all PI informants explained how they exploit their research to connect societal issues with government health policy. Societal issues included social housing, health service inequalities, elderly care, gender, legislative and health education, quality and cost of health care, wellbeing etc., while government issues primarily related to health policy formulation, drafting of legislation as well as public health care expenditure and access to care, thus overlapping considerably with the aforementioned societal issues. In addition to the illustrative evidence provided in Table 6, the following comments from informants illustrate how PIs synthesize and balance needs across society and government to capture value in use through their research.

"We all know about the obesity epidemic and the older population, putting them two together is going to be a major source of financial difficulties for the government so they are looking to reduce that burden. One way we can assist is by looking at particular problems within that. So strategically, you must always look at what the health agenda is, look at your own expertise, and then try to match those two together"

"This project addresses a relatively rare disease that costs a tremendously large amount of money to treat. The success is also attributable to some degree by the fact that it's a large Māori iwi which are affected with this condition and the declared priority that government health research has towards that group (was important) for our proposal as well"

A range of other combinations illustrating the PI brokering mechanism were identified in our data (see Table 6). For example, the aforementioned synthesis of government-society needs often incorporated industry interests, given that sub-optimal health policy and care delivery can have a detrimental economic impact through the lowering of firm productivity. Our data also shows how PIs' commercial engagements were sometimes initiated by industry as such collaborations could complement their own R&D activities and lead to innovations that could enhance healthcare delivery and outcomes for user communities. In other instances, our data showed how PIs exploited their research in a way that bridged connections between government and industry as they were well positioned to articulate the potential value in use of their research in a way that was synergistic to both stakeholder groups. It was also found that PIs forged stronger academic connections between their host institution and other universities and research institutes. Our findings provide evidence that funded research teams, through the coordinating role of PIs, develop working relationships with other world leading research groups in the area, a move which serves to enhance their universities' reputation and networks internationally. A final example of the PI brokering mechanism facilitating value capture in use relates to their fostering of capacity development in the area of science and technical human capital. More specifically, our findings provide evidence that

when forming their research teams, PIs anticipate and respond to expectations among funding bodies relating to capacity development, mentoring and succession planning in their research area. This in turn benefits universities and (potentially) industry and national economies through the provision of career and training opportunities in science, thus reflecting how connections between government, universities and industry are established through the brokering mechanism of PIs. The following comment from a PI informant further illustrates this point.

"The HRC are always looking to say, 'where is the next brain coming from in your lab? Who's next? Is it just you these days, are you it?' They really want you to show that when I sloth off there will be people behind me…reviewers love that, they think 'we've got this really bright young guy or woman coming forward with great stuff from the next generation and they're supported by some old cranky bugger who will add structure"

Table 6: PI value capture through brokering

PI brokering	Illustrative evidence	Value capture
PI-Government-Society	"We're trying to improve the conditions of people who have less choice in their housing. You know, is being in a mouldy home causing asthma and sending people to hospitals and doctors? So we are presenting cases that look at how a cost in a specific area would be really beneficial for everyone" "The whole issue about assisted dying is such a polarising issue. One of the things that worried me and that is motivating this study is what's happening in New Zealand with the end of life care bill that seems to be racing towards legislation, there's a push for legislation without us really knowing what's important to people" "We realised that if we wanted to make a change at a health policy level in New Zealand, then we needed some convincing material for government. The evidence isn't there for what they're doing in this area now and the science is terrible. We wanted to compare it with what we could do better in order to change the way we do things"	Funded PIs undertake research that connects societal issues to government policy – for example connecting issues related to poverty, health epidemics, clinical care quality and access with government health expenditure. Connecting society with proposed legislation change, ensuring health policy related to health service delivery is informed by best practice
PI-Government-Industry-Society	"We explained that the research would decrease the occurrence of absenteeism from school where parents have to take days off. Also, there is the GP visits and the medication so we said we could improve the health of children and have an economic impact" "We are trying to come up with an inexpensive shoe which meets the needs of the XXX patients and whether it can actually reduce some of that pain and disability and impairments in the foot but at a very competitive price because at the moment people can't afford the good shoes recommended"	Funded research can lead to outcomes that decrease health expenditure, benefit economic productivity (e.g. job creation or limit absenteeism) and improve educational and health outcomes
PI-Industry-Society	"Companies are now coming to us and coming on board more and more because if our research does change the way things are done in this area, it's going to change the way they provide for their markets. I mean there are thousands of children out there so if we initiate changes, it makes a huge difference to the business of big dental companies"	Funded research generates industry collaboration that can result in improved products/services for society
PI-Industry-Government	"There was a period where I was going along to functions and cocktail parties for this (industry partner). I remember they flew me down to ### (corporate event) for a particular launch and I met with all the Ministers. So you have to be aware at some stages the PI becomes very important for the collaboration. They want someone	Funded PIs foster stronger connections between industry and government through research that is of mutual interest to both

	who is the face of the project and someone who can talk about the research"	parties
PI-University-University	"We have technology relationships going on where we develop a technology and give it to (them) and they'll develop something and give it to us. It is technology that is going to drive advances in this field so you just have to be connected" "Colleagues in XXXX developed a technology that allowed this question to be answered, it suddenly made things 50 times faster. We could adapt this technology to our needs the moment the technology became available"	Funded research groups, through the coordinating role of PIs, develop international networks that facilitate cross-institutional connections
PI-Government-University-Industry	"We had an application with an early career researcher…this guy was going to be doing the bulk of the work with the guidance from four experienced investigators. I try and turn that into a positive to say 'this is capacity building as we want this person by the end of this to have substantial research and project experience and they're going to provide a lot of creative input"	Through the coordinating role of PIs, funded research strengthens science and technical human capital available to universities and industry by offering careers and opportunities for capacity development in science

4.3 Comparison of PI boundary crossing and brokering mechanisms

As detailed in the preceding two sections, to exploit and expand the reach of their funded research, our results provide evidence on two value capturing in use mechanisms, PI as a boundary crosser and PI as broker. While evidence of boundary crossing was more prevalent in our data, in terms of which is more effective between boundary-crossing and brokering, we do not have data that can conclusively answer this question. However, our findings do provide evidence that the added complexity of brokering has distinct benefits that are less accessible through boundary crossing. Specifically, we find that brokering helps to guard against individual stakeholder dominance, where PIs become preoccupied with exploiting their research to meet the self-interested needs and expectations of one particular ecosystem actor to the detriment of the overall value in use captured in publicly funded research. As brokering requires both identifying and balancing the needs of multiple actors, it helps ensure PIs do not become overly narrow in their interactions or in how they capture value in use through their research. More precisely, an openness to identifying the needs of multiple ecosystem actors helps PIs consider a range of expectations when attempting to capture value in use, rather than focusing on serving the interests of one particular actor. In this way, the value captured through PI-led funded research can potentially have a greater reach. We briefly expand on this point next with some illustrative data offering support.

Consistent with our conceptuall framing, our findings show that PIs in the first instance are fundamentally motivated to capture value through exploration, scientific discovery and are committed to academic norms related to research originality, status and

peer esteem. As illustrated in the following comments, PIs wish to establish an international reputation through world leading research.

"I'm a scientist, I am driven to find out new things. In terms of recognition, it's the international stage that's important for me. Frankly I couldn't care less what they think about me in New Zealand. It's just irrelevant to me"

"Sometimes I think I am a little naive because most politics are local but I've always pitched myself to be recognised internationally by my peers and if I'm not, then I'm no good"

Together with status and reputation, PIs pursue novel avenues of research and use research funding to accomplish their scientific vision. They are motivated to be the best and to work with the best in their field. Again, a sample of comments from our findings illustrate these points.

"I concentrate on funding my eagerness to answer questions relevant to my overall agenda on the role of XXX. I want to achieve something in this area and you cannot do that if you spread your time or simply just simply follow funding. If you focus on something and address that issue appropriately then people recognise you and you develop a reputation worldwide"

"I am now collaborating with the best in the world so reviewers will know what we've done and they (will) know we're good and that we have delivered"

On the one hand, through brokering, PIs' commitment and motivation to achieve the aforementioned goals related to academic prestige serve to buffer against any tendency (deliberate or accidental) they may have to become preoccupied with the needs of one particular actor. For example, as illustrated in the following comments, PIs can grow frustrated with perceived government expectations related to funded research, but their own commitment to scientific excellence (and their commitment to the expectations of their host universities in this regard) serve to neutralise any tendency to prioritise needs that are excessively 'short termism' in nature.

"With respect, the government is all about innovation but they have no idea what it means. It is a buzz word and I find that really frustrating. (To them) it's applying something in a new way to achieve an outcome that's immediate and marketable. They want transfer to market in a short space of time with economic benefit. That is not real innovation with new thinking and really fundamental ideas"

"The HRC depend on the government and the government strangely enough don't see the forest behind the trees and they think more about today than the future, it's very short-sighted"

Similarly in the case of industry, our findings show that PIs' engagements with industry can become problematic when industry partners try and exert too much influence over the direction/focus of the research and how research outcomes should be utilized. Again, the brokering mechanism to capture value in use helps PIs manage such complexities as it allows them to leverage their own commitment to publish novel scientific developments, thus ensuring industry interests do not become too dominant.

"There can be some conflict around control of what to do with the data at the end of the project. Usually when things go pear shaped it's because it's a negative trial and they (industry) then want to be able to either not publish, which conflicts with my academic need to publish, or else try and find some remote secondary outcome which is positive to sort of move a product forward, which of course is scientifically not correct to do. So I have walked away in the past, in one study I said I want my name removed"

"It is important to engage with industry as industry driven research can solve specific problems that industry needs and that is important and appropriate. It is a mistake though if their involvement becomes too major a component of your research effort because if you drive your research solely by what industry knows it needs tomorrow, you will never make breakthroughs into what industry didn't know it needed"

On the other hand, brokering contrastingly ensures that PIs do not become blinkered and overlook the importance of broadening the impact of their research to other ecosystem actors beyond value capture through exploration. More specifically, once funded, PIs accept responsibility to expand the reach of the value capture in their research beyond the boundaries of academia. Through brokering, PIs can leverage the expectations and influence of other relevant ecosystem actors to ensure their funded research activities serve important interests beyond the more traditional scholarly expectations of knowledge generation and research quality. For example, the following comment from a research informant illustrates how PIs are careful to incorporate societal impact alongside scholarly outputs when capturing value through their research:

"When families ask what's next, how's the research coming along? I feel very lucky. Those are the people that I want to impress. If I can say 'we've got it. We can now say that your unborn kid is not going to have to have its stomach removed or is certainly not going to die of stomach cancer', then I just feel superb. That's much more important to me than my peers saying "well done, good science"

Other respondents explained how government expectations on research impact represent important interests that cannot be overlooked by becoming preoccupied with exploratory forms of value capture.

"You know a lot of scientists are very self-righteous in a way – 'we deserve it (money) because we're doing lots of fantastic fundamental research that will shed light on things etc.' but they don't realise that the people in Treasury who hold their purse strings don't understand or necessarily value that"

"No matter how good you feel the question is, at the end of the day if it is outside the remit of the government's health agenda they're not going to fund it. No matter how good the science, it could be par excellent innovative science, it may not get funded because it doesn't fit within their agenda"

Similar to this point on government interests, brokering allows PIs to consider funding bodies' expectations with regard to research impact and value capture, which again ensures that PI motivations related to science advancement and value capture through exploration are balanced against the need to translate research for use to the benefit of other ecosystem actors. A number of comments illustrate this point. In the next section we discuss the implications of our research findings.

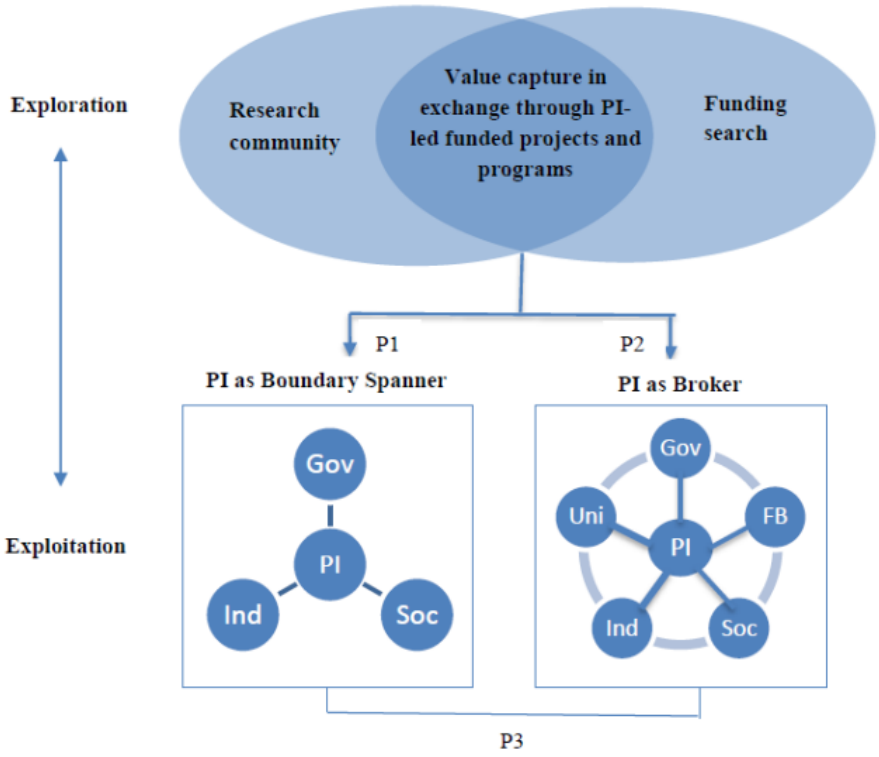
"It is clearly in the HRC strategy. The research they particularly welcome is the research which has more or less immediate impact on improving health outcomes"

"Given the pressure to show short-term outputs and immediate application it leads to real starvation of the more speculative, long-term and fundamental research. I don't think that's the intention of the HRC or its panels. I think they try to be fairly balanced but that's the result"

5. Discussion

In this research we conceptualized PI-led projects and programs as the means by which value is captured in publicly funded research, first in exchange through exploration and then in use through exploitation. In the context of funded PIs, our research validates the notion that value can be captured through resource exchange among relational actors (Chesbrough et al., 2018). Furthermore, based on this framing, we add to the literature by identifying the mechanisms by which the value capture in this research is translated and captured in use by PIs through exploitation. Our findings lead to the development of a new conceptual model (Figure 2) on value capture in publicly funded research. In it, we specify two value capture in use mechanisms – boundary spanning and brokering - PIs employ to extend the reach and impact of funded research. In the paragraphs that follow we expand on this model, developing a number of propositions relating to the value capture in use perspective in publicly funded research, before outlining the overall contribution of our research and its implications for practice.

Figure 2: PI value capture in use mechanisms in publicly funded research



The first value in use through exploitation mechanism uncovered in our research relates to boundary spanning (Paraponaris et al., 2015; Leifer et al., 1978) whereby PIs exploit their research to address structural holes in the public research environment, aiding information and resource exchange with key ecosystem actors. While extant literature has made reference

to PIs' boundary spanning roles with specific stakeholders, predominantly their host institution (Cunningham et al., 2014; Kidwell, 2014) and industry (Baglieri et al., 2014; Boehm et al., 2014; Casati et al., 2014; Kidwell, 2013), our findings develop these ideas further to show how PIs translate the impact and use of funded research beyond commercial interests. Indeed, our study provides new evidence that a key determinant of value capture in publicly funded research is PIs' ability to enlist the attention of a diverse range of otherwise disinterested ecosystem actors (Latour, 1983), such as policy makers, societal end user communities and commercial agents. For example, we find that PIs' research is often closely aligned with and supports the needs of government policy priorities; producing outcomes that are translated to benefit public communities; or undertaking research that generates industry interest and opportunities for commercial application. Thus, through boundary spanning engagement with various ecosystem actors, PIs extend value capture in publicly funded research by expanding the boundaries of interest in, and use of, their research. This leads to our first research proposition:

P1: PIs capture value in use through the exploitation of their funded research by utilizing boundary spanning to identify and address the interests of different ecosystem actors.

A second value capturing in use mechanism uncovered in our research is that of PI as broker. Again building on literature relating to knowledge brokers (Hargadon, 1998; Howells, 2006), in particular their ability to translate or exploit recombined knowledge in meaningful ways to a diverse set of end users (Boari et al., 2014), our findings show how PIs utilize their central network position (Rotolo et al., 2013) or unique 'in-between vantage point' (Hargadon et al., 1997 p.158) within the public funding research ecosystem to connect otherwise disconnected constituents. Brokering is distinct from boundary spanning as the capturing of value in use takes place across multiple actors (Boari et al., 2014; Lundberg et al., 2012) as opposed to boundary spanning between two position, i.e. science to business or science to government. Through brokering, value that is captured in exchange between the research community and funding bodies through PI-led funded projects and programmes is then further captured in use in an integrated manner among multiple stakeholders (Merz et al., 2009; Vargo et al. 2008). Thus, PIs act as orchestra conductors (Pera et al., 2016) within the publicly funded research environment, negotiating and translating the use benefits of their funded research to the individual needs of ecosystem actors. While the value captured is ultimately determined by the individual ecosystem actors (Canhoto et al., 2016; Reypens et al., 2016), this process is facilitated by PIs' wide search as they identify, leverage and balance multiple ecosystem

interests simultaneously. Thus, they not only enlist the interests of multiple stakeholders, they partake in the value creating activities of these stakeholders as they engage with their research projects and programmes, thereby demonstrating research impact and further value capture in use within the ecosystem. We see this in our findings in how PIs integrate and carefully balance various combinations of ecosystem actors' interests identified among policy makers, funding bodies, industry, community end-users, and universities. This leads to our second research proposition:

P2: PIs capture value in use through the exploitation of their funded research by acting as brokers to identify, combine and balance the interests of multiple ecosystem actors.

A third proposition arises from a closer comparison of these boundary spanning and brokering value capture in use mechanisms. Although our results do not provide clear evidence on the effectiveness of one over the other, they do provide evidence indicating that brokering has some benefits that are less accessible through boundary crossing. Specifically, the balancing approach inherent in brokering multi-stakeholder interests helps ensure that the self-interested needs of various ecosystem actors, including the PI, do not dominate (Reypens et al., 2016; Pera et al., 2016). Instead, through brokering PIs adopt a balanced approach to value capture in use in which they partake or leverage the value creating activities of multiple ecosystem actors, thereby ensuring the interests of one actor or group – be it scholarly, societal users, commercial, governmental, funding body - do not dominate in terms of exploitation and value capture. We see this in a number of ways in our data. For instance, the scholarly motivations of PIs serve to buffer against any inclination to overly conform to government, industry or funding body expectations regarding more immediate impact and short termism. On the other hand, an appreciation of policy priorities, funding body value expectations, and/or commitments to societal impact through, for example, improvements in health care access, serve to ensure value capture in use is not exclusively directed at intrinsic academic interests such as publication. PIs not only stimulate and balance engagement among different ecosystem actors, they also increase the chances of engagement among them which can result in further value creation and capture (Lundberg et al., 2012), thereby increasing the overall utility received from publicly funded research. Wide search presents PIs with the chance to identify 'interest' recombination opportunities across various ecosystem actors for exploitation through their research. However, a corollary of the wider reach of value capture in use achieved through brokering is that it is also likely to be more complicated to balance multiple interests. Specifically, value capture in use through brokering might be slower as

multiple interests need to be reconciled and worked through. In contrast, while boundary spanning is likely to be more focused and less expansive, it is also likely to be deeper and more efficient as a value capture in use mechanism because it will be oriented around the interests of individual ecosystem actors' interests. These considerations lead to our third proposition:

P3: In publicly funded research ecosystems, PIs deepen and increase the efficiency of value capture in use through boundary spanning, and widen the value capture in use through brokering.

Based on our findings and associated propositions, our research makes two overarching theoretical contributions. First, is the novel framing of value capture in publicly funded research as a form of both exploration and exploitation (Levinthal ad March, 1993; March, 1991). Building on previous literature that has pointed to the importance (Heinze et al., 2009; Azoulay et al., 2011 and Laudel, 2006) and enactment (O'Kane et al. 2015) of research exploration to acquire public funds for research, our research provides new insights on the mechanisms by which such value capture in exchange is subsequently expanded to value capture in use through exploitation. While exploration and exploitation can compete for attention (March, 1991), they are also recognised in the literature as important complementarities in academic-commercial collaborative efforts (Ambos et al. 2008; Lavie and Drori, 2011). Our research expands this theoretical understanding, with our framing of both activities emphasizing their individual but interconnected importance for value capture in the publicly funded research ecosystem. More precisely, our research suggests that value capture from publicly funded research is restricted and has a narrower reach if it is dominated by, or ceases at, exploratory knowledge generation. However likewise, the effectiveness of its potential reach and impact through exploitation is contingent on sufficient knowledge renewal through exploration. Thus, to understand value capture in publicly funded research is to understand that value capture in exploration and subsequent value capture in exploitation are reinforcing and complementary.

Our second theoretical contribution is the identification of key actors and mechanisms for value capture in use in publicly funded research. Although scholars reference the multiplicity of audiences and outcomes that should be incorporated within publicly funded research (Bornmann 2013; D'Este et al., 2018; Fini et al., 2018), little concrete insights have been put forward on the mechanisms by which this is achieved. Likewise, while scholars have conceptually outlined the value creating and capturing potential of PIs within

entrepreneurial ecosystems (Cunningham et al. 2018: 2016), to date no research has elaborated on how they enact this role. In our research we develop new theoretical insights on this subject, showing how it is PIs that instigate and complete value capture in publicly funded research, and also presenting evidence on the boundary spanning and brokering mechanisms utilized by PIs to capture value in use through their funded research.

These new theoretical insights resonate with and extend related literature. For instance, looking at science communities, Rotolo et al. (2013) show the capacity of establishing cross boundary ties for enhancing the reach and impact of knowledge exploitation. Petruzzelli et al. (2015) find that the institutional diversity inherent in cross boundary collaborations between industry and science serves to enhance value capture in the form of joint innovation outcomes as it provides a means of integrating and effectively balancing exploration and exploitation. The mechanisms uncovered in this research support and extend these and similar views (Bush, 1945; Latour, 1983), showing how hybridising the academic logic with institutional logics, commercial and other, through the pivotal coordinating role of PIs provides a platform for extended value capture in use from funded research. Overall, drawing on the analogy proposed by Perkmann et al. (2019) in their study of structural hybrids, we view value capture in use in publicly funded research as a wide range of mosaics of hybrid spaces, with the nature of each space of value capture in use dependent on the PI exploitative mechanism employed and the ecosystem actor or specific (minority) logic engaged within that space.

5.1 Policy and practical implications

These findings also have important implications for policy and practice. With respect to policy, our research highlights that value capture in publicly funded research is perhaps more nuanced, complex and challenging than originally thought. For this reason, funding agencies need to carefully design their research funding schemes and consider reconfiguring these to more explicitly and effectively support PIs' value capture mechanisms so that they can optimise the benefits arising from the research. In particular, funding agencies need to consider the resource and skill requirements that are realistically needed by PIs to effectively combine knowledge exploration and exploitation. Traditionally, many public funding schemes tend to have a predominant focus on knowledge exploration, leaving PIs having to bootstrap additional resources outside the funded activities to support the exploitation that is increasingly necessary to meet both their own ambitions as well as the shifting expectations of funding bodies and government. This task can become even more challenging due to

partner uncertainty. For example, an industrial partner can lose interest in funded research due to market changes or a change in firms' strategic priorities. Funding bodies can help to address this issue by designing dedicated funding instruments that more effectively support PIs' exploitation efforts with industry and other end users that are targeted around defined market opportunities or outcomes, thus reducing partner uncertainty for PIs.

A second policy consideration from this research is the need to prepare scientists for the PI role and to advance processes within the current public funding system, which largely rely on informal PI role preparation. Our study further affirms the notion that scientists must learn the PI role on the job (Cunningham et al., 2015), however, it extends this view in highlighting specifically how PIs must themselves learn to translate and market their research to realize its value capture through use. Therefore, we suggest that there is a collective policy challenge looming for public science with respect to what formal mechanisms can be put in place to better prepare and encourage scientists to take on the PI role. As per our research findings, the creation of any such formal mechanisms need to adequately encompass how PIs can combine the exploration and exploitation dimensions and demands of value capture in public science. A key consideration on this issue is which ecosystem actor is best positioned to provide this role preparation – funding agencies, public research organisations, universities – and what exactly are the most appropriate formal mechanisms that can be used to support and prepare scientists to become PI, or indeed when they are already PI to become more effective in the role. Providing such dedicated role preparation support has the potential to enhance the quality and reach of value capture in use in publicly funded research. In contrast, if this issue is left unaddressed, a significant portion of the value capture potential inherent within publicly funded science will go untapped.

For practicing PIs, we show it is increasingly expected that they will have the capability to create, capture and exploit value. PIs need to be able to articulate value in an accessible and credible manner to various ecosystem actors. Moreover, they need to be able to reconfigure value in response to environmental and or individual stakeholder needs. As key value capture agents, PIs need to have mastery of detail (Mintzberg, 1994) that goes beyond their scientific domain. To this end, our study highlights the need for PIs to consistently scan their environment in order to effectively combine and support their exploration and exploitation activities. Specifically, PIs need to put in place formal and informal processes within their research team structures that can systematically scan relevant environments, the outcomes from which can inform current and future research directions and ensure these remain aligned with key value drivers among industry and other end-user

communities. Furthermore, PIs should consider more purposively seeking out opportunities inside or outside their institution for their own professional development, as well as proactively growing their networks beyond academia as these networks can be utilized and leveraged in boundary crossing and brokering.

Another practical implication from our research for PIs is that it offers some insights into the potential benefits and drawbacks of utilizing different value capture in use mechanisms. Where depth and speed of access and engagement are critical to realizing use benefits, PIs should focus on relationship building with different stakeholders through boundary crossing. This mechanism is likely to be particularly important for industry engagements where speed of value capture is so important in more applied projects. However, where time is less sparse and there is greater interest and potential in breadth of reach rather than serving the interests of one particular stakeholder, brokering connections across multiple actors is likely to be more appropriate and beneficial. For example, universities, society or government may prefer more incremental and dispersed engagements with end users and policy makers when it comes to more exploratory and basic forms of publicly funded research. As such, the realisation of value capture and the accrual of beneficial outcomes for stakeholders becomes focused on a longer-term orientation rather than a more immediate or short-term one. Overall, for PIs our research shows that regardless of the type of value capture in use being sought, they need to frame their research in a credible and accessible manner to multiple audiences. While scientists may have long benefitted from pursuing an esteemed reputation among the science community, our results indicate that reputational reward is being redefined to incorporate how well they are capturing meaningful contributions across political, commercial, scholarly, societal and other audiences. Put more bluntly, perhaps having a scientific reputation is no longer enough, particularly when your science is publicly funded.

Finally, our findings also have implications for industry. Our research highlights that successfully funded projects and programmes led by PIs are a key source of public value creation and capture. In particular, in the context of science to business interactions, we find that PIs are a critical agent of value capture. While our research emphasizes the mechanisms and efforts PIs enact to realise the latent value generated through their knowledge exploration, industry actors should take note that there may be more value capture potential available than PIs are able to translate, or perhaps are aware of. Our research therefore signals to industry that publicly funded projects and programmes, and the PIs who lead these, represent key focal points for value creation with which/whom they need to more proactively

reach out to and engage with. Taking a passive approach may lead to value destruction within entrepreneurial ecosystems as PIs overlook or fail to fully understand promising market opportunities due to a lack of market knowledge. Consequently, we encourage industry partners, and other end user communities who may benefit from science, to develop their relational capacity with respect to universities, PIs and even funding bodies as it is these intuitions and individuals that resource, support and conduct the exploratory work that may be of interest. Furthermore, industry may wish to consider proactively sharing their strategic intentions and plans with the aforementioned actors and signal their openness to achieving these in a collaborative way. The effectiveness of these initiatives of course would be dependent on industry partners moving from a transactional approach and instead adopting a more strategic and longer-term perspective in their engagements with PIs and funded research programmes.

6. Concluding comments

The purpose of this research was to understand the mechanisms through which value in use is captured in publicly funded research. To address this issue we drew on value capture and exploration/exploitation theory (Chesbrough et al., 2018; Eggert et al., 2018; March, 1991) to conceptualize a two stage process of value capture in funded research, value capture in exchange through exploration and then the primary subject of our empirical enquiry, value capture in use through exploitation. That is, while we make the case that value is initially captured in the form of successfully funded PI-led projects and programmes through resource exchange (expertise for funding), in this research we were particularly interested in the actual mechanisms through which this narrow and more explorative form of value capture is subsequently widened and put to use. Our empirical context for this research was health science funded PIs in NZ.

Our research offers a number of notable contributions. Most importantly, we show that value capture in publicly funded research requires efforts targeted at exploitation as well as exploration. Specifically, we identify and propose two PI value capture in use mechanisms – boundary spanning and brokering – that serve to extend the impact and reach of funded research to a diverse range of ecosystem actors. Based on our findings we further propose that brokering as a mechanism has some benefits that are less accessible through boundary crossing. As brokering involves balancing the interests of multiple ecosystem actors, it helps to avoid value capture dominance by any one ecosystem actor, as well as providing the opportunity to widen and expand the reach and overall value capture utility realized through

publicly funded research. In essence, wide search coupled with effective brokering offers PIs the chance to identify, synthesize and exploit more 'interest' recombination opportunities across various ecosystem actors through their research. In illustrating how various ecosystem interests are enlisted in PIs' research, our research goes some way to addresses claims of conceptual ambiguity around the ideas of value creation and capture due a recurring failure to clarify the value for whom question (Chesbrough et al., 2018). Finally, our research joins a rich line of literature in this journal on value creation and capture mechanisms within a S2B context (Boehm and Hogan, 2013; Baraldi et al., 2014; Canhoto et al., 2016; Clauss and Kesting, 2017; Winkelbach and Walter, 2015). However, in addressing the opening paragraphs of this manuscript on the increasing importance and expectations relating to science funding, we develop these insights further through our novel focus on the heretofore neglected value capturing role of publicly funded PIs. To our knowledge, our research is the first to articulate that it is through PIs that value is first captured in exchange in publicly funded research, and then to show how this value capture is subsequently expanded to develop and service the wider ecosystem. In this sense, our findings show that PIs are not only at the nexus of S2B interactions, they go beyond business to stimulate and synthesize broader ecosystem engagement.

Our research is not without limitations that would benefit from future research. While we did include a selection of PIs that included male and female researchers, and PIs at different stages of their career with different levels of funding experience, we did not uncover any noteworthy differences in the value capture mechanisms that might be explained by this cross-selection of PI informants. However, we do believe a study more purposefully designed around this very subject could unearth some interesting insights on the different value capture mechanisms adopted by PIs. Notably, our research also chose to focus on the individual PI, health science researchers, and only those funded scientists based in NZ. These contextual factors naturally had an influence on the PIs' approach to value capture and the stakeholder interests they enlisted. Future researchers should focus on the team level, consider different discipline areas and also different geographic locations. For example in terms of teams and disciplinary expertise, a number of scholars have generated interesting insights on levels of specialisation and interdisciplinary in science teams and networks. Rotolo et al. (2013) show that too much specialisation or too large a science team can hinder or complicate value creation processes. Porac et al. (2004) similarly show that more heterogeneous science teams are more productive over time in terms of knowledge generation. Based on such insights, it would be interesting to pay closer attention to the team level, in particular team size and the

extent of disciplinary expertise within the team, and how this impacts their approach to value capture. Another promising area for future research relates to proximity effects. Petruzzelli (2008) highlight the importance of geographic, organizational and technological proximity when considering explorative and exploitative knowledge transfer engagements. Proximity between scientists and industry is also regarded as an important determinant of technology transfer success due to the early-stage nature of academic invention disclosures (Jensen and Thursby, 2001). We believe such proximity dimensions, particularly geographic and technological, should be incorporated when examining who and how PIs and their teams engage with to realise value capture in use from their knowledge exploration. Another interesting angle for researchers to consider is incorporating the perspectives of ecosystem actors such as business, government, FBs and other stakeholder audiences. We gathered views on value capture from PIs, however, we acknowledge that incorporating the perceptions of others could offer a more rounded and robust view on ecosystem value creation and capture. Finally, we encourage future researchers to undertake a longitudinal study on this topic that could more accurately track how initial value propositions in the form of funding proposals develop into subsequent forms of value capture. Many of these research programmes and projects run for three years or longer with potential impacts occurring long after this. The subject is therefore perfectly suited to a longitudinal research approach.

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