Technological Forecasting & Social Change 175 (2022) 121357

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

New business models for public innovation intermediaries supporting emerging innovation systems: The case of the Internet of Things

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ARTICLE INFO

Keywords:
Public innovation intermediaries
Digital transition
Internet of Things
Business models
Technology paradigm

ABSTRACT

In several countries, governments have assigned to public innovation intermediaries (PIIs) the mandate to support the digital transition, by facilitating the development and adoption of new digital technologies on the part of firms and other organisations. This new mandate requires PIIs to upgrade their business models, moving beyond their traditional involvement in firms' technology upgrading and university-industry knowledge transfer, toward supporting the creation of new innovation systems around the emerging digital technologies. To understand how PIIs are reconfiguring their business models to support the digital transition, we study four cases of PIIs operating in the United Kingdom and France, whose mandates include providing support for firms and other organisations in the implementation of new digital technologies, focusing in particular on the Internet of Things (IoT). We show that, despite their differences, all four PIIs have substantially reconfigured their business models in similar ways in order to fulfil these mandates. Both the formal legitimacy arising from their policy mandate, and the knowledge resources and informal legitimacy they have developed, have played a decisive role in their ability to orchestrate the development of innovation systems around IoT.

1. Introduction

Although intermediation is not a recent economic phenomenon, over the last two decades policymakers have invested increasing resources in creating innovation intermediaries specifically dedicated to supporting innovation and technology transitions (Bougrain and Haudeville, 2002; Brusco 1982; Klerkx and Leeuwis, 2009; Kivimaa, 2014; Musiolik et al., 2020). Innovation intermediaries are public or private organisations that support firm-level and systemic innovation in various ways, such as creating knowledge links between organisations, sharing knowledge about particular technologies, providing knowledge-intensive services, and advising policymakers (Howells, 2006; Kivimaa et al., 2019a, 2019b). Not only do they actively promote innovation diffusion and radical change within *existing* innovation systems (Howells, 2006; van Lente et al., 2003) – defined as a network of entities initiating, transferring, modifying, and diffusing new technologies (Freeman, 1995) – they also support the development of *new* innovation systems (Gradillas, 2019; Kivimaa et al., 2019a, 2019b; Klerkx and Leeuwis, 2009; Musiolik et al., 2020).

Many innovation intermediaries are partially or fully publicly funded (we call these 'public innovation intermediaries', hereafter PIIs), and as such they are requested to fulfil specific policy mandates. These include, more and more often, helping firms and other organisations to develop and adopt emerging digital technologies, such as the Internet of Things (IoT). The latter is one of the four enabling technologies underpinning Industry 4.0 – alongside cloud services, big data, and analytics (Büchi et al., 2020; Frank et al., 2019; Hennig et al., 2019) – and many governments have built their innovation and development strategies around it (Majstorovic and Mitrovic, 2019; Sung et al., 2018).

IoT is a multi-level, multi-party system of digital technologies that enable data collection and transmission between devices, connecting these devices together and enabling their identification, location, tracking, and monitoring (de Sousa Jabbour et al., 2018; Li et al., 2017). Applied to industry, IoT can improve existing processes, products, and services, and enable the development of new ones (Oriwoh et al., 2013). The emergence of IoT has placed new demands on firms that wish to remain innovative using this set of technologies (Carayannis et al., 2018; Metallo et al., 2018; OECD, 2018). Many firms, particularly small and

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https://doi.org/10.1016/j.techfore.2021.121357
Received 16 July 2020; Received in revised form 23 October 2021; Accepted 11 November 2021
Available online 20 November 2021

medium-sized enterprises (SMEs), need expert help to understand how IoT works, to reconfigure their activities in response to it, and to connect with providers of technology, services and expertise (Jones and Jain, 2002; Lee et al., 2010). Some governments have therefore appointed PIIs to expertly facilitate the development of innovation systems around IoT, either by expanding the policy mandate of existing PIIs, or by creating new PIIs. Both types of PIIs are called to govern (or participate in) change processes whose nature and direction are uncertain, and which are poorly understood by policymakers, firms, and even experts (Agogué et al., 2017).

PIIs need to design new business models for their activities, or reconfigure their existing business models, to suit their new role of developers of IoT innovation systems. While research on IoT has examined the business models emerging around this technology (Frank et al., 2019; Metallo et al., 2018), studies in this stream of literature have focused on firms rather than PIIs. Conversely, research into innovation intermediaries' business models has focused either on a specific type of private intermediation, such as crowdsourcing platforms (Lopez and Vanhaverbeke, 2009), or on specific aspects of the business model, such as the value proposition or target segments (Agogué et al., 2013; Alexander and Martin, 2013; Knockaert et al., 2014). This is a significant gap in the literature, insofar as research has widely recognised the role that PIIs play in technological transitions (Kivimaa, 2014; Kivimaa et al., 2019a, 2019b; Musiolik et al., 2020; Rossi et al., 2021).

To fill this gap, we address the following research question: How do PIIs adapt their business models to support digital transition towards IoT? Our research strategy combines insights from theory and research on innovation intermediaries with inductive theory building. We study multiple cases (Yin, 2009), using contextualised explanations and cross-case comparisons to build a model explaining the conditions that allow PIIs to adapt their business models to support the process of upgrading technological systems for digital transition. We conducted four case studies in France and the United Kingdom (UK), two leading European countries with regard to IoT technologies (Russo et al., 2021), using a combination of in-depth interviews with PIIs' internal and external stakeholders (PII staff, firms that work closely with PIIs, policymakers working in agencies funding and evaluating PIIs, academics and consultants – experts on innovation and IoT) and secondary sources.

The paper is structured as follows. In Section 2, we review the concept of business model and its application in IoT. In Section 3, we propose the framework of analysis for our research, based on a systematic review of the literature: we uncover the different roles that PIIs can play in the context of emerging technologies and infer the main features of business models suited to each role. Section 4 describes our data and methodology. In Section 5 we present our case studies: after providing background information about the four PIIs (Section 5.1), we discuss the findings of our qualitative thematic analysis (Section 5.2). In Section 6 we outline implications for innovation theory, public policy, and management practice.

2. PIIs' business models for the digital transition of industries

The development and use of complex, multi-level, multi-platform digital technologies like IoT requires increasingly open, systemic innovation processes (Carayannis et al., 2018; Lu et al., 2018). IoT is a system of complementary technologies, including software applications, connectivity, and hardware components and devices. IoT solutions are thus a platform-based ecosystem (Teece, 2018; Tiwana et al., 2010). Implementing complex digital systems – based on the collection, analysis, and exploitation of data from a variety of mutually connected sensors and other locally distributed digital tools – requires organisations to learn new methods of knowledge production and management for ecosystem innovation (Metallo et al., 2018; Su et al., 2018). According to Leminen et al. (2012), innovation in IoT requires deeper collaboration and partnerships because of the need for a panoply of competences and skills when connecting objects to the Internet (Metallo et al., 2018). This can require that PIIs develop a new business model or reconfigure the existing one.

According to Teece (2010), a business model depicts the way in which an organisation creates, captures, and delivers value. Business models can be conceptualised in different ways, ranging from cognitively manipulable devices or recipes (Baden-Fuller and Morgan, 2010), to a configuration of components or building blocks (Zott et al., 2011). In this research, we take the latter, configurational view of business models, comprising several components combined in a particular way – value proposition, target segments, organisation of activities, key resources and competences, and cost/revenue structure (Foss and Saebi, 2017; Zott et al., 2011).

External or internal factors can lead to business model change, adaptation, or full-scale reconfiguration. External factors include signals received from the environment (Colovic, 2021), technological evolution (Teece, 2018), and market-related factors such as competitors' moves, new market opportunities, and changing consumer preferences (Demil and Lecocq, 2010; Schneider and Spieth, 2013). Internal factors include technological innovation (Calia et al., 2007), the development of new capabilities (Seelos and Mair, 2007) and other organisational or strategic factors (Doz and Kosonen, 2010). Very often, several factors jointly trigger business model change.

Any change to the business model faces numerous constraints. These include not only the underlying configuration of organisational assets and routines, but also cognitive barriers, since business model change has to overcome the managers' "dominant logic", i.e., "set of heuristic rules, norms and beliefs that managers create to guide their actions" (Chesbrough and Rosenbloom, 2002, p. 531, elaboration on Prahalad and Bettis, 1986).

Bilgeri et al. (2015) highlight important changes that organisations should make to their business model to operate in IoT. First, they need to consider the various components of their business model in the context of their ecosystem, as this is the place where value is created (Westerlund et al., 2014). Second, organisations should realise that relationships no longer develop along a linear value chain, from focal company to final customer, but through networks between the various stakeholders (Ju et al., 2016; Leminen et al., 2012). Third, organisations should design mechanisms to encourage all stakeholders to participate in such networks. Fourth, since data and information are fundamental assets in IoT (Bucherer and Uckelmann, 2011; Leminen et al., 2012), organisations should structure a clear strategy for collecting information from the various devices they use.

Reorienting or creating a business model adapted to IoT may not be easy for all firms. For this reason, many countries call upon PIIs to provide businesses with knowledge, information, contacts and services. However, PIIs themselves need to have an appropriate business model to operate in this new technological environment, and this is what we focus on in this paper. In the next section we build on the literature to develop a theoretical framework linking the different roles played by PIIs in the context of emerging technologies, and the business models suited to each role.

3. PII roles and business models

Limited research has been conducted on the business models of PIIs, none of which discusses IoT intermediation. Only Brusco (1982) and Lopez and Vanhaverbeke (2009) have directly addressed intermediaries' business models, and, to the best of our knowledge, no contribution addresses the specific case of IoT intermediaries. However, several studies discuss particular aspects of the business model of PIIs, such as their ability to create value (De Silva et al., 2018), and the key resources and competences they require (Agogué et al., 2013; Alexander and Martin, 2013; Knockaert et al., 2014).

To develop our analytical framework, we systematically reviewed the literature and combined these different contributions. First, we defined a narrow set of keywords. Using the Scopus database (the

Elsevier abstract and citation database), we searched for all papers in the areas of business, social sciences and economics containing the following keywords: "innovation intermediaries" + firms / "innovation intermediaries" + enterprises. This search identified 154 academic articles published between 2008 and 2019. After excluding less relevant contributions, we were left with about 50 articles which we read in detail. We classified their content under the following themes: policy mandate and policy rationale; target segments; value proposition; organisation and structuring of activities; and key resources and competences.[1]

We used the descriptions of policy mandates and all the other business model variables to develop a taxonomy of the roles of innovation intermediaries, as shown in Table 1. PIIs may perform different roles and carry out a broad range of activities, depending on their policy mandates. They frequently operate (entirely or partially, depending on the extent of their public funding) in non-market contexts, that is, where the market or innovation system cannot operate effectively, or where they have public interests to pursue (Intarakumnerd and Chaoroenporn, 2013; Kivimaa, 2014; Russo et al., 2018). However, many PIIs also participate actively in market-based exchanges: in many countries their public funding has been reduced, and they have to compete with private intermediaries to make up the shortfall (Fukugawa, 2018; Klerkx and Leeuwis, 2008).

Our literature review showed that different PII roles correspond to different value-creating activities, and different key resources and skills. Although the literature does not address this point directly, different PII roles seem to require different business models. For a PII, the value proposition refers to the value created by PII activities. Target segments are the constituents targeted by PII activities. Organisation of activities refers to both the activities developed by PIIs, and how they organise these activities. For example, PIIs might need to call upon outside experts to offer certain services. PIIs develop diverse, varying resources and competences, including technological expertise, legitimacy, knowledge, networking competences. Finally, the business model configuration also concerns how the different components of the business model are combined together.

In their 'upgrading' role – helping firms to innovate and upgrade their capabilities – PIIs' main value proposition is to offer information, access to innovation infrastructures and other knowledge-intensive services to individual organisations (often to SMEs) that constitute their target segments (Howells, 2006; Muller and Doloreux, 2009). The main organisational activities are company visits to understand their client firms' specific needs, knowledge and technology audits (Shapira and Youtie, 2016), information-sharing events (e.g., events about new technologies, about the availability of public funding schemes), and identification of potential business and/or innovation partners (Colovic and Lamotte, 2014; Sotarauta, 2010). In terms of competences, PIIs need to be familiar with the industrial, technological, and local context in which SMEs and start-ups operate (Clark, 2014; Kilpatrick and Wilson, 2013; Knockaert et al., 2014; Sotarauta 2010) in order to address their typical cognitive and managerial failures and increase their absorptive capacity (Kokshagina et al., 2017: Shapira and Youtie, 2016). Various types of public or public-private agencies can play this role (e.g., chambers of commerce, sector-specific public agencies).

PIIs that perform a 'transfer' role facilitate the transfer of knowledge and technology between research organisations and businesses, their main target segments. Providing patenting and licensing support constitutes a key value proposition (Alexander and Martin, 2013; Kodama, 2008). In terms of activities, PIIs facilitate the match between research and industry by mapping the skills and knowledge of the two sectors and by providing opportunities to bring them together, for example through publicly funded applied research projects or staff exchanges (Alexander and Martin, 2013; Villani et al., 2017). In terms of competences, since public funding of such intermediaries is justified by the need to address industry interaction failures, PIIs need to be able to 'speak the language' of both basic and applied research (Wright et al., 2008; on multivocal agents see Russo and Rossi, 2009): hence, they generally possess both research and industrial development skills, usually related to their target sectors (Paasi et al., 2010; Smedlund, 2006), together with knowledge of the local context (Smedlund, 2006; Villani et al., 2017). They also need specialised skills in negotiation, contract development (Howells, 2006), and intellectual property management (Chau et al., 2017: Paasi et al., 2010) to manage research projects involving both public and private stakeholders (Alexander and Martin, 2013; Smedlund, 2006).

Intermediaries perform a 'systemic' role either when they support the development of a nascent innovation system whose actors are not yet connected, and in which supply and demand are not clearly articulated, or when they support innovation by weak or unconnected actors (e.g. SMEs, new firms) and their involvement with an existing innovation system (Russo et al., 2018; Wieczorek and Hekkert, 2012; Woolthuis et al., 2005). Their value proposition is to develop and maintain links between a system's different organisations, which constitute their target segment. To fulfil this role, intermediaries undertake various combinations of activities aimed at supporting the formulation of demand, facilitating the alignment of actors and possibilities, and managing a constellation of different resources (Klerkx and Leeuwis, 2008; Musiolik et al., 2020: Van Lente et al., 2003). These activities include promoting R&D projects, and supporting open innovation practices, problem broadcasting exercises (Diener et al., 2020; Lindkvist et al., 2019), and forecasting and foresight exercises (Hermann et al., 2016; Howells, 2006). In terms of competences, intermediaries carrying out systemic functions need knowledge of the specific technologies, industrial sectors and locations in which they operate (Dalziel and Parjanen, 2012; Inkinen and Suorsa, 2010; Klerkx and Leeuwis, 2008; Nauwelaers, 2011). To keep up to date, they maintain relations with universities and research centres, and they continuously monitor agents that operate or could operate in the system (Agogué et al., 2013; Russo et al., 2018), such as innovation centres and technopoles, which define practices and digital media for many-to-many collaboration (Russo et al., 2019).

Finally, intermediaries perform a 'transition' role when they support system-wide transformations. The term often refers to transitions towards sustainability, but also applies to transitions towards new innovation systems (Kivimaa et al., 2019a; Van Lente et al., 2003). Once the old system has been disrupted and the foundations have been laid for the development of a new system, the systemic role comes back into play as intermediaries support construction of the new system (Gliedt et al., 2018; Kivimaa et al., 2019b). Their main value proposition is to facilitate transformation. Their activities include organising networks of agents promoting change, helping to make collective sense of the new system, portraying the future (Boon et al., 2008), and supporting the construction of new technological architectures. To fulfil their transition role, intermediaries need advanced knowledge of the new technology and its potential fields of application (Sotarauta and Mustikkamäki, 2015). Foresight and forecasting exercises can be useful for this purpose. Moreover, intermediaries need to know their local context to understand the existing governance structure and which stakeholders could support the transition (Mattes et al., 2015; Moss, 2009). Strong leadership and negotiation skills are needed to guide the transition process (Agogué et al., 2017; Kivimaa, 2014).

To examine PII roles with regard to IoT, we will analyse their business models with respect to the business model components identified above - target segments, value proposition, organisation of activities, and key resources and competences, and how they are linked together (Foss and Saebi, 2017; Zott et al., 2011). We will thus aim to identify how PIIs define their value proposition and target segments (or how these have changed), how they organise or re-organise their activities, and what underlying resources, competences and capabilities enable the PIIs to facilitate the development of IoT.

[1] Information on the other feature of business models, cost/revenue structure, is rarely available, so is not included in our table.

Table 1
Intermediaries: roles, policy mandates, target segments, value propositions, activities, and key resources and competences.

Role of intermediary	Policy mandate and policy rationale	Target segments	Value proposition	Organisation of activities	Key resources and competences
Upgrading	Policy mandate: support business innovation and upgrading (often for SMEs) Policy rationale: address cognitive and managerial failures in an existing innovation system	Firms (particularly SMEs)	Information diffusion and networking	Providing information, access to knowledge infrastructures, and one-to-one knowledge-intensive services (Bessant and Rush, 1995; Howells, 2006; Kokshagina et al., 2017)	Technology-specific and sector-specific knowledge and competences (Knockaert et al., 2014; Russo and Rossi, 2009) Context-specific knowledge (Clark, 2014; Kilpatrick and Wilson, 2013; Sotarauta 2010) acquired for example by visiting companies (Shapira and Youtie, 2016) or recruiting staff with a wide personal network (Tushman and Scanlan, 1981) Advisory skills (Shapira and Youtie, 2016) Legitimacy acquired from the policymaker (Sotarauta, 2010)
Transfer	Policy mandate: transfer research results to firms Policy rationale: address interaction failures in an existing innovation system	Research institutions and firms	Licensing and patenting services	Supporting licensing and co-patenting; promoting researchers' mobility in firms (Alexander and Martin, 2013) More generally: supporting university-industry partnerships (Meyer et al., 2019)	Technology-specific and sector-specific knowledge and competences (Alexander and Martin, 2013; Kodama, 2008) Context-specific knowledge (Smedlund, 2006; Villani et al., 2017) acquired for example through discussions between university and PII staff (Chau et al., 2017) Ability to facilitate the management of research projects involving public and private stakeholders (Smedlund, 2006) Intellectual property management and contractual skills (Paasi et al., 2010)
Systemic	Policy mandate: facilitate the construction of a new innovation system; facilitate the involvement of new organisations in nascent or existing innovation systems (e.g., SMEs, new firms) Policy rationale: develop a new innovation system	All types of innovation system players	Value chain and innovation system creation	Mapping system competences, assessing markets and articulating demand (Boon et al., 2008; Meyer et al., 2019) Helping collaborative R&D projects or tech transfer projects generate variety and innovation, and facilitate their adoption by firms (Colovic, 2019; Colovic and Lamotte, 2014; Meyer et al., 2019) Supporting networking to align actors and possibilities, strengthen the system, and spread existing innovation (Russo et al., 2019) Promoting the adoption of and experimentation with new (organisational and technical) configurations (Janssen et al., 2014)	Technology-specific and/or sector-specific knowledge and skills (Dalziel and Parjanen, 2012; Klerkx and Leeuwis, 2009) Context-specific knowledge (Inkinen and Suorsa, 2010; Nauwelaers, 2011), acquired for example by systematically mapping the environment and assessing the feasibility of new (organisational and technical) configurations (Agogué et al., 2013; Russo et al., 2018), foresight exercises (Hermann et al., 2016), use of platforms to facilitate problem broadcasting or crowdsourcing (Diener et al., 2020) Communication and negotiation skills, and leadership abilities (Agogué et al., 2013) Adoption and diffusion of open innovation practices (Agogué et al., 2013; Kokshagina et al., 2017)
Transition	Policy mandate: support the emergence of a new (sustainable) innovation system Policy rationale: disrupt the existing system to facilitate transformation	All innovation system players and potential new participants	New technology architecture construction; facilitation of technological transition	Providing information, and promoting new networks to disrupt the existing system (Kivimaa et al., 2019b) Mobilising relevant actors to promote the transition (Kivimaa et al., 2019b) Supporting networking to align actors and possibilities, facilitate collective sense making with regard to the new system, and portray the future (Boon et al., 2008)	Technology-specific and/or sector-specific knowledge and skills (Sotarauta and Mustikkamäki, 2015) Context-specific knowledge (Mattes et al., 2015; Moss, 2009) acquired for example from foresight and forecasting exercises (Kivimaa et al., 2019a) Leadership and negotiation abilities (Agogué et al., 2017; Kivimaa, 2014)

Table 2
Interviews by type of interviewee and country.

ID	Position	Organisation	Relationship to PII	Country
I1	Manufacturing lead in business development	PII	PII staff	UK
I2	Senior Innovation Programme Lead	PII	PII staff	UK
I3	Communications Director	PII	PII staff	UK
I4	Deputy Delegate	PII	PII staff	France
I5	EdTech Community & Work Transformation Manager	PII	PII staff	France
I6	Director of Development of Enterprises and Territories	PII	PII staff	France
I7	Director	PII	PII staff	France
I8	Economics, performance and strategy lead	National innovation agency	PII funding agency	UK
I9	Evaluation Specialist	National innovation agency	PII funding agency	UK
I10	Relationship Manager	National innovation agency	PII funding agency	UK
I11	Policy officer	Regional development agency	PII funding agency	France
I12	Professor	Engineering school	Organisation member of PII	France
I13	R&D Manager	Company	Organisation member of PII	France
I14	Lead on Investment Analysis, International Science and Innovation Directorate	Ministry	Agency setting national digitalisation policy	UK
I15	Policy officer	Ministry	Agency setting national digitalisation policy	France
I16	Owner	Private consultancy	Technology expert	UK
I17	Associate professor	Business School	Innovation policy expert	France
I18	Professor	Business School	Innovation policy expert	UK
I19	Director	Policy think tank	Innovation policy expert	UK
I20	Consultant, former head of regional incubator	Consulting firm	Innovation policy expert	France

All the intermediary roles can be important to facilitate digital transition and the adoption of IoT solutions. One-to-one services provided by 'upgrading' intermediaries can be important to increase companies' awareness of their problems and the potential of IoT. Transfer intermediaries can help firms to begin to use new technologies. However, the characteristics of emerging digital technologies make the systemic and transition functions particularly important. Therefore, we expect that PIIs mandated to help firms with the digital transition will embrace business models associated with systemic and transition roles.

4. Data and methodology

We chose a multiple case study research design (Eisenhardt and Graebner, 2007; Yin, 2009), studying PIIs that work partly or totally in the area of industrial IoT. By limiting our analysis to this specific, though still broad and complex, technology and its applications, we kept the domain-related influences constant and hence maintained a manageable degree of comparability between the cases. We applied a purposeful sampling procedure, selecting cases (and respondents) based on their potential to advance understanding of the complex role PIIs play in supporting firms in their adoption of IoT solutions.

We studied PIIs based in the UK and France, where IoT systems are particularly advanced and benefit from supportive public policies. Many organisations act as intermediaries for various applications of IoT (e.g., see the IoTUK Nation Database;[2] European Commission, 2019). Having reviewed some of these organisations, we focused on four PIIs: two in the French *Pôles de Compétitivité* network, which was founded in the mid-2000s with a specific mandate to support innovation within their regions, and each *pôle* focuses on a specific sector or technology; and two in the UK's Technology Catapults network, which was founded in the early 2010s, with a mandate to support innovation at national level in specific technologies.[3]

The organisations we analysed fit the selection criteria we outlined above. They are all PIIs, they are all active in digital technology, and all support industrial IoT innovation systems. Nonetheless, they differ significantly in terms of key resources and competences that could influence their development. The *Pôles de Compétitivité* promote regional development and were created before the emergence of IoT. The Technology Catapults promote competitiveness at national level, and they were founded when early IoT applications were becoming apparent. These differences allow us to introduce greater nuance to the interpretation of our findings.

To gain a deeper understanding of these PIIs' activities, their business models, and how they have adapted over time, we adopted a qualitative methodology which, given the lack of prior knowledge about the phenomenon that we were investigating, is particularly appropriate to provide a thick description of the intermediaries' changing activities, and to capture the phenomenon's complexity.

We collected different types of data. In order to gain a broad view of how PIIs have evolved over time, particularly in terms of how they have changed their business models, and what resources they have been able to rely on in order to do so, we carried out 20 semi-structured interviews with internal and external stakeholders of these PIIs (details in Table 2). Our interviewees included: staff of the four PIIs involved in strategic and project management activities in the field of IoT; policymakers working for agencies funding and evaluating these PIIs, or responsible for designing policies for digitalisation; managers of organisations that are members of one of these PIIs; academics and consultants with expertise in innovation policy and IoT (some with experience of collaborating with PIIs). We deliberately included a variety of respondents to obtain a broader view of the PIIs and, whenever possible, triangulate the data obtained from the PII staff. Each interview lasted between fifty minutes and two hours. We conducted the interviews in English (both in France and in the UK), recorded and subsequently transcribed them.

As we were exploring an emerging innovation space, we chose semi-structured interviews to allow for the introduction of new, unexpected themes in the conversation, and to respect our respondents' natural flow of speech, hoping that this would provide rich data on the phenomenon. We encouraged our respondents to substantiate their arguments with examples and illustrations. We developed an interview guide before the data collection process, which we adapted throughout the data collection process to include important or interesting new themes that emerged during the interviews.

Additionally, we collected data from other sources, including policy documents, official policymakers' websites, PII websites, PII activity reports and evaluations, together with other grey literature, including published studies. Our informants also provided us with additional documents. For example, one of the French intermediaries provided a printed collection of short case studies, projects and initiatives led or

[2] Available at https://datamillnorth.org/dataset/iotuk-nation-database (last accessed March 2021)

[3] The choice of four cases falls within the four-to-ten-cases recommendation of Eisenhardt and Graebner (2007).

facilitated by the PII, which included many company testimonials (with *verbatims*). All these additional data sources provided us with background information about the innovation intermediaries and enabled us to triangulate the interview data. Appendix 1 includes a list of the secondary sources used in the analysis.

We analysed the data in three main steps. First, we coded each interview using Atlas.ti software. Three coders (three of the authors of this paper) independently coded about 15 interviews each – at least two different researchers coded each interview. Once this process was complete, the coders met to agree on a common coding system, after which the whole set of transcripts was recoded according to the agreed system (Kelle, 2005; Friese, 2020). In the second step, we used the coded data to analyse each intermediary separately, writing a short report for each intermediary. In the third step, we compared the findings across cases, identifying cross-case patterns (Silverman, 2013). Specifically, we aimed to identify the PIIs' roles and business models. To enhance this analysis, each researcher provided a personal interpretation of the findings, which we then compared and discussed until we agreed on a shared interpretation. To reach an agreement, and in line with Agar (1996), Dacin et al. (2010) and Kelle (2015), we went back and forth between the data and the findings, to identify rich points and to outline the analytical framework emerging from the empirical analysis.

5. Empirical analysis

5.1. PIIs' policy context and mandate

The Technology Catapults, first launched in 2011, are part of the so-called Catapult programme, managed by the innovation agency InnovateUK with government funding. This programme was inspired by an expert report commissioned by the Department for Business, Innovation and Skills, which called for the UK to create a network of technology and innovation centres similar to those in Japan (National Institute of Advanced Industrial Science and Technology – AIST), Germany (Fraunhofer Institute), and France (Carnot Institutes), and thus to strengthen the UK's innovation capacity (Hauser, 2010). Since 2011, a network of 15 Catapults has been created, each of which has a particular technological and sector specialisation. While the Catapults were initially fully government funded, public funding has gradually been reduced, and the Catapults have had to self-fund their activities in different ways, for example, through commercial activities and competitive grants.

In this study we focus on Intermediary A, specialised in digital technologies, and intermediary B, focusing on new technologies applied to the manufacturing industry. Intermediary A currently runs three key technology programmes - virtual and augmented reality solutions, artificial intelligence and machine learning, and future networks, focusing on the connectivity feature of IoT. Unlike some other Catapults that have adopted a membership model, Intermediary A has a more transactional business model, which compels it to adapt to the needs of its partners. Intermediary B is a network of seven pre-existing research centres, which were merged into a single Catapult Centre in 2011 – though the centres maintain separate identities and locations. These centres possess a wide range of capabilities in advanced manufacturing technologies, and each has at least one research programme in digital technologies, particularly digital manufacturing. Some of the centres, including one that focuses on digitalisation, have a membership model.

The *Pôles de compétitivité* were developed as part of a general reorientation of French innovation policy initiated in the 2000s. They were set up in 2006 by the Law on Research Policy and Programming, as a way of spurring collaborative innovation in the French regions (Mendez and Bardet, 2009), developing local innovation ecosystems and large innovation networks (Bellégo and Dortet-Bernadet, 2014). The government approved the creation of 71 *pôles*, divided into three categories – world-class, aspiring to become world-class, and regional – depending on their maturity and potential. Currently, *pôles* are partly funded by the government, partly by the regions and partly by the membership and service fees they receive from external organisations. In fact, most *pôles* (including those we interviewed) adopt a membership model according to which the *pôle's* services are available only to fee-paying members. In this study we consider Intermediary C – a Paris-based *pôle* focusing on ICT, artificial intelligence, software, media, and robotics – and Intermediary D – a Normandy-based *pôle* (also covering the greater Paris region) dealing with mobility solutions, smart mobility and advanced solutions for the automotive industry (seeTable 3).

Table 3
Intermediaries' basic features.

Intermediary	Date of foundation	Funding model	Focus	Policy mandate
Intermediary A	2013	Part InnovateUK, part industry (commercial services provision model), part competitive R&D funding	Virtual and augmented reality solutions, artificial intelligence and machine learning, future networks	Increase UK innovation capacity in specific industries Bridge gap between scientific research and business
Intermediary B	2011	Part InnovateUK, part industry (mixed membership/ commercial services provision model), part competitive R&D funding	Robotics and automation, additive manufacturing, digital manufacturing, virtual reality	Generate growth in strategically important global markets
Intermediary C	2006	Part government, part region, part industry (commercial services provision and membership fees)	ICT, artificial intelligence, software, media, robotics	Promote regional development Spur collaborative innovation between regional businesses and other organisations
Intermediary D	2006	Part government, part region, part industry (commercial services provision and membership fees)	Mobility solutions, smart mobility, advanced solutions for the automotive industry	

5.2. Evolving PII business models following the development of IoT

5.2.1. Changes in value proposition, organisation of activities and target segments

Our data reveals that the four PIIs have adapted their value propositions, target segments and organisation of activities to the requirements of the emerging technology, so as to support firms and facilitate the digital transition. Since their creation, all PIIs have performed traditional upgrading and transfer functions, and they have helped various types of networks to spread the use of digital technologies in business. As we will explain further below, this activity has helped them greatly to understand the players in the system they are endeavouring to change. Over time, they have expanded their activities encouraging the transition towards a new innovation system around industrial IoT.

Table 4, built from information derived from the interviews, illustrates the types of activities each intermediary performs, and the time at which each activity has been launched. The first column links such

activities to the intermediation roles identified in Section 2. The table reveals a common feature of the four PIIs: all of them have played upgrading and transfer roles since their creation, and they have taken on systemic and transition roles at a later stage.

In the initial stage of their operations, PIIs' business models aligned with their upgrading and transfer functions. The main value propositions were networking and the provision of information and knowledge-intensive services. The target segments for these activities were mainly firms and research institutions. Their activities included provision of information and access to infrastructure (third party R&D labs, workspaces or spaces for events), provision of knowledge-intensive services, and support for networking both between firms and between firms and research institutions (by organising events and participating in networks).

For example, Intermediary C organises about 120 events per year. It also contributes to cross-cluster networks, in France, in Europe, and beyond. Intermediary D has links with automotive clusters in different parts of the world. Intermediary A takes part in fairs and events, it has a network of tech contacts, and develops partnerships with other public intermediaries. Intermediary B periodically organises technology forums to foster networking amongst agents in the system.

> *"So we create a lot of events and also sometimes we create content about [technologies] especially if we say, oh this is what we think will happen next year, we print that. […] We try to help our members to get projects funded in Europe. We've got some actions about accelerations, we help some companies to grow faster and to raise money through private funds […] We help them also to go international, we help them to work with designers, we help them to improve the way they manage human resources, how they hire, how they should perhaps sometimes restructure". [I4]*

While maintaining these activities,[4] PII business models have increasingly aligned with the systemic and transition functions. All PIIs have gradually moved from facilitating the development of networks, to helping the diffusion of existing technological solutions. Their value proposition now directly supports the emergence of innovation systems.

In particular, while the previous value proposition was built around PIIs' ability to provide business services, they increasingly take an active role in changing the system, promoting complex configurations of actors to spread system innovation, and experimenting with new IoT applications. Thus, the value proposition is now multi-faceted and can respond to an array of both company and ecosystem needs.

> *"We focus on support for the innovation system and on adoption of digital technologies in different contexts. We support the growth of small business that are new to these technologies and looking at exploring them, but we also support large organisations implementing IoT in their processes and exploring new possibilities." [I1]*

The new PII activities emerged from their having previously mapped the competences of their members or of the other players they worked with. As they gained better understanding of their context and of the requirements needed for innovation to occur within the new technological paradigm, PIIs began to construct parts of the innovation system, putting together complex projects and value chains. For example, Intermediary D organises and facilitates so-called SME "groupements" to respond rapidly and practically to the needs of large industrial firms with regard to the digitalisation of production sites. These *groupements* propose partnerships with large firms to generate technologies and new uses for the "factory of the future" (Rossi et al., 2021):

> *"We try to help SMEs to make a collaborative business and that is what we call a groupement of SMEs […] The idea is to bring together SMEs with high technology value, which are complementary, so they make a larger value chain and propose it to the big companies. We did that because the big companies are not very well organised in [order to] seize innovation […] So the idea of the groupement of SMEs is to build the system and to propose a system to the big companies". [I6]*

> *"There was an initiative in France to organise and create something that would organise the sector, in the area of precision medicine. At the beginning it was a pharma company, a big one and a smaller one. They tried to create something by themselves but it didn't work. They contacted [Intermediary C] and [another PII]. Together they organised meetings and communication about this idea of creating a structure, a group, gathering different players in this field. We identified some opportunities for us and we're still in this network". [I13]*

PIIs have also begun to help firms to articulate their demand for new technological solutions, framing their problems in the light of the new possibilities offered by IoT. In this specific technological context, support for demand formulation goes hand in hand with the organisation of the offer. In fact, most of the systems are built on their users' specific problems, with tools and organisational solutions that are not commercially available but have to be developed ad hoc. The number, complexity and need for compatibility of the various system components have increasingly required PIIs to act as an innovation system developer.

> *"A company who has an idea, who has a project, who is looking for partners, who doesn't have a relationship with a local authority and wants to be put in a relation to make sure that they can experiment on the territory. Our role is to help them to qualify their project, the perimeter of this project, what kind of partners they are looking for and to scout for any of these partners to get them to meet in the same place and then they can discuss this and build the project together. Another part is then how we can [help them] fund the project" [I6]*

> *"Sometimes a large organisation can say, I wanted to talk or explore AI but I don't know where to start and then there is lots of exploratory consulting initially to identify what are the key areas of interest and what kind of challenge those guys are facing, how to prioritise those challenges and then have a tech team there that really understand the technologies, [..] we call these 'tech 101' sessions to get to a deeper level of understanding first and then be ready to take a decision why they should be focused on and where they're looking to the ecosystem, who they should engage with and then even sometimes interfering or giving directions where the strategy should go". [I2]*

Over time, all the PIIs have strived to become IoT system builders, supporting both the provision of and the demand for IoT. Thus, Intermediary A organises actor networks to respond to the specific requests of companies. This process comprises calling on companies to participate in the network, assessing their potential contribution, facilitating cooperation within the network, and ensuring delivery of the output to the company that placed the request.

> *"We go through a process which we call a pit stop, which is this open innovation methodology, which basically goes into a deep dive on what the actual challenge is. Who are the customers? Who are the stakeholders? What is the data available? What is the state of the data? Really trying to uncover it. Then we bring that up a number of levels and put it into an open call which we send out to our network of tech start-ups and scale-ups. We have about 12,000 companies in our network and we've worked directly with about 2500 of those [..] We basically get all the applications in, we interview all the companies on there, do a bit of research, and figure out which we think are the best ideas and proposals to take back to [the client]" [I1].*

[4] Some PIIs indicated that they have discontinued some activities, particularly the provision of space for working and events. They justified this by the fact that numerous private companies have starting providing such space on a commercial basis, making a public service unnecessary.

Some intermediaries have taken their transition role even further, by helping players to make collective sense of the emergent system and portray the future, and even by taking an active role in the construction of new technology infrastructure. For example, Intermediary B has organised networking activities to build roadmaps. Intermediary A has led the development of 5G infrastructure in several projects, working with various companies in the delivery of a proof-of-concept system.

> *"We might decide to go and start an activity with a future scoping exercise, then the second piece might be around identify the key challenge areas and then what is up with the market now and then measure these with the future scoping so they can start to look into a more long-term strategy piece, and then sometimes there is a lot of players already in the market looking to the solution or working the solution so we do a panel and meet those guys to talk about how they are dealing with these issues and then this helps to inform as well." [I2]*

> *"The pit stop could be seen – is a great innovation methodology, but it still relies on a lot of in-house resource to follow it through and to deliver the benefits. A lot of industry has basically said to us is that they want us to […] take it on to the next level. We've developed a number of different sprint methodologies that we can actually take some of these ideas through and go ahead and do the development work ourselves […] An example of this would be what we did with the Organization X, for example. They had a fairly well-defined challenge in that they wanted to understand the health and location of high-value assets in remote, hazardous locations. We went and deployed a private LPWAN network for them. […] That's a delivery of a proof of concept, rather than going and finding start-ups". [I1]*

Target segments have expanded over time. In particular, PIIs increasingly target all kinds of organisations as system builders, including large firms, SMEs, and firms that were not previously members of IoT innovation systems. At the same time, several PIIs have stated that they have narrowed the range of application sectors they focus on. This is consistent with their undertaking a system builder role. Application sectors involve different characteristics and actors; to build systems effectively, PIIs need to know the current or potential system agents, with their skills and knowledge, and since this is a resource-intensive process, they need to focus their efforts. So Intermediary A has pivoted to three key technology programmes (immersive technology, AI and machine learning, IoT connectivity) from an earlier stage where they also worked with content developers such as gaming companies, and in areas like digital health. Similarly, Intermediary C now focuses on software development and hardware (the latter mainly in the field of robotics), having moved away from digital content development (film, videogames, music, digital heritage).

5.2.2. Changes in key competences and resources

The first important resource that has allowed PIIs to adjust their business model is knowledge of the technologies and industries they are applied in. As we discussed in the previous section, the new systemic and transition roles that PIIs have undertaken require them to engage in sophisticated activities where they bring together technology providers, help companies to articulate their demand for technology and sometimes to find the best technological solutions, organise networks to address technological needs, and even take a lead in the development of proof-of-concepts. Good understanding of the technology and its applications is crucial for PIIs to be able to engage in these activities, as they need to be able to 'speak the same language' of the companies and research groups they work with. Interestingly, we found that while all PIIs have access to technology and industry knowledge, they have taken different approaches to secure such access. For Intermediary A, increased awareness of the importance of industry-relevant technological knowledge has led to the recruitment of staff with knowledge and competences in target industries such as mechanics/automotive or aerospace; this process has been accompanied by a three-fold growth in size (from less than 50 to 140 staff at the time of our interview).

> *"The tech team is deep with technical capability who are genuine experts in their field. We've then got the innovation services team who run all our open innovation programmes who are real experts in convening ecosystems, the consultative approach, asking the right questions, building these roadmaps on Post-it notes on the walls, and working with clients. In our business development team, that's where we've built the outward-facing side. That used to be quite a small team; it's now quite a big team. Not only do we have the industry leads […] but alongside we've built technical product leads as well". [I1]*

Intermediaries C and D have mainly relied on their external networks in order to access technological knowledge, and their size has remained stable, at 45 and 15 staff respectively. It could be argued that their earlier foundation date and their membership model have allowed them to develop a large, fairly stable network of trusted partners that can be tapped for relevant technological and industry knowledge. Intermediary B, which also has a membership model, adopts a mixed internal/external model combining reliance on partners and internal recruitment. It has seen a growth rate of about 50%. Many of the new hires have worked for major consulting firms, and have a technology background and industry experience.

Knowledge of the innovation system context – its important actors and their mutual relationships – has also proved crucial in order to allow PIIs to reach out to suitable partners in the delivery of complex projects. Knowledge of the local and especially regional context, is particularly important for *pôles* with an additional local development mandate. To build such knowledge of their context, the PIIs' networking, mapping, and service provision activities, in which they had been engaged for some time before taking on their new role as innovation system builders, have proved very helpful.

> *"One is the network that we met and then we engaged so far so we are probably getting closer to ten thousand small businesses mapped and engaged with different activities that we run." [I2]*

> *"[We map companies through] the application form, and also when we meet them we have our own mappings of start-ups that we try to keep in mind". [I4]*

Legitimacy is another important resource. Indeed, organisations can only exist if either formal or informal institutions grant them legitimacy (Suchman, 1995). PIIs enjoy legitimacy because it was formally conferred on them by the public policy that created them (Dalziel and Parjanen, 2012). This formal legitimacy has helped them gain the informal legitimacy conferred by other system stakeholders, because it has favoured the development of trust in the PII as an impartial, neutral player in the innovation system.

> *"Firms trust us because they know we are not commercial enterprises. We don't have our own technology to sell them, but we're here to sound out various opportunities, evaluate all possible technologies in an unbiased way, and then offer them a tailored solution". [I1]*

> *"[the Pôle's] brand and the operational support of the Pôle were crucial to support the legitimacy of our value proposition. The Pôle has also played an important cohesion role to maintain the collective dynamics and the pursuing of our common objectives" (Mov'eo success stories, 2018 edition)*

PIIs have also gained informal legitimacy over time through the development of trust in their competences, reliability and trustworthiness – for example, the belief that the PII will adequately protect the knowledge shared during the process of client engagement.

Finally, in terms of tangible resources, secure, long-term public funding has proved important to allow PIIs to change to align with emerging technology. This is for at least two reasons. First, they need a sufficiently long decision-making horizon that encourages them to plan

strategically and respond to changes in their environment by investing in necessary organisational change processes. Second, they need time to develop the intangible resources underpinning their new activities and roles in line with the new emerging technology, as discussed earlier.

The new PIIs' activities we observed are underpinned by competences, knowledge, legitimacy development, and trust building, which have been a long time in the making. When they were created, it would have been impossible for the PIIs to predict which competences they would need several years later, and to invest in their development from the start. In fact, the demand for the activities that these competences would make possible, did not even exist (or was not yet articulated) only recently. Hence, the PIIs would not have developed these competences had they been primarily funded through commercial activities, or had their public funding been very short-term. While all the PIIs we studied have had to work in a context of reduced public funding, and have been pushed to find alternative funding by charging their members or clients for the services they deliver, substantial public funding has proved essential for PIIs to perform the system and transition roles successfully.

> *"The "Thirds model" – government, competitively run R&D, commercial [income] – has a really interesting effect […] Having commercial income of course keeps you focused on what industry needs. Having competitively won collaborative R&D income keeps you at the leading edge. And the core grant from government means that you're able to fund the capability that keeps you at the leading edge. But the R&D and the commercial income there is an interesting tension between those two that holds you in the right spot so that Catapults are focusing that capability in areas where it's actually going to drive some benefit to the UK". [I3]*

> *"Each of the catapults has a logic model and evaluation process which essentially looks at the activities and looks at the wider sector and provides back an impact report […] Obviously, this is quite a long-term process because a lot of the things that we're trying to do with the catapults have quite distant outcomes, so you put the effort into the organisation at year one. You might not expect to see any of your impacts from your outcomes until maybe year ten or 15". [I10]*

Table 5 summarises how the PIIs' business models have changed over time, focusing on the five dimensions of value proposition, organisation of activities and their structuring, target segments, key resources and competences, and cost/revenue structure.

6. Conclusions

The implementation of technological solutions based on IoT requires the bespoke integration of hardware and software technologies offered by different providers rather than off-the-shelf solutions. Therefore, PIIs have needed to restructure the way they respond to the needs of business. This trend has been influenced by the fact that, in the UK and France, as well as in other parts of the world, public funding for intermediary activity has been gradually reduced. To a certain extent, therefore, intermediaries have been pushed more towards responding to market demands.

We find that all the intermediaries we studied have modified their business models. Rather than simply coordinating or brokering between players that provide or need technological solutions (to address innovation system failures through upgrading and technology transfer), they have begun to create complex networks of players to solve complex problems. This evolution in business models is underpinned by changes in their value proposition, target segments, organisation of activities, and key resources and competences. The latter include both in-depth knowledge of the relevant technologies and industrial and social context (developed through activities like networking and technology/competence mapping) and the competences required to build systems (developed both internally and through the creation of a reliable network of outside experts). They also include the legitimacy to act as system builders: both formal legitimacy, conferred by the policymaker, and informal legitimacy, conferred by the stakeholders in the system. Despite cost/revenue structures becoming more market-based, public funding continues to play a crucial role in our framework, since it gives the PIIs a sufficiently long-term decision-making horizon to be able to think strategically and develop and reconfigure the resources they need to be effective systemic and transition intermediaries.

Our findings have significant theoretical, policy and management implications. In theoretical terms, we have provided two main contributions. First, we have identified and characterised, building on a rich stream of literature on innovation intermediaries, a set of different roles that innovation intermediaries can play in their innovation systems, ranging from upgrading firms' capabilities (Bessant and Rush, 1995; Howells, 2006; Kokshagina et al., 2017) and transferring knowledge (Alexander and Martin, 2013; Meyer et al., 2019) to actively constructing the innovation system (Boon et al., 2008; Colovic and Lamotte, 2014; Janssen et al., 2014) and helping it to transition to new technology paradigms (Kivimaa et al., 2019b). We have shown empirically that PIIs do play these multiple roles, and that their engagement with an emerging technology leads them to expand the set of roles they perform, introducing more complex system-building and transition-supporting activities, and expanding their target segments to the whole innovation system. Second, we have identified the key resources and competences that PIIs require to support digital transition and new digital systems, including knowledge (of technologies, industries and context) and formal and informal legitimacy. We have found that the PIIs we studied – despite their different histories and contexts – have reconfigured their business models in broadly similar ways (though with some different nuances, for example in the ways in which they access knowledge and build legitimacy). This general framework could be evaluated in other contexts, including PIIs working with other emerging technologies.

In management terms, our findings identify the conditions that allow PIIs to support the digital transition, or any transition to a new innovation system involving an emerging technology. These PIIs are advised to pay particular attention to having a sufficiently long decision-making horizon underpinned by sufficiently long-term resources; to having adequate formal and informal legitimacy; and to building the appropriate knowledge resources in relation to both the relevant technologies, industries and innovation system context.

In terms of policy, our findings suggest that PIIs play a unique role in the context of innovation systems around emerging digital technologies. PIIs are considered as impartial and trustworthy by all constituents, as they are not linked to commercial interests of large firms. Moreover, as they act as guarantors that the interests and assets of different players will be respected in collaborative relationships in which they perform their intermediation role, PIIs ensure the inclusion of innovative start-ups and very small players in large innovation projects. Policy should design tools that allow PIIs to preserve their distinctiveness in innovation systems, stimulating them to be competitive at the same time. Additionally, public funds are very important to allow innovation intermediaries to experiment with new technologies, learn how best to adapt their business model to the new context in order to provide an effective service to firms.

Our study is not without limitations, which point towards areas of future research. The focus of our study was the evolution of business models of PIIs. Further research could deepen the study of this phenomenon by focusing specifically on the obstacles that PIIs encounter in restructuring their business models to address the challenges of an emerging technology; it could also address what makes PIIs comparatively more effective in fulfilling their policy mandates and in responding to the needs of their different stakeholders. We studied intermediaries operating in only two European countries, France and the UK. While we have purposefully sampled our cases for their potential to contribute to theory, we acknowledge that a broader study involving PIIs in a greater number of settings would yield richer insights; in particular, the analysis of a larger sample of PIIs could allow to explore

Table 4
Changes in PIIs' activities.

Role	Activity	Public Innovation Intermediaries			
		A	B	C	D
Upgrading role	Providing information				
	Creating learning events				
	Providing access to third party R&D labs				
	Providing space for events/workspace				
	Providing labs for firms to experiment with technology				
	Providing business acceleration services				
	Providing business internationalisation services				
	Facilitating project creation				
	Providing training				
Transfer role	Supporting licensing and co-patenting				
	Promoting researchers' mobility in firms				
	Supporting university-industry partnerships				
Systemic role	Competence mapping				
	Evaluation of markets and formulation of demand				
	Supporting collaborative R&D projects				
	Forming a complex configuration of actors				
	Promoting learning of and experimentation with new configurations				
Transition role	Destabilising existing networks and promoting new configurations				
	Supporting networking				
	Constructing a new technology architecture				

Note: Highlighted in white: activity not performed by the PII; in light grey: activity occurring from the start but later abandoned; in dark grey: activity occurring since PII creation; in black: activity introduced later. .

Table 5
Main changes in the PIIs' business model.

Business model components	Changes from earlier business models
Value proposition	PIIs propose to create/shape the system rather than simply providing innovation support services
Organisation and structuring of activities	Growing commitment to activities promoting organisational forms (networks, temporary associations, consortia) that solve problems arising from application of new technologies or exploration of new areas of application
Target segments	PIIs support a wider range of businesses (SMEs, large businesses, other organisations)
Key resources and competences	Ability to rely on: • technological knowledge acquired through recruitment of specialised personnel and/or outside experts • industrial knowledge acquired via recruitment of specialised personnel and/or outside experts • context-specific (territorial) knowledge obtained from earlier activities • formal legitimacy conferred by the policymaker (encourages firms to trust the PII) • informal legitimacy gradually developed through successful flagship projects, long-term membership, transparent and codified procedures • secure, long-term public funding that allows PIIs to change and to align with emerging technology
Cost/revenue structure	Reduction in public funding and adoption of market-based activities

in greater detail the differences between them, beyond the broadly similar process of adaptation to a new business model. It would also be valuable to test this framework on PIIs supporting the transition to new innovation systems in contexts other than IoT.

Author statement

All authors contributed equally to the following activities in the preparation of this manuscript: Conceptualization; Data curation; Investigation; Methodology; Writing - original draft; Writing - review & editing

Acknowledgements

We are grateful to the Editor and three anonymous reviewers for their insightful comments and suggestions. This research was supported by British Academy grant number SRG18R1\180931. For helpful comments and suggestions on how to improve the paper, we are very grateful to participants at the following conferences: R&D Management conference, Paris, 19–21 June 2019; OECD-CREA workshop "Digital Innovation in Agriculture and Beyond: Policy Insights", Rome, 23–24 September 2019; Regional Studies Association Winter Conference, London, 14–15 November 2019; GeoInno 2020 conference, Stavanger, Norway, 29–31 January 2020; HSE-OECD-STEPI workshop "What new policy approaches support co-creation? Peer discussion on best practices", 5–6 March 2020.

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