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Innovation ambidexterity and public innovation Intermediaries: The mediating role of capabilities☆

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ABSTRACT

We lack an in-depth understanding of how the different roles played by public innovation intermediaries during their engagement in collaborative projects enable them to generate ambidexterity. By adopting a sequential mixed methods research design to gather data from 122 Research and Technology Organizations (RTOs) operating in Europe, the findings suggest that public innovation intermediaries performed two different roles in collaborative projects namely, knowledge integration and network building, and these have a differential impact on the generation of distinct types of in-house innovation. The knowledge integration role is conducive to exploratory innovation, whereas the network building role contributes to exploitative innovation. Importantly, relational, and internal capabilities mediate between these roles and innovation. Yet, this mediation effect varies depending on the nature of the public innovation intermediary's role and innovation profile. How public innovation intermediaries should utilise their key roles to generate in-house ambidexterity is crucial in leveraging the impact of public funding in this area.

1. Introduction

Public innovation intermediaries, broadly defined as publicly funded organisations that support collaboration between two or more parties, play a key role (Howells, 2006; Caloffi et al 2018; Landoni 2017) in enabling external actors to work together to generate value (Boon et al., 2011) in national and regional innovation systems. Public intermediaries were originally formed to bridge gaps between science and the market (van Lente et al., 2003) and often support relatively high-risk collaborative projects that address a government mission (Caloffi et al 2018; Rossi et al 2022). They, in addition to bringing partners together for collaboration, offer a research-based role involving the sharing of knowledge and technologies. Public innovation intermediaries typically operate in highly innovative and open task environments which necessitate them to be innovative in order to support their clients (Meyer et al., 2019). The effective use of external knowledge for public intermediaries' own in-house innovation processes is therefore crucial for them to foster collaborative activities and innovative processes of their client firms, and thus to make the optimum use of public funding (Landoni 2017; Li-Ying et al 2022).

Past research has focused on understanding the function of intermediaries and how they generate value to their clients (Knockaert & Spithoven, 2016), rather than how innovation intermediaries generate different types of innovation for themselves (De Silva et al., 2018). This is the gap this paper seeks to address by paying special attention to public innovation intermediaries. Analysing this gap is important since public innovation intermediaries (a key set of actors who need to be innovative in their owen right), have a greater multiplier or 'amplification' effect on the wider national systems of innovation as they help other firms and organizations in the innovation process (Howells, 2006; De Silva et al., 2018). This contribution therefore responds to the call for more research to better understand how to sustain the role of public intermediaries (Feldman et al., 2019). The paper develops two research questions to address this specific gap, which are discussed below.

Public intermediaries are constantly adjusting the need for innovation to be harnessed for both fundamental and riskier long-term

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objectives, as well as shorter-term goals centred on incremental and accretive change. These innovative activities focus in particular on organizational forms of innovation relating to '*exploratory innovation*' and '*exploitative innovation*'. 'Exploratory innovation' creates new skills and knowledge that are additional to the existing knowledge base of the firm; whilst 'exploitative innovation' involves improving the existing knowledge and skill set of the firm which respond to the current clients' needs (Benner & Tushman, 2002; Lavie et al., 2010; Jansen et al., 2006; Kraft & Bausch, 2016). The mechanisms by which firms balance between these two sets of distinct types of innovation is defined as 'innovation ambidexterity' (Andriopoulos & Lewis, 2009; Mueller et al., 2013; Luger et al., 2018; Kraft & Bausch, 2016) and builds on earlier work associated with the concept of 'organizational ambidexterity' (He & Wong, 2004; O'Reilly & Tushman, 2004; Raisch & Birkinshaw, 2008; Raisch et al., 2009; Cao et al., 2009). Firms increasingly rely on using external sources of knowledge to accelerate the innovation process (Raisch et al., 2009; Schulze & Hoegl, 2008) and support their ambidexterity in relation to the innovation process. Even though studies have investigated how external knowledge augment in-house generation of exploratory and exploitative innovation (Zobel, 2017; Martinez et al., 2017), less attention has hitherto been paid to investigating this with respect to public innovation intermediaries. This paper thus seeks to deepen our understanding in relation to how the two key roles played by innovation intermediaries have different impacts on their in-house exploratory and exploitative innovation activities. Extant literature suggests that innovation intermediaries play two major roles in facilitating and managing collaborative projects (Howells, 2006: 716-18): (a) a '*knowledge integration role*' by fostering multilateral knowledge exchange and integration between collaborators (Klerkx & Leeuwis, 2008; Acworth, 2008; Hargadon & Sutton, 1997); and, (b) a '*network building role*' by acting as a network agent bringing together collaborative partners and coordinating and fostering network ties between these parties (see Zhang & Li 2015 – exploring a wider group of public intermediaries). Our first research question is therefore, "how do the two key roles played by public intermediaries (knowledge integration and network building) have different impacts on their internal exploratory and exploitative innovation processes?".

Secondly, there still remain gaps in terms of investigating the effect of relational (i.e., the ability to capitalise on relationships with external parties), and internal (i.e., the ability to use the capabilities of internal employees), capabilities on different types of innovation, a research area which is not well understood (Zahra & George, 2002; Kim et al., 2012; Khan et al., 2018; Ngo et al 2019). While the literature on innovation intermediaries has discussed their role in enabling the ecosystem to develop dynamic capabilities (Randhawa et al 2022), the current literature is silent on how different internal and relational capabilities of public innovation intermediaries contributes to their internal ambidexterity. Our second research question is therefore "how do the internal and relational capabilities of public innovation intermediaries contribute to their internal exploratory and exploitative innovation?".

This paper, by adopting a sequential mixed methods research with empirical evidence drawn from Research and Technology Organizations (RTOs) based in Europe, makes two original contributions. First, our results indicate that knowledge integration role of public innovation intermediaries is associated with public intermediaries' 'exploratory innovation'. By contrast, network building role is associated with 'exploitative innovation'. By being able to capitalise on both these roles to generate 'exploratory innovation' capacity and 'exploitative innovation' capacity, is seen as being essential for long-term sustenance of public innovation intermediaries. Second, the paper reveals that the relational capabilities mediate the relationship between the two distinct roles of public innovation intermediaries and their internal capabilities., In turn, the study found that internal capabilities mediate the relationship between the relational capabilities of public intermediaries and the type of innovation involved. While internal, and relational, capabilities were not essential for exploratory innovation activity (even though they accelerate exploratory innovation), such capabilities did have a full mediation effect between network building role and exploitative innovation activity.

The remainder of this paper is organised as follows. The next section outlines a set of hypotheses developed to indicate how knowledge integration and network building roles of public innovation intermediaries generate exploratory and exploitative innovation, and how these relationships be mediated by internal and relational capabilities. This will be followed by a methodology section and the paper then concludes by discussing the results, implications, limitations and future research directions of the study.

2. Theoretical framework and hypotheses development

2.1. Exploratory and exploitative innovation and the role of public innovation intermediaries

Public innovation intermediaries play an important role in connecting diverse set of organizations. When looking at the role played by public innovation intermediaries it is apparent that past research on innovation intermediaries can be used to conceptualise their main roles in collaborative projects. The roles played by innovation intermediaries in collaborative projects identified in past research could be categorised into two main roles. First, intermediaries have a network building role connecting two or more organizations (Burt, 1992), as a way of bridging structural holes (Burt, 1997). Håkansson et al. (2011: 267) highlight the wide and very different dimensions associated with this network building role of intermediaries by noting their "…. ability to maintain a contact network spanning a broad set of otherwise disconnected actors; the ability to maintain an organizational memory about these actors, their needs and capabilities and the ability to act as a credible mediator, helping building mutual trust and attenuating the risk of opportunistic behaviour." Secondly, there is the knowledge integration role of innovation intermediaries (Klerkx & Leeuwis, 2008), in which they are involved in bridging a wide array of knowledge gaps and conducting applied research (Smedlund, 2006; Klerkx & Leeuwis, 2008; Andersen & Blanc, 2013). Essentially in this latter role, innovation intermediaries engage in the transfer and integration of external knowledge (Hargadon & Sutton, 1997) to facilitate multilateral knowledge flows between collaborators (Klerkx & Leeuwis, 2008; Acworth, 2008; Håkansson et al., 2011; Khan et al., 2015).

Since innovations are generated in a social context, studies point out the important role of external sources of knowledge for in-house innovation (Majchrzak & Malhotra, 2013; Fritsch & Franke, 2004; Zeng et al., 2010). Hence, when public innovation intermediaries are engaged in network building and knowledge integration roles, they are likely to seek to access useful knowledge that is of value to their in-house innovations. Such knowledge may include both technical knowledge as well as a deeper awareness of the 'core' competencies of external actors (Howells, 2006). Hence, capitalising on knowledge accumulated in trustworthy relationships increases the reliability, breadth and depth of tacit and codified knowledge available (Nielsen, 2005; Vlaisavljevic et al., 2016) to intermediaries, thereby improving their innovative performance (Martín-de Castro, 2015).

Yet, the very differences in their roles imply that there will be differential impacts on their own in-house innovation process. Studies have found that intermediaries benefit by having a central brokerage position within networks because it provides them with access to a diverse set of resources and ideas (Lingo & O'Mahony, 2010; Burt, 1992; 2004; Ireland & Morgan 2007). However, recent evidence suggests that firms experience great difficulties orchestrating networking interactions effectively to the benefit of their own innovation performance (Rod et al., 2014; Gronroos, 2011; Ireland & Morgan 2007). The complex, and sometimes paradoxical nature, of collaboration in networks suggests that the network building role of public intermediaries might be less likely to provide them with knowledge of value for exploratory

innovation since this type of innovation requires the acquisition and internalisation of radically new knowledge (Benner & Tushman, 2002: Levinthal & March 1993; McGrath, 2001). In the network building role, it is speculated that as public intermediaries are mainly involved in bringing parties together for collaboration and coordinating relationships, they might not necessarily have deep interactions with such parties that is conducive to the exchange of novel ideas and knowledge. This may be because the building of trust during network building interactions is low due to the strength of the ties being weak (Ahuja, 2000; Coleman, 1988), or that the quality and composition of network (Wasserman & Faust, 1994) hinders the acquisition of novel knowledge, conducive for the development of exploratory innovation. Knowledge exchange is therefore more likely to be related to what public intermediaries already know (and similar to their existing knowledge base) enabling them to augment their existing knowledge, and skills. Hence, such knowledge may enable them to pursue exploitative innovations (cf. Jansen et al., 2006; Gulati & Puranam, 2009) in these network building type roles, with there being less likelihood to generate radically new ideas due to over embeddedness in existing networks. Also, due to the 'lock-in' (Saviotti, 1996) effect of existing network ties, the knowledge coming through these sources might be 'stale' and insufficiently novel or fine-grained for the pursuit of exploratory innovation. Based on the above discussion, it is hypothesized that:

H1: *The network building role of public innovation intermediaries is more positively associated with the generation of exploitative innovation rather than exploratory innovation.*

In contrast to their network building role, public intermediaries are in a much better position to gain access to diverse ideas and knowledge during external knowledge-based engagement with specific partners and other types of collaborators. This is where the focus is on public intermediaries enabling collaborators to exchange and integrate their knowledge rather than the concentration being on more general network formation or the functioning of the collaboration process as an end in itself. Innovation intermediaries within their knowledge integration activities work very closely with their clients, through recombining and transferring knowledge and helping in the development of innovation related skills associated with applied research (Gassmann et al., 2011). These knowledge integration activities are likely to provide public intermediaries a closer working relationship with their clients enabling a better platform to acquire and internalise new knowledge for new product, service or process development. For these knowledge integration activities, therefore, intermediaries exhibit an exploratory innovation profile (Colombo et al., 2011). As exploratory innovation has a greater reliance on external knowledge (Hagedoorn & Duysters, 2002) than exploitative innovation (Rosenkopf & Nerkar, 2001; Rosenkopf & Almeida, 2003), knowledge integration role, which provides direct access to external knowledge would support in-house exploratory innovation by public intermediaries. Close knowledge-based relationships with a range of actors enhance the opportunities for intermediaries to combine knowledge and develop new knowledge that underlies exploratory innovation (Atuahene-Gima, 2003; McFadyen & Cannella, 2004; Gulati & Puranam, 2009). Close interaction also allows the development of mutual trust, co-operation and embeddedness with external partners, thereby reducing the transaction costs of accessing and internalizing new knowledge (Zollo et al., 2002; Caloghirou et al., 2004; Zhang et al., 2019), again enhancing public intermediaries' in-house exploratory innovation. In addition, unlike their network building role where public intermediaries interact with several partners, in their knowledge integration role public intermediaries interact with a specific set of partners, allowing 'narrow' knowledge search that is found to be positively associated with exploratory innovation (Laursen & Salter, 2006; Ireland & Morgan 2007). Thus, whilst the knowledge integration role of public intermediaries, might also have positive influences in improving existing knowledge, exhibiting certain traits of exploitative innovation, its impact on exploratory innovation is expected to be much stronger than exploitative innovation. Based on this discussion, we propose the following:

H2: *The knowledge integration role of public innovation intermediaries is more positively associated with the pursuit of exploratory innovation rather than with exploitative innovation*

2.2. Internal and relational capabilities of public innovation intermediaries

Since exploratory and exploitative innovations present paradoxical challenges to firms and organizations, firms need to develop certain set of specific capabilities in order to engage and benefit from these two distinct activities (Gibson & Birkinshaw, 2004). Yet, there is generally a lack of understanding of how different capabilities (such as internal and relational) combinatorially work together to facilitate the use of external knowledge to the simultaneous achievement of exploratory and exploitative innovation (Gibson & Birkinshaw, 2004; Simsek et al. 2009; Lin et al. 2017). As knowledge resides both internal and external to the organization (Hull & Covin, 2010; Jansen et al., 2006), capabilities of firms to integrate and leverage external sources of knowledge with internal knowledge is crucial for in-house innovation (Lorenzoni & Lipparini, 1999; Kogut & Zander, 1992). A capabilities perspective moreover stresses the importance of two key sets of capabilities: *internal capabili*ties (i.e. capabilities vested within individuals as employees) and *relational capabilities* (i.e., the ability to manage and capitalise on relationships with external parties), for the transfer of knowledge and the resultant innovation (Cohen & Levinthal, 1990; Dyer & Singh, 1998; Zahra & George, 2002). Previous research has focused on investigating the effects of internal, and relational, capabilities separately on generating exploratory and exploitative innovation (Subramaniam & Youndt, 2005; Song & Thieme, 2009; Obal, 2015). These studies have, however, not considered how these capabilities *together* enable the pursuit of innovation ambidexterity, even though there is recent interest on investigating the effect of the use of a combination of firm capabilities on the simultaneous pursuit of both exploratory and exploitative innovations (Lin et al., 2013; Khan et al., 2018). Following the resource-based view, internal resources play a vital role in the development of competitive advantage (cf. Barney, 1991), whereas a relational view suggests that competitive advantage largely depends on the utilization of network relationships and ties (Dyer & Singh, 1998). Yet, there is relatively limited research that has explored how both capabilities interact and act as mechanisms for the development of innovation ambidexterity. On this basis, this study investigates how internal (i.e., the ability to use the capabilities of internal employees), and relational (i.e. the ability to capitalise on relationships with external parties), capabilities of public innovation intermediaries *together* foster the use of knowledge acquired through their different roles (i.e. *knowledge integration* and *network building* roles) to the simultaneous generation of in-house exploratory and exploitative innovation.

It is not the capabilities themselves per se, but the *use* of such capabilities that enables firms to innovate and be innovative (Porter, 1991; Stalk et al., 1992). This paper, therefore, following other studies (such as Lin et al., 2017), defines two types of capabilities as mechanisms that: firstly, ability the use of capabilities vested within individuals as employees offering two different roles (i.e. internal capabilities; Wuyts and Dutta, 2014); and, secondly, and the ability to capitalise on relationships with external parties (i.e. relational capabilities) (c.f. Barreto, 2010) in fostering innovation ambidexterity. Intermediaries in orchestrating collaborative projects use *relational* capabilities by way of capitalising on relationships with external network partners, such as business, universities national and supra-national organizations (Arranz & de Arroyabe, 2012; see also Howells & Roberts, 2000). Mechanisms used to leverage *internal capabilities* include: retaining and capitalising on key, successful, experienced, staff involved in the delivery of knowledge integration and network building roles, and exchanging scientists and engineers between partners to develop internal capabilities (Dahlander & Gann,

2010). Relational and internal capabilities therefore enable public innovation intermediaries to use the capabilities of internal employees related to functional deliveries of their roles as well as to capitalise on their network for in-house innovation activities.

In order for the two roles of public innovation intermediaries to generate in-house innovation, discussed in the first two hypotheses, the use of internal capabilities is essential. Yet, the relationship between the role of public intermediaries and the use of internal capabilities to generate innovation seems to be occurring through the use of relational capabilities. This is because when public intermediaries are engaged in their knowledge integration and network building roles, they are more likely to use relational capabilities that in turn enable intermediaries to transfer external knowledge to their own firm boundary (Foss et al., 2013; Cepeda-Carrion et al., 2012). Studies suggest that during the innovation process knowledge acquired by the firm through network relationships (i.e. through the use of relational capabilities) are complemented and combined with internal capabilities (Dyer & Singh, 1998; Walker et al., 2013). This argument is further supported by the work on absorptive capacity, which has argued that firms that use relational capabilities to leverage external knowledge, are better able to benefit from their internal capabilities (Wuyts and Dutta, 2014) for the transformation and exploitation of external knowledge (George & Zahra, 2002). When public innovation intermediaries are involved in knowledge integration or network building roles, they are more likely to use relational capabilities to transfer external knowledge to firm boundaries, which is then integrated with internal knowledge through the use of internal capabilities. It is hypothesised, therefore, that:

H3: *Relational capabilities positively mediate the relationship between the roles of public innovation intermediaries [i.e. knowledge integration and network building] and their internal capabilities.*

While some past studies have argued that relational capabilities support in-house innovation (Song & Thieme, 2009; Obal, 2015), these have not explicitly discussed how this process works. Hence, by developing the arguments laid out in the H3, we argue that relational capabilities would generate in-house innovation, only when the internal capabilities are used. Building on the literature that have argued that firms with strong internal capabilities could combine external knowledge with internal knowledge to generate innovation (Srivastava and Gnyawali 2011; Subramaniam & Youndt, 2005), we argue that public intermediaries with strong internal capabilities can transform external knowledge to in-house exploratory and exploitative innovation. High internal capabilities are found to enhance firm's ability to identify, understand and utilise external knowledge for in-house innovation (Srivastava and Gnyawali 2011). Studies have found that firms that build an internal capability to leverage external knowledge are better able to exploit and transform knowledge for the generation of innovation (Wuyts & Dutta 2014). It is therefore likely that internal capabilities play a major role in transforming external knowledge to firm innovation by integrating with the internal knowledge base of the organization. Additionally, due to the common characteristics associated with both relational and internal capabilities such as employees' commitment to relationships, adoption of better communication strategies and building of trust with both internal and external parties (Wuyts & Dutta 2014), it could be argued that public intermediaries who use relational capabilities are likely to use internal capabilities when generating in-house innovation. In turn, relational capabilities may interact with internal capabilities, when transforming and exploiting external knowledge to exploratory and exploitative innovation (Zahra & George, 2002). We thus hypothesise that:

H4: *Internal capabilities positively mediate the relationship between relational capabilities and in-house innovation [i.e. exploratory and exploitative innovation] of public innovation intermediaries.*

Even though, due to lack of relevant literature, it is not hypothesised how internal and relational capabilities may have differential influence on two different roles and innovations, it is the aim of this study to investigate if such differences may exist.

In summary, it is hypothesised that public innovation intermediaries pursue innovation ambidexterity by way of their knowledge integration role having a greater positive influence on the generation of exploratory innovation, whilst their network building role having a greater positive influence on the generation of exploitative innovation. The generation of both these types of innovation through their roles in collaborative projects is in turn made possible through the mediation effect of relational, and internal, capabilities. Relational capabilities may positively mediate the relationship between each type of role and internal capabilities, whilst internal capabilities may positively mediate the relationship between relational capabilities and each type of innovation. In turn, the internal capabilities are likely to be predominantly involved in integrating external knowledge and exploiting this knowledge with internal knowledge to generate in-house innovations. By contrast, relational capabilities are associated with transferring external knowledge to the public intermediaries' firm boundary. Based on the above discussions, the identified relationships are presented in Fig. 1.

3. Methodology and analytical framework

3.1. Methodology and data

The empirical base of this study, and the unit of observation and analysis for the survey, is Research and Technology Organizations (RTOs) operating in Europe. RTOs are considered a major type of public innovation intermediaries operating in Europe (defined above) engaged in a wide array of tasks and activities, ranging from bringing different parties together for collaboration to providing applied research based contributions in an innovation consortium (Howells, 2006; Arnold et al., 2010). RTOs play a major role in European Union (EU) Framework Programmes (FPs), coordinating a third of all EU research and innovation projects (which comprise a minimum of three partners and run typically for three to seven years) and have been awarded 32% of all Framework Programme 6 (FP6) funded projects as well as 44% of FP6 funding (Arnold et al., 2010). EU Framework Programmes are funded by the European Commission (EC) to facilitate research and innovation within the European Research Area (ERA). Focusing on RTOs' engagement in EU projects therefore provided a rich empirical base to test our hypotheses as both roles of such public intermediaries are less known in the context of different types of innovation. A database of RTOs compiled by the Big Innovation Centre identified a total of 122 European RTOs (Andersen & Blanc, 2013) has been used as a basis for the study. The focus of this study is on public innovation intermediaries and specifically to investigate how their knowledge integration role and network building role, performed when they are supporting collaboration (i.e. EU projects in this case), enable them to generate their own in-house exploratory and exploitative innovation, through the use of their relational and internal capabilities.

A sequential mixed method approach, consisting of an initial qualitative data gathering phase, an online survey, an in-depth interview phase and a validation event, was used to further test and improve the validity of this study and to initially frame and then explore in more detail the underlying relationships that emerged from the quantitative analysis (Tashakkori & Teddlie, 1998; Bisbe et al., 2007) [Fig. 2].

Initially, twelve in-depth interviews were conducted with a diverse set of key actors. Respondents comprised eight directors of RTOs, one representative each from the EC and the European Association of Research and Technology Organizations (EARTO) (Appendix A). The main purpose of these initial interviews was to validate the literature review and aid the development of the survey. Since there was no contradiction between the responses from the12 interviews, data collection was not extended. These initial interviews were mainly analysed in relation to the roles of public innovation intermediaries, their in-house innovation, and how they develop internal and relational capabilities. One of the major findings of this phase was that RTOs are likely to engage in both knowledge integration and network building

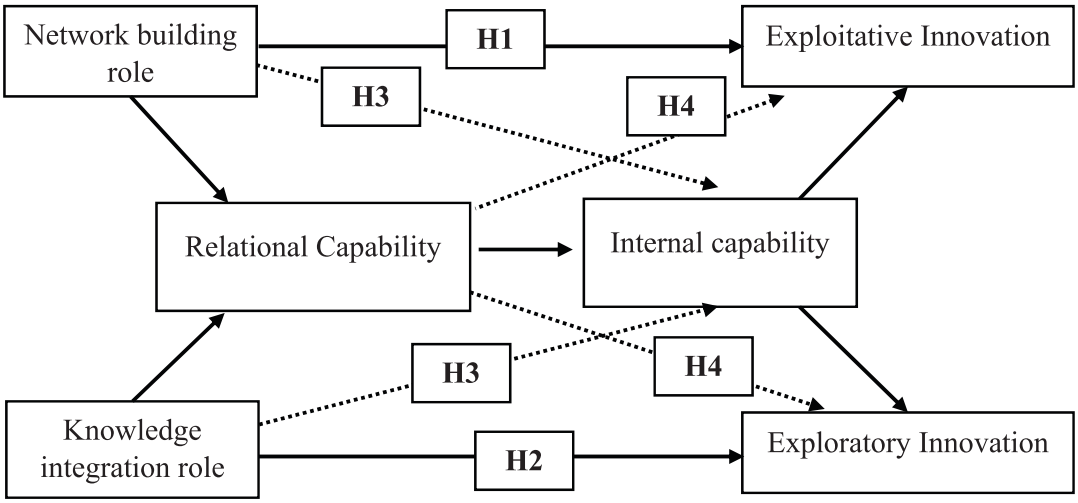

Fig. 1. Conceptual Framework.

Phase 1: Initial data gathering	- Validate the applicability of the theoretical foundation developed from past research - Gain insights to improve the construct validity of the survey used in the Phase 2
⬇	
Phase 2: Quantitative Survey	- To gather data for hypothesis testing
⬇	
Phase 3: In-depth interviews	- To gather context specific in-depth data to validate the relationships identified in the quantitative data analysis in the Phase 2, which increases the internal validity.
⬇	
Phase 4: Validation event	- The findings were presented and got validated from intermediaries and their collaborators in order to increase the generalisability.

Fig. 2. Data Collection Strategy - Sequential Mixed Method Design.

roles associated with exploratory and exploitative innovation activities to varying degrees during their engagement with EU FP programmes, which further justified the appropriateness of the evidence base. The initial interviews also helped adapt and interpret statements derived from the literature review, which measured the types of innovation, capabilities and roles to suit the context and operations of public innovation intermediaries. The use of these validated findings to develop the online survey helped improve construction validity, particularly because the paper investigates a relatively underexplored research area (Edmondson & McManus, 2007; Autio et al., 2013).

This first phase was followed by gathering quantitative data through an online survey sent to Chief Executive Officers or Directors, who were directly involved in such EU projects. The survey consisted of questions covering: public innovation intermediaries' role and organizational characteristics; innovation and other benefits generated when involving in EU FP programmes; mechanisms with regard to relational, internal and other capabilities; and, how RTOs influence other actors. In order to improve data reliability, the questionnaire was piloted with Directors of four RTOs and the survey gained a response rate of 48.3 %[1]. Sideridis (2014) recommended that a sample size of 50–70 would be enough for a model involving 4 or less latent variables, thus confirming the adequacy of responses (N = 59) for Structural Equation Modelling, which is used for quantitative analysis.

During the final phase of the study, in-depth interviews were conducted with a sample of twenty representative of the respondents of the online survey (Appendix B). The main objective of these interviews was to gain context specific and in-depth understanding of the causality derived from the findings of survey data; a strategy often adopted in research to improve the internal validity (Downward & Mearman, 2007). Accordingly, the interviews were analysed against the findings of

the survey mainly to understand why certain relationships were found in this specific context (e.g. those relationships outlined in the hypotheses), which was important to triangulate and validate the findings of the survey (Downward & Mearman, 2007). Since the validation was the main objective (Kim & Miner, 2007; Autio et al., 2013), the interviews were analysed manually against the key findings of the survey and constantly compared and contrasted with the theoretical framework [i.e. the findings on the relationship between knowledge integration and network building roles, and internal exploratory and exploitative innovation of public innovation intermediaries; and the mediation role of internal and relational capabilities]. Finally, a validation event was held with survey participants, together with their collaborating businesses and universities, EARTO and the European Commission to further verify the study findings. This validation event encompassing the RTOs' wider collaborators was important to overcome any bias since the data on other previous phases were gathered mainly from RTO directors and managers. These validation steps that confirm the findings of the on-line survey provide additional support for the adequacy of the number of responses for the intended analysis.

3.2. Variable construction and robustness testing

The data from online survey was the main source employed to test hypotheses and the findings of the in-depth interviews were used to validate the former and also to gain a better understanding of context specific relationships (Kim & Miner, 2007; Autio et al., 2013). The data was collected in relation to the RTOs' engagement in the FP7 EU programme. A comprehensive list of statements derived from the literature (Section 2) in relation to the innovations and capabilities were presented to interviewees during the initial interview phases. These were then amended to align with the function and activity profile of public innovation intermediaries, before sending the questionnaire survey. The innovation variables were the two types of innovations – in-house exploratory and exploitative innovation – generated by public intermediaries during the last three years of their engagement with the EU FP7 projects. Respondents were presented with two statements (adapted from He and Wong, 2004; Jansen et al., 2006; Afuah, 2003) indicating exploratory innovation and four statements (adapted from Benner and Tushman, 2002; Barirani et al., 2015; Raisch et al., 2009) in relation to exploitative innovation and requested to rate on a Likert scale of 1 to 5 (1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always) to indicate the extent to which RTOs generate each type of in-house innovation (Table 1). Four statements each for relational (Barreto, 2010), and internal (Wuyts and Dutta 2014), capabilities were also used to investigate the extent to which RTOs adopt use these during their engagement in FP7programme during a seven year period during which the FP 7

Table 1
Variable construction.

Variable construct	Measure	Components	Uni-dimensionality	Internal consistency
DEPENDENT VARIABLE: Innovation				
Exploratory Innovation *(Exploratory_ Innovation)* (adapted from He and Wong, 2004, Jansen et al., 2006; Afuah, 2003)	The extent to which public intermediaries generate each type of innovation during EU projects (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always)	1. Developed new equipment and/or technologies *(EI_Eqip_Tech)* 2. Developed new products and/or services *(EI_Product_Service)*	Factor loading- 0.876 0.876 Eigenvalues 1.53, 76.67%	Cronbach's Alpha 0.7 CR 0.9
Exploitative Innovation *(Exploitative_ Innovation)* (Adapted from Benner and Tushman, 2002; Barirani et al., 2015; Raisch et al., 2009)	The extent to which public intermediaries generate each type of innovation during EU projects (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always)	1. Improve existing knowledge *(EXP_New_Knowledge)* 2. Improve existing skills *(EXP_Research_Capability)* 3. Improve existing processes *(EXP_Management_Capability)*4. Improve existing products and services *(EXP_Research_St)*	Factor loading- 0.763 0.698 0.689 0.685 Eigenvalues 2.01, 50.31%	Cronbach's Alpha 0.7 CR 0.8
MEDIATOR VARIABLES – Relational and internal capabilities				
Internal capabilities *(Internal_ Capability)* (Wuyts and Dutta 2014)	*Extent to which public intermediaries use following capabilities during EU project engagement (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always)*	The ability to use the capabilities of internal employees by: Capitalising on the capabilities of experienced staff when engaging in EU Framework programmes *(IC_Capitalise_Staff)* Making an effort to retain those employees with successful EU experience *(IC_Retain_Employees)*Exchanging staff between organizations / universities / industry to develop internal capabilities (i.e. placements) *(IC_Exchange_Staff)* Having a dedicated team working on EU engagements *(IC_Team_EU_Engagements)*	Factor loading- 0.828 0.823 0.797 0.677 Eigenvalues 2.46, 61.38%	Cronbach's Alpha 0.8 CR 0.9
Relational capabilities *(Relational_ Capability)* (Barreto, 2010)	*Extent to which public intermediaries use following capabilities during EU project engagement (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always)*	1. Ability to develop and capitalise on relationships with key business players in the market *(RC_Relationships_Key_Bus_Players)* Ability to establish useful relationship with local/national government *(RC_Relatiosnhips_Govt)* Ability to engage effectively with universities *(RC_Relationships_Universities)* Ability to pursue a productive relationship with European Commission *(RC_Relationships_EC)*	Factor loading- 0.825 0.807 0.586 0.523 Eigenvalues 1.95, 48.73%	Cronbach's Alpha 0.7 CR 0.8

programme was run (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always).

These data were used to construct variables for two types of innovations and capabilities. As evident in Table 1, the results of factor analysis confirmed the uni-dimensionality of the variables: analysis generated only a single factor with an Eigen value>1 for each variable: exploratory innovation (1.53, 76.67%), exploitative innovation (2.01, 50.31%), relational capabilities (1.95, 48.73%) and internal capabilities (2.46, 61.38%). Cronbach's Alpha for exploratory innovation, exploitative innovation, relational capability and internal capability being 0.7 or above indicates an acceptable level of internal consistency among items. The Composite Reliability (CR) indices being>0.7, further confirms the reliability of the measures (Chin, 1988). The respondents were requested to rate on a Likert scale of 1 to 5 to indicate the extent to which the RTOs involve in offering a knowledge-based support to collaborators ranging from knowledge exchange and knowledge re-combination (Howells, 2006; Håkansson et al., 2011; Khan et al., 2015) in FP 7 Programme (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always), the data on which was used as the variable for the degree of engagement in the knowledge integration role. Similarly, the data on the respondents' rating of the extent to which the RTOs involve in the role of bringing partners together and coordinating collaboration (Håkansson et al., 2011) during their engagement in FP 7 Programme (Likert scale of 1- Never, 2- Rarely, 3- Sometimes, 4- Often, 5- Always) were used as the variable indicating the level of involvement in the network building role. Initial interviews confirmed the appropriateness of using the two statements to gather data on their role since public innovation intermediaries are familiar with the distinction between these two roles.

As control variables, the general characteristics of RTOs were used as they were seen as having an influence on the ability of intermediaries to generate exploratory and exploitative innovation, such as turnover (Hauser, 2010), age (Bruneel et al., 2010), sector and number of employees (Kirkels & Duysters, 2010). Additionally, the Technology Readiness Levels (TRL)[2] of projects was also controlled for. TRL is a measure where the higher levels of readiness, the closer to the market orientation of the project (Mankins, 1995). The respondents stated the highest TRLs they engaged in when undertaking EU FP7 programmes. Three main levels were identified: those reaching to TRL 4; up to TRL 6; with the rest on TRL 7. None of the RTOs worked at TRL levels 8 or 9. A categorical variable was created to indicate this heterogeneity, which is believed to control the influence of the market readiness of the project on the exploratory and exploitative innovation (Kirkels & Duysters, 2010). Structural equation modelling, with AMOS 24.0 (maximum likelihood estimation), was conducted to test the hypotheses.

Several measures were undertaken to address potential endogeneity issues (Shadish et al., 2002). First, the sequential mixed method design adopted comprising four stages, is believed to improve the construct and internal validity of the study. Second, satisfactorily meeting the requirements of non-response bias tests, Cronbach's Alpha, CR and factor loading criteria confirmed the reliability and validity of the chosen constructs, minimising measurement errors. Third, as illustrated in the Results section, the outcome of structural equation modelling adopting Baron & Kenny's (1986) approach was further validated by using the recommendations by Iacobucci et al. (2007) and Preacher & Hayes (2008) as to calculating direct, indirect and total effects using bootstrapping method. Fourth, the study also tried to overcome the common method bias. For instance, the data on turnover was derived from secondary sources. Additional questions asked during the survey covering benefits to RTOs other than innovation, and other capabilities (such as communication capabilities used to influence the actors) as well as the inclusion of the mediation effect in the model sought to limit respondents' ability to predict the model. In addition, the survey questions were mixed in a way where respondents were unable to guess the independent and dependent variables. The highest correlation among the constructs was 0.68 with a majority<0.3 (Bagozzi et al., 1991) (Appendix C). Harman's one-factor analysis (Podsakoff & Organ, 1986) on common method bias also extracted three factors with eigenvalues above 1.0 with the first factor accounting only for 30.05% variance (i.e. the requirement is to yield more than one factor). Finally, as presented in the Results section, the model satisfies the model fit criteria. This comprehensive approach towards robustness checks seeks to highlight that the model does not suffer from endogeneity problems and is robust.

4. Results

The descriptive statistics indicate that a public innovation intermediary's engagement in EU projects generated both in-house exploratory (M = 3.98, SD = 0.79) and exploitative (M = 3.89, SD = 0.56) innovations, engaged in both knowledge integration (M = 4.05, SD = 0.92) and network building (M = 3.92, SD = 0.68) activities, and used both internal (M = 3.81, SD = 0.71) and relational (M = 3.72, SD = 0.66) capabilities. These findings further justified the appropriateness of the empirical base to test the four hypotheses. A step-wise analysis, using Structural Equation Modelling, was then conducted to understand the effects of main and mediating variables (Table 2). To further validate the presence of mediation effects (Iacobucci et al., 2007; Preacher & Hayes, 2008; see also use in innovation studies by Rosenbusch et al. 2013; Spanjol et al., 2012; Lin et al., 2013), direct, indirect and total effects were then calculated, further strengthening the rigour of the analysis (Table 4). In this validation step, the level of significance of the mediation effects was assessed by the 'bootstrapping' method (Preacher & Hayes, 2008). The direct effects refer to the unmediated effects of network building and knowledge integration roles on exploitative and exploratory innovations. The indirect effects represent the paths from the both the roles to capabilities and from the capabilities to both the innovation types.

The results suggest that knowledge integration role of public innovation intermediaries was significantly associated with exploratory innovation ($\beta = 0.448$, $p < 0.001$), but their relationship with exploitative innovation ($\beta = 0.177$, $p > 0.1$) was not significant (Model 1, Table 2). By contrast, network building role was significantly associated with exploitative innovation ($\beta = 0.475$, $p < 0.001$), although their relationship with exploratory innovation was not significant ($\beta = 0.177$, $p > 0.1$). These findings clearly support the first and second hypotheses, which predicted that knowledge integration role of public innovation intermediaries would generate more exploratory type innovations for them than exploitative ones. Similarly, network building roles were found to have a major impact on the generation of exploitative innovation, but did not have a significant influence on exploratory innovation. These results hold even after adding control variables, further validating the findings in relation to the first two hypotheses on the effect of the type of role performed by public innovation intermediaries on the nature of their in-house innovation.

These findings were further confirmed by post-survey, interviews. For instance, Table 3 highlights illustrative quotes on how external knowledge acquired through public intermediaries' knowledge integration role was, on the one hand, used to develop new equipment, technologies, products and services, indicating in-house exploratory innovation by public innovation intermediaries. On the other hand, other responses indicate how the network building role of a public intermediary in a consortium enabled the public intermediary to improve its knowledge, skills and research streams, exhibiting a more exploitative innovation profile. Interestingly, the in-depth interviews also reported the positive effects of knowledge integration activities on exploitative innovation as well on exploratory innovation. Nevertheless, it was evident during in-depth interviews that the influence of the former (i.e. those relationships that were significant), was more prominent than the latter (i.e. those relationships that were not significant, but still positive). The reason for this was seen as being the different levels of engagement provided by the two roles. For instance, in the knowledge integration role, public intermediaries were closely working with partners from different disciplines, enabling them to acquire and

Table 2
Models.

	Model 1	*p*	Model 2	*p*	Model 3	*p*
Exploratory innovation ← Network role	0.177 (0.116)	0.128	0.087 (0.123)	0.480		
Exploratory innovation ← Knowledge role	0.448*** (0.116)	0.000	0.413*** (0.116)	0.000	0.380*** (0.114)	0.000
Exploitative innovation ← Network role	0.475*** (0.114)	0.000	0.422*** (0.124)	0.000	0.206 (0.127)	0.106
Exploitative innovation ← Knowledge role	0.177 (0.114)	0.120	0.181 (0.116)	0.120		
Exploratory innovation ← Internal capability					212+ (0.112)	0.060
Exploitative innovation ← Internal capability					0.460*** (0.118)	0.000
Internal capability ← Network role					0.347** (0.106)	0.001
Internal capability ← Knowledge role					0.023 (0.099)	0.813
Relational capability ← Network role					0.286* (0.127)	0.025
Relational capability ← Knowledge role					0.230+ (0.120)	0.055
Internal capability ← Relational capability					0.546*** (0.102)	0.000
Control variables						
Exploratory innovation ← Turnover			0.112 (0.223)	0.616	0.133 (0.216)	0.536
Exploitative innovation ← Turnover			-0.134 (0.225)	0.549	-0.041 (0.201)	0.840
Internal capability ← Turnover					-0.173 (0.183)	0.332
Relational capability ← Turnover					0.104 (0.231)	0.652
Exploratory innovation ← TRL level			0.286* (0.115)	0.027	0.259*** (0.118)	0.028
Exploitative innovation ← TRL level			0.186+ (0.130)	0.153	0.174 (0.116)	0.135
Internal capability ← TRL level					-0.004 (0.107)	0.938
Relational capability ← TRL level					0.168 (0.134)	0.209
Exploratory innovation ← Sector			-0.012 (0.116)	0.916	-0.019 (0.113)	0.865
Exploitative innovation ← Sector			-0.048 (0.117)	0.680	-0.041 (0.104)	0.693
Internal capability ← Sector					-0.017 (0.095)	0.826
Relational capability ← Sector					0.106 (0.120)	0.376
Exploratory innovation ← Size			0.068 (0.233)	0.772	0.076 (0.208)	0.958
Exploitative innovation ← Size			0.271 (0.235)	0.248	0.012 (0.222)	0.716
Internal capability ← Size					0.230 (0.187)	0.213
Relational capability ← Size					0.110 (0.242)	0.651
X^2 (df)	7.797 (1) **	0.005	4.903 (3) *	0.027	5.454 (5)	0.363
GFI	0.941		0.970		0.981	
RMSEA	0.342		0.165		0.040	
RMR	0.078		0.051		0.026	
TLI	0.127		0.722		0.982	
IFI	0.869		0.974		0.998	
CFI	0.854		0.970		0.998	
CMIN/DF	7.797		2.588		1.091	
AGFI	0.408		0.638		0.791	
NFI	0.852		0.959		0.980	

***p <=.001, **p <=.01, *p <=.05, +p <= 0.1.

internalise new knowledge, develop new technologies, equipment, products and services. However, by contrast, when they were engaged in network building role, their chances of engaging in deeper collaboration is relatively low, and thus, the projects mainly result in advancing their existing knowledge and capabilities (Table 3).

In order to test the other two hypotheses, Model 3 (Table 2) introduces the extent to which the relational and internal capabilities of a public innovation intermediary played a mediating role between knowledge integration and network building roles of their activities and the innovation process. Table 4 presents associated, direct, indirect and total effects. The level of significance of the mediation effects was assessed through the use of bootstrapping method. As illustrated in Table 2 (Model 3), Table 4 and Fig. 2, the direct and indirect effects suggest that the relational capability mediates the relationship between the network building role and internal capability of public innovation intermediaries (indirect effect between network building role and internal capability 0.155, p <.05; direct effects between network building role and relational capability 0.286, p <.05, and relational capability and internal capability 0.540, p <.001). Internal capability was also shown to mediate the relationship between relational capability and exploitative innovation (indirect effect between relational capability and exploitative innovation 0.248, p <.001; direct effects between relational capability and internal capability 0.540, p <.001, and internal

Table 3
Illustrative quotes.

Relationship	Illustrative quotes
Exploratory Innovation ← Knowledge integration role	*"There is a development you want, for example to develop bio-markers for animal health, then you need to look at different diseases, look at different breeds, use different techniques …logically you need a critical mass of diverse skills, of resources, that you don't have in-house…You work with these people [knowledge integration role] and make a big technological step going beyond your area of expertise [exploratory innovation]" [C01, Appendix B]*
	"In order to be competitive in EU project applications we need to be up-to-date with our knowledge, and technologies…We see the EU projects as a platform for producing new knowledge, technologies, products and services to engage in future industry projects [exploratory innovation]; we see it as a strategic platform. We see it as a platform for building new competence in a long-term perspective, it's mainly possible when we closely work with collaborators in applied research [knowledge integration role]" [C14, Appendix2]
	"When we introduce new combinations of knowledge and use our knowledge to achieve project outcomes [knowledge integration role], it's often that we get often very specialised know-how, so the things we don't have here in the institute [exploratory innovation]" [C08, Appendix B]
Exploitive Innovation ← Network building role	*"Through that networking [network building role] we get access to knowledge and exchange knowledge so we can also through such collaboration advance our knowledge [exploitative innovation]" [C10, Appendix B]*
	"Engaging in EU framework programmes is by and large a little bit more effort than joining a national programme especially if you're a coordinator [network building role] but it's worth the effort. some projects which are called conference projects, it has like 50 partners so every time there is a project meeting every partner sends at least one person but typically 2 or 3 so there are 100–150 people there essentially presenting the results of various national projects. It is an incredibly worthwhile exchange of knowledge and good practice [exploitative innovation]" [C04, Appendix B]
	"When we coordinate projects [network building role], we try to select projects that are closer to our area …..without the EU funding we would develop and grow in our research areas much slower than we are doing now [Exploitative innovation]" [C13, Appendix B]

Table 4
Direct and indirect effect.

Path	Direct	*p*	Indirect	*p*	Total	*p*
Network role → Internal capability	0.346**	0.004	0.155*	0.019	0.501*	0.002
Network role → Relational capability	0.286*	0.043	0.000		0.286*	0.043
Relational capability → Internal capability	0.540***	0.000	0.000		0.540***	0.000
Relational capability → Exploitative innovation	0.000		0.248***	0.000	0.248***	0.000
Network role → Exploitative innovation	0.206	0.137	0.230**	0.001	0.436**	0.004
Internal capability → Exploitative innovation	0.460**	0.001	0.000		0.460**	0.001
Knowledge role → Exploratory innovation	0.380**	0.004	0.031	0.196	0.411**	0.003
Knowledge role → Internal capability	0.023	0.880	0.124+	0.052	0.148	0.269
Knowledge role → Relational capability	0.230+	0.084	0.000		0.230+	0.084
Internal capability → Exploratory innovation	0.212+	0.065	0.000		0.212+	0.065
Relational capability → Exploratory innovation	0.000		0.114*	0.038	0.114*	0.038

***p <=.001, **p <=.01, *p <=.05, +p <= 0.1.

capability and exploitative innovation 0.460, p <.01). These findings clearly support our third and fourth hypotheses in relation to the network building role and exploitative innovation, which predicted that relational capabilities mediating the relationship between network building role and internal capabilities, whilst internal capabilities mediating the relationship between relational capabilities and exploitative innovation. Since the third and fourth hypotheses also address the mediation effect in relation to knowledge integration role and exploratory innovation, below we discuss relevant findings.

As presented in Table 2 (Model 3), Table 4 and Fig. 2, relational capabilities are found to mediate the relationship between knowledge integration role and internal capability (indirect effect between knowledge integration role and internal capability 0.124p <.1; direct effects between knowledge integration role and relational capability 0.230, p <.1, and relational capability and internal capability 0.540, p <.001). It was found however that internal capabilities mediate the relationship between relational capability and exploratory innovation (indirect effect between relational capability and exploratory innovation 0.114, p <.01; direct effects between relational capability and internal capability 0.540, p <.001, and internal capability and exploratory innovation 0.212, p <.1). These findings clearly support our third and fourth hypotheses in relation to the knowledge integration role and exploratory innovation, which predicted that relational capabilities mediating the relationship between knowledge integration role internal capabilities while internal capabilities mediating the relationship between relational capabilities and exploratory innovation.

Accordingly, our third and fourth hypotheses are supported. Interestingly, as a result of the introduction of relational and internal capabilities, the direct, positive relationship between network building role and exploitative innovation became insignificant (prior to the introduction – Model 1: 0.475, p <.001, after the introduction – see Model 3: 0.206, p >.1). This indicates a full mediation effect of relational and internal capabilities on the relationship between network building role and exploitative innovation of public intermediaries. However, the direct, positive relationship between knowledge integration role and exploratory innovation remained significant even after introducing relational and internal capabilities in the Model 3, only with a slight reduction in the strength (prior to the introduction – Model 1: 0.448, p <.001, after the introduction – Model 3: 0.380, p >.1) (Model 3, Table 2). Yet, the total effect (being higher than the direct effect between knowledge integration role and exploratory innovation) means that the capabilities accelerate the development of exploratory innovation through the knowledge integration role (Direct effect 0.380 and Total

effect 0.411). The findings illustrate an interesting dimension where '*deep-level*', knowledge-based interactions with collaborators, which public innovation intermediaries have (regardless of their own relational and internal capability usage) during their knowledge integration activities, do contribute to exploratory innovation activities. However, the use of these internal capabilities accelerates the generation of exploratory innovation.

The model fit measures of the final model that includes all the relevant variables confirm the appropriateness of the model. $X^2(5) = 5.454$, $p > 0.1$ (Barrett, 2007),GIF = 0.981 (>0.95) (Tabachnick & Fidell, 2007); RMSEA = 0.04 (<0.05), $p = .570$ (>0.05) (Byrne, 1998); RMR = 0.026 (<0.05) (Byrne, 1998; Diamantopoulos & Siguaw, 2000) TLI = 0.982 (>0.95); IFI = 0.998 (>0.95); CFI = 0.998 (>0.95) (Tabachnick & Fidell, 2007); CMIN/DF = 1.091 (p =.480) (<2) (Carmines & McIver, 1981). The comparison of the fourth model with the first two models without the mediation effect (model 1 $X^2(1) = 7.797$, $p > 0.01$; model 2 $X^2(3) = 4.903$, $p > 0.1$) indicates that the last model has the best fit.

The in-depth interviews were useful in further highlighting the interplay between the relational and internal capabilities and helped providing a deeper, more holistic perspective to the study (Andriopoulos & Lewis, 2009: 707). Thus, when public innovation intermediaries are collaborating with partners (whether it was through their knowledge integration or network building roles), their employees develop relationships with external parties (i.e. using relational capabilities). It is this mechanism by which, they as individuals acquire knowledge and resources and develop strategic networks, is conducive for building innovation activities between partners(Gulati & Puranam, 2009). An illustrative quote is mentioned below:

> "*our unique role meant that we cannot survive without building our network with key players and using the network for our operations. As much as we help these different actors, we also learn from them and get the opportunity to access their resources and networks*" [C8, Appendix B]

When public innovation intermediaries use internal capabilities (such as the skills and networks of experienced individuals), they gain the opportunity to make use of knowledge, resources and networks developed by employees through their relational capabilities. The use of internal capabilities therefore provides public innovation intermediaries with the ability to internalise knowledge as well as resource or network capabilities developed through the use of relational capabilities. This interplay between internal and relational capabilities, and between individual and organizational level capabilities, was therefore found to be important in public intermediaries' network building role in being able to generate exploitative innovation as well as to accelerate the generation of exploratory innovation through their knowledge integration role. The qualitative interviews support such assertions:

"At the end of the day what is very good is to have a group of frequent collaborators with whom you are confident, who you trust and they are good in some particular topics, and with whom you can be successful in one proposal and be successful in a follow-on proposal and so on [use of relational capabilities]….Adding to this, we need to make the most out of employees engaged in EU projects. These projects run for about 5 years and those who engage in these projects develop invaluable experience, new knowledge and network, among other aspects. These are mostly tacit and difficult to transfer. Therefore, we always try to retain these members [use of internal capabilities]. We ensure that we have dedicated staff for EU projects. In this way we could make use of network of contacts of our long-term employees" [C17, Appendix B].

Fig. 3 summarises these findings. In summary, the greater the knowledge integration role that public intermediaries are engaged in, the more likely they are to develop exploratory innovation in terms of new technologies, equipment, products, and service. By contrast, the greater the network building role public intermediaries are engaged in, the more likely they are to develop exploitative innovation, i.e. enhancing the scope of their current knowledge, research streams and managerial and research skills. The relational capabilities mediate the relationship between the role of public innovation intermediaries (i.e. network building or knowledge integration roles) and internal capabilities. The internal capabilities mediate the relationship between relational capabilities and the type of innovation (i.e. exploratory or exploitative innovation). This means that public innovation intermediaries' engagement in knowledge integration and network building roles generate exploratory and exploitative innovations, respectively, when relational capabilities enable the transfer of external knowledge to the firm boundary, which are then integrated with internal knowledge by using internal capabilities that generate respective

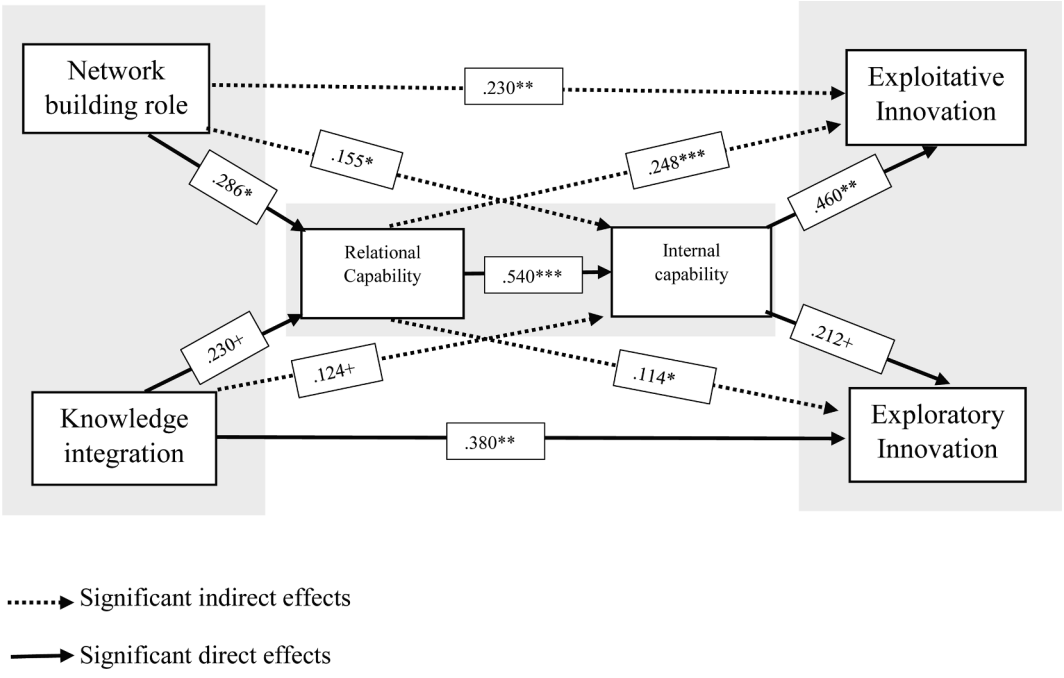

Fig. 3. Findings Summary.

innovation types. While the interplay between internal and relational capabilities fully mediate the relationship between network building role and exploitative innovation, it accelerates the generation of exploratory innovation through knowledge integration role without necessarily mediating such a relationship.

5. Discussion and implications

5.1. Theoretical implications

This study was motivated to examine how the different roles (network building and knowledge integration) a public intermediary performs, in turn, generate in-house exploitative and exploratory innovations since there have been relatively limited studies on this topic. While the literature has often discussed how intermediaries generate value to their clients and the ecosystem (Ritala et al 2022), there is significantly lack of understanding on how intermediaries should generate inhouse innovation, which is vital for their role (Landoni, 2017). The effective use of external knowledge for public intermediaries' own in-house innovation processes is important for them to then foster collaborative activities and innovative processes of their client firms, and thus, to make the optimum use of public funding. These novel findings help set out a strategic framework that is important for public innovation intermediaries to seek a sustainable long-term growth trajectory. Findings of this paper also add value to research on innovation ambidexterity and organizational capabilities literature (Zahra & George 2002; Jansen et al., 2006; Tiwana, 2008; Raisch et al., 2009; Kim et al., 2012; Ozer & Zhang, 2015; Khan et al., 2018). It does so by analysing the interplay between relational, and internal capabilities, supporting the use of external knowledge for innovation ambidexterity, and how this process has differential impacts depending on what type of innovation is being considered. Below the theoretical implications of the findings are discussed.

The original contribution of this study to extant research and theory development has been twofold. Firstly, the study makes an original contribution by unveiling how public innovation intermediaries simultaneously develop exploratory and exploitative innovation using their specific roles in collaborative projects; the understanding of which is crucial given the increasingly significant role they play in an ecosystem (Howells, 2006; De Silva et al., 2018). As hypothesised, the study found a strong and clear association between knowledge integration role of public innovation intermediaries and the generation of in-house exploratory innovation. External knowledge acquired through close knowledge-based relationships with collaborators during public intermediaries' knowledge integration role is used to develop new equipment, technologies, products and services, indicating exploratory innovation. This finding, by bridging two literature domains on the knowledge integration role of innovation intermediaries (Gassmann et al., 2011) and the conditions conducive for exploratory innovation (Colombo et al., 2011; Atuahene-Gima, 2003; McFadyen & Cannella, 2004), makes an original contribution by unveiling how knowledge-based contributions to a collaborative project by public innovation intermediaries pave the path for in-house exploratory innovation.

On the other hand, the study found that network building role of public innovation intermediaries has a major impact on the generation of in-house exploitative innovation but have no significant influence on exploratory-type innovations. Here, the network building role of public intermediaries in a consortium enabled them to improve their existing knowledge, skills, processes, products and services, exhibiting a more exploitative innovation profile. This is a reflection of the relatively less time spent on, and depth of interaction with, collaborators during their network building activities (when compared with the knowledge integration role). This is thus conducive for more incremental improvements to existing knowledge, defined as exploitative innovation (Benner & Tushman, 2003; Danneels, 2002), rather than exploratory innovation. Previous research on network suggests that intermediaries can gain diverse knowledge and resources, which are vital to improve their performance (Burt, 2004; Lingo & O'Mahony, 2010). Yet, networks may provide redundant information or members in a network may have same information (Burt, 1992) which might not help them to generate exploratory innovation. However, existing research has *not* documented that the network building role of public innovation intermediaries specifically generates exploitative innovation (as opposed to exploratory innovation), which is one of the key contributions of this paper.

Secondly, this study makes an original contribution by illustrating how both internal (i.e., the ability to use the capabilities of internal employees), and relational (i.e. the ability to capitalise on relationships with external parties), capabilities harness the knowledge integration and network building tasks in order to be ambidextrous in terms of innovation. The study did, indeed, find that internal, and relational, capabilities fully mediate the relationship between the network building role and exploitative innovation, but not the knowledge integration role and exploratory innovation (although there was a partial mediation effect). The full mediation effect in relation to the network role and exploitative innovation may be because when organizations do not have close knowledge integration interactions with external actors during their network building activities (Benner & Tushman, 2002: McGrath, 2001), the acquisition and transfer of the external knowledge to the organizational boundary requires the use of relational capabilities. Then the interaction between relational and internal capabilities is required to generate exploitative innovation through their network role. The study therefore found a stronger nexus around networking, relational and especially internal capabilities with exploitative innovation, than on the knowledge side where there is a significant link between the knowledge role and exploratory role. During the knowledge integration role, innovation intermediaries are likely to engage in deep collaborations with clients (Gassmann et al., 2011), which is likely to offer a platform to generate exploratory innovation. However, using internal and relational capabilities would accelerate the generation of exploratory innovation during public intermediaries' knowledge integration role.

As noted above, the role of individual employees was seen as being important. Knowledge above all is about how individuals or small groups of individuals interact with each other and share knowledge, much of which is tacit and informal in nature (Howells, 1996; Gulati & Puranam, 2009), requiring a range of socialization mechanisms. Undoubtedly how organizations, in this case public innovation intermediaries, harness and coordinate the skills and networks of experienced individuals is crucial here in terms of successfully leveraging them for the organization to be innovative. This interplay between individual and organizational level contributions in innovation ambidexterity is important, but has been under-explored in previous studies (Raisch et al., 2009: 687-87). Even on the network side, in relation to innovation ambidexterity, the role of individuals has been neglected (Justin et al., 2005).

These findings thus offer important insights into the capabilities-based view and the means through which these enable exploitative and exploratory innovation through different roles performed by public innovation intermediaries (Gibson & Birkinshaw, 2004). Whilst previous research has mainly highlighted differential roles played by internal, or relational, capabilities on the type of innovation (Jansen et al., 2006; Ozer & Zhang, 2015; Song & Thieme, 2009; Subramaniam & Youndt, 2005; Obal, 2015) or more recently on different types of actor (such as supplier, customers and competitors) (Ardito et al., 2020) in such interactions, this study has highlighted how the *interplay between these capabilities* enables an organization to make use of external knowledge to achieve ambidexterity.

5.2. Practical implications

The results suggest several implications for managers and employees of public innovation intermediaries and policy maker, to support the intermediary role to strategically harness their output and in turn to

generate more value from public funding. This paper has used the lens of ambidexterity of public innovation intermediaries, to further our understanding of managerial reach and practice in this aspect of technology transfer in Europe. Particularly, our findings provide guidance on how to use knowledge integration and network building roles of public innovation intermediaries for the generation of in-house exploratory and exploitative innovation, respectively. This is essential for the long-term sustenance and growth of public innovation intermediaries.

Our work shows that for an organization to be ambidextrous in relation to exploratory and exploitative innovation, not only must an organization be able to do two things at the same time (He & Wong, 2004; Gibson & Birkinshaw, 2006; Simsek, 2009), but it must also handle two different types of external engagements, namely those in terms of knowledge regimes, on one hand, and network regimes, on the other. Specially this paper highlights the need for the managers of public innovation intermediaries to use their knowledge integration and network building roles strategically to achieve exploratory and exploitative innovation, respectively. Both managers and employees of public intermediaries should strategize their engagement with clients to be able to be ambidextrous. Having clear aims as to how to capitalise on their different roles to generate specific types of innovation is crucially important for employees to make the most out of their engagements with clients. Additionally, in relation to policy makers, when evaluating the performance of public innovation intermediaries, it is important to evaluate the extent to which they use engagement for internal ambidexterity, which will ensure the sustenance of the public intermediary role.

To achieve innovation ambidexterity, it is important that public innovation intermediaries develop, and are supported to develop, internal and relational capabilities. The results in relation to the interplay between relational, and internal, capabilities suggest that the employees of public intermediaries should strategically develop relationships with external parties when engaging in collaborative innovation (i.e. relational capability) in order to acquire external knowledge and skills, which should then be transformed to innovation through the use of internal capabilities (i.e. associated mostly with retaining and capitalising on experienced and skilled employees). Manager of public innovation intermediaries should thus strengthen the interphase between relational, and internal, capabilities where external knowledge and skills being transformed to innovation. As relational, and internal, capabilities are vested within employees, public innovation intermediaries should aim to motivate, and training to, employees to develop and strategically use these capabilities to achieve innovation ambidexterity. Lastly, publicly funded organizations are facing legitimacy issues in terms of being relevant to outside stakeholders, as well as generating revenues for their own survival, therefore, it is in the best interest of the policy makers to support innovation intermediaries in fine tuning their range of internal and relational level capabilities since these are important conduits to gain return on innovation and engagement activities.

5.3. Limitations and future research

This study is not without limitations, which indicate a need for further research on this topic. Firstly, this study took a simultaneous rather than sequential approach towards ambidexterity although the debate is still out whether this is correct or whether organizations can and do ‘flex’ between the two over time. Certainly the temporal dimension in relation to the conceptualisation of ambidexterity remains a big issue (Wang et al., 2019) that requires further research to be resolved. In addition, treating exploratory and exploitative activity in innovation as a bipolar either/or choice, is equally inadequate as firms and organizations move between the two. By treating it as a spectrum with the two ends being complimentary to, rather than being substitutive for each other (Ardito et al., 2020), is a beginning here, although how this is measured and articulating what lies in-between remains a further issue.

Secondly, in terms of network building activities, public innovation intermediaries often occupy very different positions within a network (such as focal or peripheral) and future research could focus on the different functions and position a public intermediary may have in a network, as well as the quality of the network and link it with the duration of such roles being performed by a public intermediary on the generation of innovation. Thirdly, the breadth, depth and relatedness to the knowledge base of public intermediaries, their knowledge search processes, or their knowledge generation need to be examined in more detail. Further research could focus on examining knowledge and innovation search strategies and the nature of knowledge being generated by the public intermediaries and its impact on innovation. Lastly, the study was confined to RTOs based in relatively developed European countries as a specific form of public innovation intermediaries and the findings might not be generalised to other contexts where the nature of such public intermediaries could be different. As noted earlier, RTOs represent one form of actor in this process of innovation and knowledge exchange in the wider realm of public technology transfer in Europe (Charles & Howells, 1992: 60). The study in particular has stressed their network building role within the European innovation system, but also the role of individuals in this process. This is not to deny that there are significant variations in terms of the behaviour and impact by sector (Klerkx & Leeuwis, 2008; Kivimaa and Martiskainen, 2018) and by function (Gredel et al., 2012) for public innovation intermediaries across Europe. Thus, future research needs to examine different types of public intermediaries and disentangle the impact of public intermediaries on innovation and performance. There is also potential to further expand this study beyond public innovation intermediaries to other types of innovation intermediaries (Howells 2006) to investigate how their roles and capabilities may impact on the ability to be ambidextrous.

CRediT authorship contribution statement

Muthu De Silva: Conceptualization, Funding acquisition, Data curation, Writing – original draft, Writing – review & editing, Visualization, Investigation, Validation, Formal analysis, Methodology. **Jeremy Howells:** Writing – review & editing, Writing – original draft, Conceptualization. **Zaheer Khan:** Writing – review & editing, Writing – original draft, Conceptualization. **Martin Meyer:** Writing – review & editing, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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FOOTNOTE

[1] No significant difference between the responding RTOs and the full data base of 122 RTOs was reported: in relation to sector of operation of RTOs [$X^2(3, 179) = 1.546$, $p = .672 > 0.05$], type of centre [$X^2(5, 179) = 2.217$, $p = .818 > 0.05$], number of employees (i.e. categorised as small medium and large) [$X^2(2, 179) = 1.272$, $p = .529 > 0.05$], and turnover of RTOs (i.e. categorised as small medium and large) [$X^2(2, 179) = 3.308$, $p = .191 > 0.05$].

[2] TRL 1- Concept proposed with scientific validation; TRL 2- Application and validity of concept validated or demonstrated: TRL 3 - Experimental proof of concept completed: TRL 4 - Production validated in lab environment: TRL 5 - Basic capability demonstrated: TRL 6 - Process optimised for production rate on production equipment: TRL 7 - Capability and rate confirmed: TRL 8 - Full production process qualified for full range of parts: TRL 9- Full production process qualified for full range of parts and full metrics achieved

Appendix A. Initial interviews

Position	RTO Group	Country
CEO	Funding Agency for Technology and Innovation (SHOK–TEKES) centres	Finland
CEO	Funding Agency for Technology and Innovation (SHOK–TEKES) centres	Finland
Head of EU Initiatives	Technical Research Centre (VTT)	Finland
Director	Fraunhofer Institute	Germany
Strategy Development, International Business Development	Fraunhofer Institute	Germany
Director of Innovation – High-Tech Systems and Materials	TNO	Netherlands
Director ICT Division – European	TECNALIA	Spain
Software Institute		
Director of Technology Transfer	French Carnot centres	France
Head of Operations - Transfer and Innovation Department	French Carnot centres	France
Director	GTS	Denmark
Director, International Centre	GTS	Denmark
Secretary General	EARTO - European Association of Research and Technology Organizations	Brussels

Appendix B:. Follow-up in-depth interviews

No	Initiative	Sector	Size	Age	Turnover
C01	Carnot	Bioscience	Large	1–25	>E50m
C02	Carnot	Engineering and Energy	Large	1–25	E10m-E50m
C03	Carnot	ICT	Large	26–50	>E50m
C04	Fraunhofer	Engineering and Energy	Medium	1–25	E10m-E50m
C05	Fraunhofer	Bioscience	Medium	1–25	E10m-E50m
C06	Fraunhofer	Bioscience	Medium	50–75	E2m-E10m
C07	Fraunhofer	Multi-sector	Medium	26–50	E10m-E50m
C08	Fraunhofer	Engineering and Energy	Large	26–50	>E50m
C09	GTS	Multi-sector	Large	> 75	>E50m
C10	GTS	Bioscience	Large	26–50	>E50m
C11	GTS	Engineering and Energy	Medium	> 75	E10m-E50m
C12	GTS	Engineering and Energy	Large	50–75	E10m-E50m
C13	GTS	Engineering and Energy	Small	26–50	E2m-E10m
C14	SINTEF	Multi-sector	Large	50–75	>E50m
C15	SHOK / TEKES	Engineering and Energy	Micro	1–25	E0-E2m
C16	SHOK / TEKES	Bioscience	Micro	1–25	E0-E2m
C17	Tecnalia	Multi-sector	Large	50–75	>E50m
C18	TNO	Multi-sector	Large	> 75	>E50m
C19	TNO	Multi-sector	Large	> 75	>E50m
C20	VTT	Multi-sector	Large	50–75	>E50m

Note: In-depth interviews were conducted with 20 directors (of those who have responded to in-depth interviews) engaged in EU projects in following institutes. Categorical variables of size, age and turnover, constructed from the absolute values collected during the on-line survey, are presented in the table to ensure anonymity.

Appendix C:. Correlation matrix

			Estimate	S.E.	P
ZNetwork_Role	< –>	ZKnoweldge_Role	0.280	0.134	0.037
ZNetwork_Role	< –>	ZTurnover	-0.144	0.130	0.269
ZKnoweldge_Role	< –>	ZTurnover	-0.068	0.129	0.601
ZTurnover	< –>	ZTRL	0.001	0.129	0.994
ZTurnover	< –>	ZSector	0.296	0.135	0.028
ZTurnover	< –>	ZSize	0.858	0.171	0.000

(*continued on next page*)

(*continued*)

			Estimate	S.E.	P
ZTRL_	< –>	ZSector	0.255	0.133	0.056
ZSector	< –>	ZSize	0.319	0.136	0.019
ZTRL	< –>	ZSize	0.112	0.130	0.388
ZKnoweldge_Role	< –>	ZTRL	0.280	0.134	0.037
ZNetwork_Role	< –>	ZTRL	0.447	0.142	0.002
ZKnoweldge_Role	< –>	ZSector	0.207	0.132	0.116
ZNetwork_Role	< –>	ZSector	0.047	0.129	0.716
ZKnoweldge_Role	< –>	ZSize	-0.146	0.131	0.263
ZNetwork_Role	< –>	ZSize	-0.179	0.131	0.172

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