The Role and Function of Cooperative Research Centers in Entrepreneurial Universities: A Micro Level Perspective

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Abstract

Purpose: The purpose of this paper is a micro level examination of the role and function of cooperative research centers (CRCs) in entrepreneurial universities from a principal investigator (PI) perspective.

Design/methodology/approach: This study uses a qualitative research design and is based on 38 semi-structured interviews with PIs who are publicly funded at the Centre for Research in Medical Device (CÚRAM) based in Ireland. CÚRAM has a multiple mission focus of supporting scientific excellence, industry engagement, educational and public engagement that supports the Irish medical device sector.

Findings: Our findings reveal that CRCs' role and function at the micro level constitute a necessary and functional organization architecture that supports PIs who are required to meet multiple scientific, commercialization, educational and public engagement objectives. Specifically, from the micro level PI perspective, the role and function of CRCs focus on (1) research quality enhancement, (2) brokerage, networks and collaborations, (3) addressing research impact and (4) resource enhancement and appropriation.

Practical implications: Our research emphasizes the importance and necessity for the creation of CRCs as part of the entrepreneurial architecture of entrepreneurial universities that provides the necessary appropriate local environmental conditions and enhanced supports to enable micro level actors to fulfill multiple mission objectives with respect to research excellence, industry, educational and public engagement and impact.

Originality/value: This study contributes to the limited literature on new institutional configurations that support entrepreneurship and addresses recent calls for further research. In taking a micro level focus, we identify the role and function of CRCs from a PI perspective in an entrepreneurial university setting.

Keywords: Entrepreneurship; Principal Investigators; Entrepreneurial Universities; Entrepreneurship Research Centers; Entrepreneurship Centers; Cooperative Research Centers

Classification: Research Paper

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study. The authors wish to acknowledge and thanks two anonymous reviewers for their constructive feedback which has shaped this paper.

1. Introduction

The growing body of empirical research related to entrepreneurial universities has provided a richer understanding of how universities are responding and coping with an evolution in their core missions, i.e. education, knowledge creation, knowledge transfer and commercialization. According to Urbano and Guerrero (2013: 43), the entrepreneurial university is "a natural incubator providing support structures for teachers and students to initiate new ventures: intellectual, commercial, and conjoint". Empirical studies have further shed light on how entrepreneurial universities are meeting the increasing external and internal demands and expectations of students, staff, industry, government and society. For example, based on a UK study, Guerrero et al. (2015) have shown that entrepreneurial universities' activities do have an economic impact across all missions. For universities to adopt an entrepreneurial university philosophy, they have to be entrepreneurial with respect to culture, structures, strategies and processes (see Cunningham et al., 2017a).

One way that entrepreneurial universities have responded to these challenges is by scaling its entrepreneurial architecture through establishing dedicated entrepreneurship centers, entrepreneurship research centers or cooperative research centers to effectively and sustainably address socio-economic demands and expectations (see Boardman and Gray, 2010; Cassia et al., 2014; Katz, 1991; Maas and Jones, 2017). These new institutional configuration units seek to support entrepreneurship activities along other mission objectives and this is reflected by the scope of their activities. Entrepreneurship centers (ECs) have a focus on students and on established businesses (see Menzies, 2000) and promote what Del-Palacio et al. (2008) describe as 'entrepreneurial attitudes' throughout the university and beyond. The core focus of entrepreneurship centers is on applied entrepreneurship activities, which are aimed at supporting new venture creation among university stakeholders. Entrepreneurship research centers (ERCs) on the other hand have a broader remit and scope, which combines research and applied entrepreneurship activities with other various activities, and is financially supported by different internal and external stakeholders such as government (see Sandberg and Gatewood, 1991). Cooperative research centers (CRCs) are organized differently to promote entrepreneurship and they are focused on achieving social and economic outcomes by supporting and enhancing science and technology. Boardman and Gray (2010: 450) define CRCs as "an organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation".

Set against this background, and reflecting the spirit of Bowers and Alon's (2010) observation of these differences with respect to creation paths and functions of these institutional configurations within universities to support entrepreneurship, the purpose of this paper is to examine at the micro level the role and function of CRCs in entrepreneurial universities from a principal investigator (PI) perspective. Entrepreneurial activities are part of CRCs' mission and activities, however their embodiment and creation path is through responding to industry needs and/or government policies (Boardman and Gray, 2010). Our study thus contributes to the limited literature and responds to recent calls for further research focused on different institutional configurations that support entrepreneurship within an entrepreneurial university setting (see Mass and Jones, 2017). Our paper thereby makes contributions to the extant literature on these new institutional configurations with respect to the

role and function of CRCs supporting entrepreneurship. Taking a micro level focus from a PI perspective, we identify the role and function of CRCs. Our findings reveal that CRCs' role and function at the micro level constitute a necessary and functional element of the entrepreneurial architecture that supports PIs that are required to meet demanding scientific, alongside other commercial and impact objectives that are necessary to enable entrepreneurship, innovation and technology transfer. Specifically, at the micro level PI perspective, the role and function of CRCs focus on (1) research quality enhancement, (2) brokerage, networks and collaborations, (3) addressing research impact and (4) resource enhancement and appropriation.

The remainder of the paper is structured as follows. The next section provides a literature review of entrepreneurial universities, entrepreneurship centers, entrepreneurship research centers, cooperative research centers and principal investigators. The subsequent section outlines the methodological considerations and describes our data collection procedure and analysis. Section four explains the main findings, whereas section five discusses the results in relation to the extant literature. A final section concludes with some implications for policy, practice as well as suggests some future avenues of research on CRCs.

2. Literature Review

Entrepreneurial Universities

Entrepreneurial universities have been the focus of increasing research attention within the entrepreneurship and innovation literature. This growing interest reflects the expanded university mission to encompass third mission activities that include knowledge and technology transfer (Cunningham and Harney, 2006; Meyers and Pruthi, 2011). The philosophy of entrepreneurial universities is to pervade and embrace a culture of entrepreneurialism (see Thorpt and Goldstein, 2013) to overcome some of the traditional barriers to entrepreneurship such as hierarchical structures, controls, rules, procedures as well as limited entrepreneurial talent (see Kirby, 2006). Therefore, as Guerrero et al. (2015: 751) argue, entrepreneurial universities need to adapt and change in order to "provide adequate environments for their students, academics and staff to explore/exploit entrepreneurial activities". Furthermore, Röpke (1998: 2) suggests that "the university itself, as an organization, becomes entrepreneurial" and Schulte (2004: 187) posits that universities "operate in an entrepreneurial manner". To capture the complexity of this entrepreneurial orientation, Kirby et al. (2011) developed a framework for entrepreneurial universities that links formal and informal factors to outcomes with respect to teaching, research and entrepreneurial activities such as technology transfer. One of the formal factors of relevance for this study that Kirby et al. (2011) identified focuses on flexible organizational and governance structures enabling the effective bridging of university, industry and government boundaries. Citing relevant literature, they suggest that limited hierarchy and "horizontal coordination is advocated as a means to promote intellectual, financial and physical resources" (Kirby et al., 2011: 304).

The theme of organizational structure within entrepreneurial universities is further reflected by Clark (2004) who notes the presence of an increasing number of units operating in universities that are clearly not traditional or discipline-centered departments. These units particularly take the form of interdisciplinary and trans-disciplinary research centers focused on a wide range of societal problems. Such configurations have implications for knowledge management within and outside the

university boundaries. This brings into the focus how entrepreneurial universities structure and organize their entrepreneurial architecture to support entrepreneurship throughout the university communities and beyond (see Hallam et al., 2014; Morris et al., 2014; Vorley and Nelles, 2009). Taking this entrepreneurial architecture perspective of entrepreneurial universities, Nelles and Vorley (2011) provide examples of formal organization mechanisms such as programs, incubators, and technology transfer offices (TTOs) and suggest that internal factors play a role in the success of these formal structures, particularly culture and leadership. They also suggest that in taking this conceptualized entrepreneurial architecture focus the embeddedness of technology transfer actors and supports into any structural form is crucial in an entrepreneurial university context. In building what Sporn (2001: 129) describes as "adaptive universities", structure was identified as a critical factor. She hence suggests that universities create competence fields around differentiated internal units that have autonomy in terms of activities and focus but are accountable to the university. Therefore the knowledge management that universities adopt with such units and institutional configurations requires that they are flexible with their knowledge management systems and processes to meet the needs of internal and external stakeholder communities. In summary, in supporting entrepreneurship, entrepreneurial universities have created new institutional configurations that are described and discussed in the following section.

Entrepreneurship Centers, Entrepreneurship Research Centers and Cooperative Research Centers

Entrepreneurship centers (ECs), entrepreneurship research centers (ERCs) and cooperative research centers (CRCs) are different institutional configurations within the entrepreneurial architecture of entrepreneurial universities to support entrepreneurship. These institutional configurations directly and indirectly contribute to creating and developing entrepreneurial trajectories within and beyond the academic context. In creating these centers, institutions need to take account of contextual factors – institutional and regional – to ensure an alignment to the respective needs and opportunities (Mass and Jones, 2017). There has been limited research disentangling entrepreneurship centers from entrepreneurship research centers and cooperative research centers. Entrepreneurship centers (ECs) have a core focus typically around students and faculty. Mass and Jones (2017: 12) define their remit as follows: "Entrepreneurship centers should play a direct (e.g. presenting their own programmes and activities) and indirect role (e.g. undertake joint programmes/activities with other faculties) in promoting enterprise and entrepreneurship activities". In their study of US ECs, Bowers et al. (2006) found that their core activities were focused on education and their activities consisted of seminars, courses for credit, business plan competitions and networking events. ECs collaborating with university-based TTOs can also enhance entrepreneurial attitudes and activities as well as technology transfer (Boh et al., 2016). In their concluding remarks of their international study of entrepreneurship centers, Bowers and Alon (2010: 124) call for further research on this topic and note that "the paths to creation and function of these centers differ".

There has been a significant growth in another institutional configuration as part of the universities' entrepreneurship architecture that supports entrepreneurship activities, that is entrepreneurship research centers (ERCs). There is such diversity of entrepreneurship research centers that Sandberg and Gatewood (1991: 20), based on

their US study, concluded that entrepreneurship research centers are "a diverse, eclectic group". In the US, Finkle et al. (2006) estimated that there were over 1,600 ERCs and found that beyond qualified faculty, access to funding seems to be a pivotal factor directly related to the performance of ERCs. More recently, Cassia et al. (2014) classified ERCs into three groups – pure ERCs, educational ERCs and multi-service ERCs. Cassia et al. (2014: 383) define a multi-service ERCs as a center that "dedicates its effort in equal shares in to research, education and transfer activities" and pure ERCs as centers "dedicating more than 50% of their effort to research". Moreover, in their study of 46 ERCs, Cassia et al. (2014) concluded that knowledge transfer of ERCs does enhance their research performance.

In taking inspiration from Cassia et al.'s (2014) ERC multi-service definition and Bowers and Alon's (2010) observation of these differences with respect to creation paths and functions of entrepreneurship centers, another institutional configuration that entrepreneurial universities use to infuse entrepreneurship activities, attitudes and outcomes are cooperative research centers (CRCs). The growth of CRCs is driven by the multidisciplinary nature of scientific discovery, the need to commercialize such discoveries through entrepreneurship and innovation and the demonstration of the socio-economic impact and benefits to firms, society and government (see Boardman and Gray, 2010). While there are different definitions of CRCs, Boardman and Gray (2010: 451) identified three common characteristics: (1) engagement in research, (2) exhibition of organizational formality, and (3) promotion of organizational and cross-sector collaboration and transfer. They also posit that CRCs can be involved in other activities such as facilitating business formation. Studies of CRCs have focused on issues such as CRCs' contribution to regional development (Clark, 2010), their economic impact (Roessner et al., 2010), firms' motivational factors in joining CRCs (Hayton et al., 2010) and trust (Davis and Byrant, 2010). In order to achieve these value creating outcomes and foster collaboration across disciplines, trust as well as an ongoing exchange between university administrators, scientists, industry and government entities needs to be created and ensured (see Davis and Bryant, 2010). To date, no research has specifically focused on the role and function of CRCs. Thus, the creation of an understanding of the role and function of CRCs at the micro level is crucial to understand how this institutional configuration facilitates the creation of new entrepreneurial trajectories.

From a faculty or scientist perspective, Garrett-Jones et al. (2010) found in their study of Australian CRCs that scientists benefitted from membership through skills development, career development, knowledge acquisition with respect to IP and commercialization and industry engagement. Moreover, in their concluding thoughts on CRCs and faculty satisfaction, Coberley and Gray (2010: 563) note that their results "suggest that a faculty member's subjective evaluation of their involvement is the product of a complex set of contextual factors and individual factors related to institutional support, personal rewards and a psychological contract with their external partners. Unless these factors are supportive, faculty satisfaction and potentially organizational commitment may suffer". CRCs are facilitators of collaborations between stakeholders and CRCs need to constantly align stakeholder interests to survive and thrive (Lind et al., 2013). Therefore, the design of such centers is critical to their survival and performance as Simeone et al. (2017: 58) suggest that the "design can play a relevant role in fostering entrepreneurial activities and value creation in academia, by supporting the translation of the different needs and interests of

stakeholders into a shared meaning that allows a coordinated way of working".

The institutional configuration origins of ECs, ERCs and CRCs in how they support entrepreneurship and more broadly the exploitation of knowledge are different. CRCs' origins are more externally instigated and are instruments of government policy and/or industry needs (Boardman and Gray, 2010). They are configured to achieve multiple missions that are usually aligned to specific industry needs. ECs' and ERCs' origins tend to be more internally instigated and reflect the intellectual trajectory of the entrepreneurship field (Katz, 2003). They are a response to the needs and demands of internal stakeholders particularly students and faculty.

Principal Investigators

CRCs are typically supported in the initial stages through publicly funded research that requires scientists undertaking research programs to demonstrate tangible entrepreneurship and innovation benefits for industry partners. Consequently, this means that scientists in CRCs take on the role of being a PI. Cunningham et al. (2016: 72) define PIs as "scientists who orchestrate new research projects, combine resources and competencies, deepen existing scientific trajectories or shape new ones that are transformative in intent, nature and outcome that can be exploited for commercial ends and/or for societal common good". The growing body of empirical research on PIs at the micro level has focused on themes such as strategic behaviors, managerial challenges, technology transfer mechanisms, gender, time allocation, barriers, etc. (see Cunningham et al., 2018, 2019; Del Giudice et al., 2017; Kastrin et al., 2018; Kidwell, 2014; Mangematin et al., 2014; Menter, 2016; O'Kane 2018; Romano et al., 2017). However, within this body of empirical research, there have been no studies in relation to how they understand the role and function of CRCs they are members of to support their expanded role as a PI.

PIs are at the forefront of knowledge creation (Kidwell, 2014) and interact with various stakeholders to create new knowledge, enhance value and push the scientific boundaries (Cunningham et al., 2018, 2019). Their role also means that they are at the forefront of the exploitation and commercialization of knowledge and play a key role in establishing and managing networks within CRCs and beyond. In particular, membership of CRCs accrue symmetry benefits with industry (see Coberly and Gray, 2010). Consequently, PIs seek organizational settings that enable them to fulfill their role as Kidwell (2014: 33) notes that PIs actively sought organizational alignment that allowed them "to make things happen while keeping harmony between the university and enterprise". Furthermore, Baglieri and Lorenzoni (2014) in their study of scientist-user PIs active in biotechnology, medical devices and nanotechnology conclude that institutional environments can dissuade PIs from undertaking technology and knowledge transfer.

Furthermore, studies have revealed the hidden complexities of this role and where PIs, through their boundary spanning engagement, create and enhance value through technology and knowledge transfer and push the scientific and knowledge boundaries (Cunningham et al., 2018, 2019). They are involved in knowledge management of their scientific discoveries through their own institution and this is also influenced by their industry partners (Cunningham et al., 2015). In particular, one of the reported managerial challenges of PIs focus around IP and the lack of dedicated technology transfer support (Cunningham et al., 2015). PIs are perceived as scientific

entrepreneurs who shape and reshape new paradigms and boundaries, broker science and innovate by bridging the gap between science and industry (Casati and Genet, 2014). Boehm and Hogan (2014) describe PIs as a 'jack of all trades' who create and enhance collaborative networks in scientific knowledge commercialization. Moreover, scientists in the PI role learn on the job whereby the lack of dedicated institutional support is a barrier for PIs (see Cunningham et al., 2014; O'Kane, et al., 2017; O'Reilly and Cunningham, 2017). The institutional and environmental context that PIs choose to be located matters in fulfilling the PI role, meeting and exceeding the expectations of stakeholders, particularly external stakeholders with respect to entrepreneurship outcomes. In summary, scientists in the PI role need the CRC institutional configuration, given their core and boundary spanning role of creating and exploiting scientific knowledge (see Mangematin et al., 2014). Consequently, given their role, position and needs, PIs are best positioned to offer insights at the micro level with respect to the role and function of CRCs.

3. Methodology Considerations, Data Collection and Analysis

The research question for our study is a micro level examination of the role and function of cooperative research centers (CRCs) in entrepreneurial universities from a principal investigator (PI) perspective. To address this question we undertook a qualitative case study approach of CÚRAM, the Irish Centre for Research in Medical Device, as a CRC, investigating it from the micro-level perspective of CÚRAM PIs. This micro-level perspective of PIs was chosen due to the influential and boundary spanning position and role of PIs as outlined in our literature review. This qualitative methodology can be categorized as a single, holistic case study that is exploratory in nature, in line with Yin (2003), with CÚRAM as the typical-case, single-case study and PI interviews as the main data source. Yin (2003) outlined how a case study methodology allows for the study of contemporary phenomena within real-life context, and described this methodology as particularly useful in studying programs and people, which aligns with the aim of this study. Yin's case study methodology also allows for prior development of theoretical propositions, as presented in this paper, in order to direct data collection and analysis processes. The primary data source are semi-structured, open-ended interviews carried out with 38 PIs based at CÚRAM who are involved in medical device research in Ireland. The interview data, alongside archival records, was analyzed using a flexible thematic analysis as outlined below (see Hair et al., 2011).

Study Context

CÚRAM, the Irish Centre for Research in Medical Device, is co-funded by the European Regional Development Fund and the Science Foundation Ireland (SFI), Ireland's statutory body with responsibility for funding basic and applied science, technology, engineering and mathematics (STEM) research. CÚRAM is one of SFI's 16 cooperative research centers, hosted at various Irish academic institutes, an "academic-industry-clinical 'super center' designing the next generation of 'smart' medical devices" (CÚRAM, 2018). The creation of these centers, including CÚRAM, was instigated by mandated government research prioritization policies to "develop a distinctive industry-focused culture" (DBEI, 2012: 15), promoting multidisciplinary research activities and industry-academic collaborations, with medical device research constituting one of the identified priority areas of focus for taxpayer investments. As an agent of government, a key objective of SFI's strategic plan, Agenda 2020, was to develop these centers to provide major economic impact for Ireland, creating

partnerships between academia and industry to address crucial research questions and contribute to the Irish economy. To this end, CÚRAM received an initial investment of €49 million over six years from SFI and industry. As such, CÚRAM can be viewed as an instrument of recent government policy to develop cooperative research centers with integrated goals of research, entrepreneurship, education and outreach. Thus, CÚRAM PIs have a clear remit to foster industry partnerships and engage in boundary spanning, technology and knowledge transfer and commercialization activities, alongside the traditional roles of education and research.

The medical device sector in Ireland is recognized as one of the five global emerging hubs, with nine of the top ten medical device companies globally having their bases in Ireland, and alongside this growth, medical device research has become a key national research priority (Cunningham et al., 2015; Giblin, 2011; Giblin and Ryan, 2012). CÚRAM as the national center for medical device research places particular focus on chronic ailments such as heart disease, wound healing, diabetes and musculoskeletal diseases, and thus works across a wide variety of disciplines, including biomaterials, drug delivery, tissue engineering, regenerative medicine, device design and glycoscience. The center has thereby secured over €135 million in total grant value (€25.2 million CÚRAM team share) through previous EU Framework programs. Through European funding, SFI and industry co-funding, CÚRAM currently employs over 500 researchers, with 61 academic leads (PIs) and eight clinician collaborators. While led by National University of Ireland Galway, CÚRAM's academic partners include University College Dublin, University College Cork, Trinity College Dublin, University of Limerick and Royal College of Surgeons Ireland. The center has partnered with a network of ten national academic institutions in total, including six Irish universities, and has established 28 industrial partnerships, made up of 18 SMEs and 10 MNCs (CÚRAM, 2018). Multinational industry partners include Boston Scientific, Medtronic, Novo Nordisk and Arch Therapeutics. Alongside supporting research excellence, the center also supports product development and the creation of spinout companies. To date, CÚRAM has supported the creation of over 100 industrial contracts/engagements, 10 spin-out companies, 15 licensed technologies, and over 40 approved patents (see Table 1). CÚRAM has also completed a first-in-human clinical trial, one of the key goals of the center.

- Insert Table 1 about here -

As a CRC, CÚRAM supports these various lines of research, technology and knowledge transfer and commercialization activities through a variety of initiatives and programs related to scientific excellence, industry engagement and education as well as public engagement, to promote innovation, technology and knowledge transfer, and training in medical device research and clinical application. CÚRAM offers a network of national and international academic, industry and clinical collaborators, intending to enable rapid translation of research results to clinical applications. CÚRAM's Industry Program Team is focused on establishing "long-term strategic relationships" with industry (CÚRAM, 2018), providing PIs with knowledge and expertise in IP, facilitating academic-clinician-industry interactions, determining the type of funding and IP model, supporting the definition and allocation of resources and budget, and identifying further activities and future projects to advance the technologies. The center also offers a wide range of guest lectures and

seminars, industry workshops and networking events for PIs, and researchers in general, to enhance industry and clinician engagement, and to support greater levels of knowledge transfer. For example, in February 2019, CÚRAM was one of seven SFI research centers to receive funding, as part of a UK-Ireland joint initiative, for doctoral training for future innovation leaders through the establishment of lifETIME: an Engineering and Physical Sciences Research Council (EPSRC) Centre for Doctoral Training in Engineered Tissues for Discovery, Industry and Medicine. Additionally, CÚRAM's Education and Public Engagement program seeks to better engage primary and secondary students, teachers and the general public in medical device science, through three core residency programs for artists, filmmakers and teachers. This program was designed to support SFI's Agenda 2020 objective of "having the most scientifically informed and engaged public".

Data Collection

Data collection is based on semi-structured interviews with 38 PIs. The group for this study was selected due to their involvement with CÚRAM, as publicly funded PIs in charge of medical device related publicly funded research projects. All CÚRAM-supported PIs were systematically contacted by email to invite them to partake in a semi-structured interview on their experiences to date as a PI and their views on impact and the role and function of CRCs in entrepreneurial universities, with a total of 38 respondents (of a total of 56 CÚRAM-funded investigators identified at the time and contacted). The majority of PIs interviewed were male (29 compared to 9 female PIs), with 22 PIs holding professorships (19 males, 3 females). Domain areas of PIs varied widely across health-related disciplines, from basic science domains such as cell biology and anatomy, through to applied and translational disciplines, for example biomedical engineering and biostatistics (see Table 2 for a summary of PIs' title, position, gender, type of research and experience). The PI interviewees in this study worked across five Irish academic institutes, with the vast majority (27) located in NUI Galway, with the other eleven interviewees being spread across five other Irish universities and academic institutes.

- Insert Table 2 about here -

The interviews were conducted either in person or over the phone, with interviews lasting between 25 minutes and over one hour, averaging 33 minutes, carried out between September 2017 and February 2018. The interview transcriptions amounted to over 250 pages of interview data, averaging 4,300 words per interview transcription. The interview schedule, aligned to core themes of the literature review outlined above, employed open-ended questions on the respondent's experience to date as a PI, looking specifically at their motivations for taking on the role of PI and the challenges involved, their main undertakings as PI, and then investigating how each respondent views the impact of their research and the efforts they make to realize that impact as well as the role and function of CÚRAM in supporting their activities. All interviews were semi-structured and open-ended in design.

Data Analysis

Following data collection, interviews were transcribed by the authors, and then analyzed using the NVivo 11 software package. NVivo was chosen as an appropriate qualitative analysis software due to the possibility to powerfully manage the large amount of data gathered, as well as to identify patterns and themes from the data, to

prevent information overload and make more sense of the data (Miles and Huberman, 1994). Braun and Clarke's (2006) model of thematic analysis was the method chosen for analyzing the data, first and foremost due to the flexibility of the model. This approach involves five stages of data analysis beginning with data familiarization (Phase 1; primarily involving the verbatim transcription of interview data and active reading and rereading of the transcriptions) and the systematic generation of initial codes, collating data relevant to each code (Phase 2). Following best practice guidelines as outlined by Braun and Clark (2006), the members of the research team collated codes into potential themes (Phase 3). Phase four involved reviewing these themes in relation to each coded extract and across the entire data set. Finally, themes were defined and named by the team, analyzing the specifics of each theme and the overall story the analysis provided (Phase 5). For the purpose of this paper, the focus was placed on codes and themes specifically related to the roles and functions of CRCs among our PI interviewees (see Figure 1 for the sample of relevant first order codes and the identified themes relating to our research question, as identified through thematic analysis of the collected data).

4. Findings

Through the qualitative case study methodological approach outlined above and the process of thematic analysis of interview data, key themes were identified relating to the key roles and functions of CÚRAM as a CRC from the micro-level PI perspective: (1) research quality enhancement, (2) brokerage, networks and collaborations, (3) addressing research impact (including technology transfer) and (4) resource enhancement and appropriation (see Figure 1). Findings related to these key themes as well as some interrelated subthemes identified, are presented in the following sections. It is worth noting that, although for some of the findings presented below there are only a small number of PIs supporting the themes, the high level of PI experience of our respondents and level of detail of certain responses was taken into account. In particular, for those subthemes identified below with less than five respondents, it was agreed upon by members of the research team to include these subthemes depending on the experience level of the respondents involved, as well as by the quantity and quality of individual first order codes under analysis.

Research Quality Enhancement

Ten principal investigators interviewed in this study highlighted the role CÚRAM played in supporting their research activities and in enhancing the quality and scientific and knowledge transfer impact of their research. One method identified by five PIs to enhance the quality of their scientific exploits was through engaging in multidisciplinary research, which was supported through CÚRAM's role as a mediator and promoter of multidisciplinary research projects.

> *"The main thing, and I think it is being cultivated in CÚRAM, I really think a multidisciplinary team is a really good team." (PI35)*

CÚRAM was also identified by two experienced PIs as influential in terms of building research teams in a more general sense, leading to more successful research projects, with one PI (*PI30*), strongly emphasizing the importance of the research team to enhance the research they carried out and for effective knowledge transfer; *"…together, that's where that success rate comes from*". Furthermore, *PI01*, a professor focused primarily on basic science with over 25 years of experience as PI,

mentioned the "*stimulating*" environment created through CÚRAM, "*the interface with engineers, physicists, chemists…*" as beneficial to their research success, with the center's emphasis on multidisciplinary research being important for publication in "*the very successful big impact journal papers". PI12*, a senior lecturer with over 15 years of PI experience and focused primarily on basic research, also made note of the positive influence of CÚRAM in relation to scientific impact, to "*improve and enhance the quantity and quality of research*". It should be noted that the knowledge management formal mechanisms offered by CÚRAM, such as seminars and workshops, were not highlighted by any of the PIs interviewed.

Brokerage, Networks and Collaborations

Nine PI respondents pointed to CÚRAM's brokerage capabilities, as mediators or intermediaries between academia and industry (often single individuals within CÚRAM acting as mediators) as a valuable function of this cooperative research center. The cooperative focus of CÚRAM in ensuring scientific excellence alongside translational research often requires greater levels of brokerage with industry and clinicians, developing relationships and networks, connecting and mediating between academia and various relevant stakeholders, as acknowledged by *PI17*:

> *"…somebody then in the middle being able to put us in the right direction, and put two groups together and say you might be able to help each other on this." (PI17)*

Similarly, in relation to brokerage, from the micro-level PI perspective, nine PIs emphasized specifically the positive effect of the center on PIs' boundary spanning activities, to develop relationships with potential academic, clinical or industry partners and to share knowledge:

> *"That is what I find healthy about the CÚRAM initiative, though it sounds like a plug for CÚRAM, but it's not really. The important aspect of it is don't stay in your silo, go talk to someone." (PI01)*

Furthermore, the strategic platform pushed by the center focused on knowledge brokering and engaging with relevant stakeholders influenced some PIs in their own views of knowledge transfer strategies and activities, creating another benefit for PIs to work with the cooperative research center:

> *"CÚRAM is part of that, so a positive in that way, the EU projects almost force you to go looking for people in different areas, in companies and other types of partners." (PI24)*

One of the selling points offered by CÚRAM is their knowledge of and access to a "unique network of academic, industry and clinical partners" (CÚRAM, 2018). Informal mechanisms offered by the center in relation to networking, as a mechanism for entrepreneurship, were referenced by six PI interviewees as important reasons for becoming and remaining involved with the research center, to connect more efficiently and effectively with the most relevant stakeholders of their research, including industry partners, regulatory bodies, clinicians and patient/ public groups. The center's networking capacity and training support was emphasized by *PI24*, a professor with over 15 years of PI experience focused on more applied, translational

research, as an important mechanism offered by CÚRAM to increase the PI's technology and knowledge transfer potential:

> *"I think you can really flounder, cold-calling companies and getting nowhere, talking to reps whose job is mostly about selling the product rather than engaging in partnerships, so again it is like a number of other things we talked about, you are not really trained for it, and this is a lot of what CÚRAM is about, is actually training people in those types of interactions, and supporting them better than they are currently supported." (PI24)*

The center's strategy to promote and support collaboration, particularly industry collaborations, was another common theme identified through thematic analysis, with ten of the 38 PIs interviewed making reference to the influence of the research center on their industry collaboration and engagement activities. Speaking about CRCs in general, *PI16*, a professor with 11 years of experience in the PI role, placed significant emphasis on the role of CRCs in creating strong links with companies:

> *"What has been really helpful there has been the [name] center, because they basically have a team that know what I do, they are kind of the front door for companies, and then they really funnel potential partners towards the academics. We've a couple of very strong company relationships, they've been driven through the center." (PI16)*

CÚRAM's focus on the entrepreneurial mechanism of industry collaboration was mentioned by a number of PIs as influencing their own attitudes on industry-academic partnerships and views on academia in general, and as an advantage for PIs in creating more effective and efficient industry collaborations:

> *"…before that we always thought science is there, and at the other end is the big bad industry… and those barriers have been broken down, and certainly CÚRAM is a perfect example of that. But that's made my life easier. From the point of view of, it's less distasteful now to be seen to be bringing in funding from industry, and there's many more calls where you can marry those two, co-funding or that, and that makes a big difference." (PI35)*

In conclusion, the interrelated themes of brokerage, networking and collaboration were identified by several PIs as important functions of CÚRAM as a CRC to enhance the translational, or impact potential of their research, serving to more effectively connect PIs with potential academic, clinician and, in particular, industry partners. In general, collaboration was seen by the PIs in this study as vitally important in technology transfer and commercialization activities, such as patenting and licensing, particularly with regard to industry collaborators.

Addressing Research Impact

As the scope of our study is on how PIs understand impact, and how they approach and action their environment to create impactful research, one of the roles and functions of the CRC identified by several PIs was, perhaps quite naturally, in supporting PIs to better address and understand the impact of their research projects. One of the main focuses of the CÚRAM team is in encouraging PIs and researchers to reflect on and action the technology transfer and translational potential of their work,

the commercial impact, with *PI23* pointing this out specifically, stating *"…if we have something worth patenting we patent it. If we don't we won't"*. CÚRAM was identified and emphasized strongly by three of the PIs as playing a part in their impact orientation in terms of supporting them in developing translational trajectories for their research and developing potential economic, technology and knowledge transfer impacts from their projects:

> *"But I'd like to, sort of, examine that, and CÚRAM is very good at getting researchers to examine how they can translate impact from the basic science stuff to the more translational piece…. getting you to look at, well why don't we file this and then we can talk about licensing and whatnot." (PI31)*

Four PIs, two with over 15 years of PI experience, made reference to the benefit of involvement with CÚRAM in relation to dealing with impact in the writing of 'impact statements' within funding applications, for some particularly in relation to helping them identify and develop potential economic outputs, outcomes and impacts:

> *"I probably would have found the industrial/economic impact a bit tricky had it not been for the research centers, they have really helped with that process, so again possibly lucky in that sense that the centers came around and enabled that for me" (PI16)*

Another aspect of addressing impact related by seven PIs was that of the current requirements of funding applications for greater levels of patient and public engagement, and societal impact. As outlined above, one of the key strategic goals of CÚRAM is to promote and support greater levels of patient and public engagement and education. At the micro level perspective of the PI, five respondents found that the center influenced them in their public and patient engagement strategies:

> *"I am engaging very regularly with those patient advocacy groups. So incentives by CÚRAM are really important in that they can enable that, like the big EU programs enable that." (PI30)*

These findings suggest that, for some respondents, CÚRAM plays an important role in supporting PIs in addressing the often-complex and misunderstood notion of impact of research, particularly with regard to the increasing emphasis placed by funding agencies and governmental policies on the broader, societal impacts of research, and public and patient engagement in research (see Castaño-Martínez et al., 2015).

Resource Enhancement and Appropriation

Another key theme identified through the thematic analysis of the interview data was that of resource enhancement and appropriation through involvement with CRCs, particularly in relation to access to appropriating funding for research, researchers (i.e. postdoctoral) and materials. This is particularly important for PIs involved in medical device research, due to the increased costs involved in running a medical device research-related lab. Industry involvement was of particular importance in terms of material resources, for example for *"kits, diffusion chambers that are in the lab"* (*PI06*). Four PIs placed emphasis on the benefit of involvement in the center in accessing suitable PhD students and postdoctoral researchers, and funding for these

researchers: *"the postdocs come very easy"* (*PI26*). The role of the center was highlighted by four experienced PIs as increasing the opportunity and likelihood of success in relation to accessing funding of research. *PI38*, a professor and head of his research unit, emphasized the role of another SFI center in more easily accessing funding;

> *"[Centre C] has been great because what it has done, it does allow you get access to funding, if you are interested in that, probably easier in some ways than having to apply through ERCSET or other forums." (PI38)*

Three of our highly experienced PIs (more than 15 years PI experience) mentioned this particular benefit of involvement with a CRC as a specific motivation for becoming and remaining involved, with the belief that it is easier to get funded when applying through the CRC. Interestingly, two of the less experienced PIs mentioned this as an issue, that attaining funding was only possible through a CRC, particularly for early-stage researchers: *"...finding it hard to get a project funded unless you were through a center"* (*PI05*). It should be noted that, when PI interviewees spoke about funding, this related to funding of research as opposed to funding through commercialization activities such as spin-offs.

5. Discussion

Our findings suggest that CÚRAM, as a CRC, infers some important roles and functions for scientists in the PI role, in this case PIs involved in medical device research, in enhancing research, in brokerage, networks and collaboration activities, particularly with industry and clinician partners, in addressing various aspects of impact, and in resource enhancement and appropriation, specifically in increasing the chance of obtaining and maintaining funding for research.

Our paper makes several contributions. First, our study extends our understanding of the entrepreneurial architecture in an entrepreneurial university setting by specifically examining the role and function of CRCs from a micro level PI perspective. Our study highlights that different institutional configurations within an entrepreneurial university setting can be used to achieve the common goals of supporting entrepreneurship. In particular, our study extends Mass and Jones (2017) argument for the need of institutions to take account of contextual factors – institutional and regional – in creating such centers. Our study highlights that supporting entrepreneurship can be undertaken by using a different institutional configuration that takes account of contextual factors that form part of the entrepreneurial architecture in a university. In doing so, such institutional configurations meet the actual needs and demands of internal stakeholders at the micro level, while also meeting multiple missions and demands that have been placed on CRCs through their creation path that is instigated by government policy and/or industry needs (see Boardman and Gray, 2010). Moreover, our study suggests that there is a need to consider other institutional configurations beyond EC and ERCs within a university context that are designed to achieve similar entrepreneurial activities, attitudes and outcomes while balancing and delivering other contextual and institutional objectives and outcomes such as public engagement, societal benefits etc. Furthermore, our study extends the limited literature on CRCs through identifying their roles and function from a micro level perspective. We also have extended previous studies of

CRCs (such as Boardman and Gray, 2010; Hayton et al., 2010) beyond a North American into an Irish context, where CRCs are a new phenomenon.

Second, our findings show that CRCs provide a suitable environment or what Boardman and Gray (2010) describe as the 'organizational formality' for PIs enabling them to fulfill the various roles, responsibilities and stakeholder expectations as well as reducing some of the traditional barriers to entrepreneurship, knowledge and technology transfer (Kirby, 2006). By focusing on CRCs, we have built on and extended the classification of Cassia et al. (2014) with respect to multi-service ERCs. CRCs, similar to ERCs, have a research mission combined with other multiple missions but, as Bowers and Alon (2010) note, there are different paths to creating such centers. There is also a unifying commonality of purpose among ECs, ERCs and CRCs of supporting entrepreneurship and entrepreneurial outcomes despite their different institutional configurations as units within the entrepreneurial architecture in an entrepreneurial university. Our study highlights how the role and function of CRCs enhance the environment and supports at the micro level, particularly with respect to brokerage, networks and collaborations all necessary to support entrepreneurship on the demand side. These roles and functions of CRCs are necessary to support entrepreneurship activities particularly with respect to supporting new venture creation. Furthermore, our study indicates that CRCs provide PIs with the structural holes as part of their wider institutional setting that enables individual actors to purse multiple objectives and create value (Kidwell, 2013). CRCs provide them with the environment that enables them as Kidwell (2014) states 'to make things happen' and supports more autonomous researchers. In essence, this institutional configuration is aligned to role demands and expectations that scientists have in the PI role.

Third, our study provides some evidence how the role and function of CRCs can provide tangible supports and expertise that address the specific scientific domain, industry, entrepreneurship and impact challenges along with the needs that micro level individual actors experience. CRCs provide PIs with the ability to focus their efforts simultaneously on different activities similar to what Cassia et al.'s (2014) definition of multi-service ERCs. One of the key differences is that the research focus is not on entrepreneurship, but on the roles and functions identified by PIs at the micro level supporting entrepreneurship directly and indirectly. Our study also extends Garrett-Jones et al.'s (2010) study of the benefits of membership of CRCs for scientists such as funding, resources, knowledge acquisition. Specifically, in examining the roles and functions of CRCs from a PI perspective, we found that some of the barriers with respect to technology transfer, industry collaborations, and expertise (see Cunningham et al., 2014) can be met through the CRC's organizational structure. Moreover, the findings of our study also extend the work of Simeone et al. (2017) by highlighting targeted supports and expertise for individual actors – in this case PIs – providing them with an ability to meet different stakeholder expectations. In particular, CRCs' combination of supports and environment facilitate and provide individual actors with the capacity to develop sustainable collaborations and networks with industry and other stakeholders that are necessary prerequisites for knowledge and technology transfer. For the individual actor at the micro level, CRCs can realize some of the posited macro level dimensions of entrepreneurial universities (see Etzkowitz, 2003; Formica, 2002; Jacob et al., 2003) as well as contribute at a macro level to the economic impact of an entrepreneurial university (Guerrero et al., 2015).

Fourth, our study extends the current understanding of the different institutional configurations that support entrepreneurship beyond ECs and ERCs (see Bowers and Alon 2010; Mass and Jones, 2017). Our study also extends the interpretation of Nelles and Vorley (2011) of entrepreneurial architecture in an entrepreneurial university setting by including CRCs as another institutional configuration similar to ECs and ERCs that supports entrepreneurship. Furthermore, our study has shown that CRCs also may confer some competitive advantage for individual actors in pursuing and appropriating resources from a variety of stakeholders, particularly access to funding to pursue scientific discovery with relevant industry partners to support these firms' corporate entrepreneurship and innovation. We found no evidence in our study that CRCs conferred any funding advantage for PIs with respect to entrepreneurship unlike ECs or ERCs. However, we suggest that this should be a focus for future research.

Fifth, a surprising finding at the micro level is that PIs did not identify knowledge management as one of the key roles and functions of a CRC, particularly as our study's contextual setting requires effective knowledge management. This is critical and fundamental to the medical device sector with respect to the exploitation of new knowledge. The more formal mechanisms of knowledge sharing as part of knowledge management were not highlighted as a crucial role or function of CRCs by our respondents in this study. This is somewhat counterintuitive as respondents highlighted how the role and function of CÚRAM was research quality enhancement. One possible explanation for this unexpected finding is that in an Irish context, CRCs may have adopted and embedded standardized national arrangements with respect to industry collaboration, IP management and exploitation and knowledge and technology transfer, and as such, PIs may not intrinsically acknowledge or recognize the more formal mechanisms of knowledge sharing and management taking place as functions of CRCs. In some respects, it would suggest from an organizational structure perspective that knowledge management is part of the everyday of PIs in a CRC. However, we suggest that further investigations in other contexts and CRCs are required.

6. Concluding Thoughts and Future Research Avenues

Our study has highlighted the role and function of CRCs, is yet not without limitations. PIs interviewed in this study were all funded through CÚRAM, and so may have felt the need to positively mention the financial support in the interviews and as well as speaking positively about CÚRAM. Consequently, there might be some bias that we tried to address through our probing during the semi-structured interviews. Another possible limitation of this study is that we only spoke with those PIs willing to be interviewed, hence there might be a success bias among these PIs. However, given the paucity of research at the micro level on the role and function of CRCs, we chose in-depth interviews to provide new contributions that can build the basis for large-scale studies of CRCs. The use of the single-case study methodology focusing solely on CÚRAM could also be considered a limitation of the study. Future research could look to undertake a multiple-case study approach of a variety of CRCs to compare roles and functions across different contexts and research areas.

Our research has implications for policy makers, university managers and PIs. Policy makers need to give due consideration to the entrepreneurship outcomes that they

envisage through the creation of policy instruments and sustainability of the funding model that establishes CRCs. CRCs, unlike ECs and ERCs, have to manage multiple often more complex missions, agendas and objectives from stakeholders within and outside a university setting. Our study highlights that CRCs provide the necessary supports to their role and function that enable PIs to pursue different forms of entrepreneurship. Some of their entrepreneurial activities does not necessarily end with a new venture formation. This raises an interesting policy question that requires an empirical focus of under what conditions policy makers should use CRCs as an instrument to orchestrate change and support for industry and university stakeholders.

University managers need to appreciate that there is an array of institutional configurations that can be used as part of the entrepreneurial architecture within a university setting to support entrepreneurship and knowledge transfer. These different institutional configurations such as ECs, ERCs, and CRCs have a shared commonality of supporting entrepreneurship but achieving this through different means while being clearly focused and aligned to their core stakeholders. Consequently, this variety clearly meets different needs but is essential and complimentary in supporting the entrepreneurial architecture within a university setting. University managers should consider means by which organizational knowledge and know-how is shared among such units within a university setting. Such cross-fertilization could yield even further environmental enhancements and entrepreneurship outcomes (see Leyden & Menter, 2018). Moreover, our study specifically highlights the specific role and function of CRCs that are aligned with PIs and this could be a useful guide to university managers that seek to create and set up effective CRCs. Moreover, university managers need to consider how realistic or advisable it is to have a co-existence of such institutional arrangements.

For scientists in the PI role, our study provides a tangible guide to better understand if not to evaluate their own participation in CRCs. As CRCs evolve and the demands placed by external stakeholders such as industry and government grow, PIs need to ensure that the role and function of CRCs keep pace with these demands. Moreover, PIs need to evaluate their participation in CRCs to see if their current needs are met particularly with respect to entrepreneurship or if they are better suited engaging with an EC or ERC to realize their entrepreneurship ambitions.

Finally, based on our study, we suggest that future research should focus on the interplay between these differing institutional configurations within the entrepreneurial architecture within entrepreneurial universities aimed at fostering the transfer and commercialization of knowledge. In particular, there is a need for comparative studies of the knowledge management practices of CRCs and needs to be extended also to other institutional configurations supporting entrepreneurship. Furthermore, the role of the directors of CRCs needs to be further investigated as only an aligned strategy that manages intellectual capital through a collective intelligence approach promises impactful outcomes (Secundo et al., 2016). Therefore, a broad set of data collection methods should be utilized to capture the inherent complexities within these institutional configurations (Cunningham et al., 2017b). A deeper understanding of technology transfer mechanisms and processes might thereby be derived from combining a macro level institutional perspective and a micro level PI perspective.

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Table 1: Overview of CÚRAM

Established	2014
PIs	61
Researchers	500+
Clinician collaborators	8
Industry partners	28
MNCs	10
SMEs	18
Commercialization activities	
Commercialization awards	54
Technologies licensed	15
Patent applications	123
Patents approved	44
Economic development activities	
Industry contracts/engagements	100+
Spin-out companies	10

* Figures correct as of June 2018

Table 2: Interviewee Participant Summary Overview

ID	Title	Academic Position	Gender	Primary type of research	Years as PI
PI01	Prof	Head of Department	M	Basic	>15
PI02	Dr	Other	M	Applied	5-15
PI03	Prof	Director of Center	M	Basic	>15
PI04	Dr	Senior lecturer	M	Basic	5-15
PI05	Dr	Lecturer	M	Applied	<5
PI06	Prof	Head of Department	M	Applied	5-15
PI07	Prof	Head of Department	M	Applied	>15
PI08	Dr	Head of School	F	Applied	5-15
PI09	Dr	Head of Department	M	Basic	>15
PI10	Prof	Professor	M	Applied	5-15
PI11	Prof	Professor	F	Applied	>15
PI12	Dr	Senior lecturer	F	Basic	>15
PI13	Dr	Lecturer	M	Applied	5-15
PI14	Prof	Director of Center	M	Applied	>15
PI15	Dr	Senior lecturer	M	Applied	>15
PI16	Prof	Head of Department	M	Applied	5-15
PI17	Prof	Professor	F	Applied	5-15
PI18	Prof	Head of Department	M	Applied	>15
PI19	Dr	Senior lecturer	M	Applied	5-15
PI20	Dr	Director of Center	M	Applied	<5

PI21	Prof	Senior lecturer	M	Basic	5-15
PI22	Prof	Head of School	M	Basic	5-15
PI23	Dr	Senior lecturer	F	Applied	5-15
PI24	Prof	Professor	M	Applied	>15
PI25	Dr	Lecturer	F	Basic	<5
PI26	Dr	Lecturer	M	Applied	5-15
PI27	Prof	Professor	M	Applied	5-15
PI28	Prof	Professor	M	Basic	>15
PI29	Dr	Senior lecturer	F	Basic	>15
PI30	Prof	Associate professor	F	Applied	5-15
PI31	Dr	Lecturer	M	Basic	5-15
PI32	Prof	Professor	M	Basic	>15
PI33	Prof	Professor	M	Applied	>15
PI34	Prof	Professor	M	Basic	<5
PI35	n/a	Director of Institute	F	Applied	5-15
PI36	Prof	Professor	M	Applied	>15
PI37	Prof	Director of Centre	M	Applied	<5
PI38	Prof	Senior lecturer	M	Applied	5-15

Figure 1: Visualization of Braun and Clarke's (2006) Model of Thematic Analysis as Applied to our PI Interview Data Collection