Climate Services xxx (xxxx) xxxx

Contents lists available at ScienceDirect

Climate Services

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

Original research article

Business models for climate services: An analysis

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ARTICLE INFO

Keywords:
Climate services
Business models
Network text analysis
Qualitative methods
Interviews

ABSTRACT

Climate services support mitigation and adaptation to climate change and encourage a science-based and climate-informed policy development. A performing market is vital for supporting uptake of climate services. The diffusion of innovations depends on how business models – meant as firms' strategic choices to create, capture and share value within a value network – are employed. Innovation in business model, rather than product innovation only, has been proved useful for overcoming bottlenecks associated with development and diffusion of technologies. But only few studies have analysed how business models are used within the context of climate services. We fill this gap by using a sample of 32 climate services provisions at different stage of development. We use an original and revised version the Business Model Canvas as a framework to facilitate the data collection and analysis processes. A quali-quantitative approach is employed to tackle the content of the administered semi-structured interviews and to map them into a connected set of nodes representing concepts as provided by the selected informants. By combining Content and Network Analysis we present how business model aspects interact both within and across components. We find that the Value Network in which climate services operate is crucial for success, while a subscription, online-based infrastructure is a widespread tool in reaching the target users. The creation of partnerships and consortia of organisations allows mutual learning opportunities to happen and boosts the innovation behind these products. We focus on the graph giant component to highlight the role of co-creation approach in generating direct and indirect incremental innovations while delivering seasonal forecasts and tailor-made services. Finally, we call for tighter link between business and climate-related aspects to enhance the importance of financial considerations around climate services provision.

Practical Implications

Provision of quality-assured climate information is crucial for science-based decisions and policy making. Climate services entail the generation, dissemination and translation of climate-related data to support users in coping with a climate variability and change (Vaughan and Hewitt, 2018; Vaughan et al., 2016; Vaughan and Dessai, 2014). They connect science, technology and policy to support building of climate-smart societies. Climate services necessitate application of new business models and frameworks to accelerate innovation and help overcoming economic, political and institutional barriers of climate action.

In this article we explore business models for climate services, understood as "strategic choices to create and retain value" generated by climate information and knowledge (Shafer et al., 2005). First, we explain the role of business models for fostering incremental innovation and supporting Knowledge-Intensive Business Services (KIBS), such as climate services. Business models help to identify users and stakeholders that constitute the core of a value network. Second, we explore frameworks capable of assessing the relevance of business models for boosting the market of climate services. To this end we interview a sample of 32 climate services providers and their strategic marketing choices. We used a quali-quantitative approach to *(i)* analyse the interviews (content analysis) and *(ii)* explore the role of different concepts in shaping the narrative around business models (Network Analysis).

We found that the most pressing issues are located within the business ecosystems in which the services operate: a close involvement of users and stakeholders is essential to deliver a tailor-made service for both publicly-funded and private climate services. We focus on financial structure as a relatively uncharted area of business models. Public providers tend to focus more on value proposition and value network, while private firms concentrate on revenue streams and value-driven character of services. Often this poses economic viability of the services at risk. We have split the transcribed narratives into a network in which nodes are constituted by key concepts/codes identified during the

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https://doi.org/10.1016/j.cliser.2019.100111
Received 25 September 2018; Received in revised form 5 July 2019; Accepted 30 July 2019

content analysis, and nodes are … As next, we have analysed structural properties of the network. We then analyse the business models used. We found that:

- Co-creation approach is central for delivering innovation and works both offline (via increased competences within the network) and online (through the provision of web-based products).
- Sectors in which co-creation and tailor-made approaches are more effective include energy, water management and disaster risk reduction.
- Climate services use mainly "e-business model": an online, web-based infrastructure installed and updated under the payment of a monthly, seasonal or yearly subscription.

1. Introduction

Substantial efforts have been made in recent years to develop and foster use of climate-services for climate adaptation policy and decision making. Defined as "timely production, translation and delivery of useful climate data, information and knowledge" (Barron, 2001), climate services and products embrace climate records, catalogues of extreme events, reanalyses, forecasts, projections and indices used in vulnerability and risk assessments. Given the growing interests and application in many sectors (Vaughan and Hewitt, 2018; Bruno Soares et al., 2017; Bruno Soares and Dessai, 2016), development of climate services has progressively shifted away from top-down, supply-driven (pushed) towards user-centric and -tailored (pulled) innovation processes. This has helped climate services' projects to overcome the *"valley of death"* (Brasseur and Gallardo, 2016), a critical stage between prototype and operational phase in which resources are often lacking to launch a product or make it fully operational (Barr et al., 2009).

Climate services require novel approaches to reach those who need it most (Buontempo et al., 2018; Soares et al., 2018). Inadequate engagement of users stood as a barrier preventing greater adoption for individual and collective decision making (Brasseur and Gallardo, 2016). Research has identified business models as tools to close this gap: they enhance innovation (e.g. (Boons and Lüdeke-Freund, 2013); (Chesbrough, 2010), support sustainability (Hansen et al., 2009) and overcome barriers in the product development stage (Chesbrough, 2010). They link production and consumption sides (Boons and Lüdeke-Freund, 2013; Long et al., 2017) and function as market devices (Doganova and Eyquem-Renault, 2009).

In this paper we explore critical factors behind business models using a sample of 32 climate services. The set comprises ongoing and completed collaborative innovation projects, but also in-house innovations of single businesses. We conducted semi-structured interviews with senior-level managers, using the business model canvas (BMC) as a framework. BMC makes it possible to identify nine components that are constantly interacting and evolving throughout the life span of a service. We revised the standard BMC and added two cross-case building blocks that are important for an embryonal market. We employed content analysis and assigned codes to various token of the transcribed interviews. By using graph theory and network analysis, we assessed the relationship between key topics, representing them in a directed graph where nodes are codes and links are weighted on the proximity between words in each token of text.

To our knowledge, this paper is one of the first attempts to analyse the role of business models for deployment of climate services. To do so we combine several methods within a consistent analytical framework. The paper is organised as follows: Section 2 reviews the existing literature on business models and explains the methodological background; Section 3 describes the data and methods used; Section 4 discusses the main results and their implications. Section 5 summarises main conclusions, recommendations and suggestions for future research.

2. Business models: a multi-purpose tool

2.1. Defining business models

A business model is a "representation of firms' underlying core logic and strategic choices for creating and capturing value within a value network" (Shafer et al., 2005). How a company generates and retains value is a part a business strategy. Value network constitutes a space for interaction with clients, suppliers, purveyors, donors and civil society (Shafer et al., 2005). By serving as "market device" (Doganova and Eyquem-Renault, 2009), business models help to mobilise internal (e.g. skills, knowledge and financial resources) and external (e.g. access to financial capital) resources and promotes new ways of sustainable innovations (Vaughan et al., 2016; Chesbrough, 2010; Long et al., 2017).

Research on business models identified three recent evolutionary streams (Wirtz, 2009). The first, technology-driven stream originates in the dot-com era. Rapid increase of web-based products and online platforms initiated "e-business models". In a second stream, business models are used as tools of strategic management, by proving their relevance in boosting the positioning of a company along the value chain. Instead of focusing on product innovation alone, researchers identified the role of process innovation and changes in enhancing productivity ceteris paribus. These changes are addresses by business models and their building blocks (Tikkanen et al., 2005). The third stream places emphasis on market competition (Chesbrough, 2010). Business model innovation sets off a new field of competition, complementary to the value proposition (Casadesus-Masanell and Ricart, 2010). As a result of incremental changes in value network and customers' segments, two comparable products may gain different shares of the market only because of the business model they use.

Business models are triggers of innovation capable of creating new realities (Falloon et al., 2013). This is done by supporting ideation, development and marketing of innovations characterised by disruptive forces: new services in a new market or new services capable of reshaping existing business dynamics (Schilling, 2008). In the context of climate services, business model innovation stimulates growth of efficient, policy-oriented and science-informed business ecosystems. Finally, business models for climate services also serve an educational purpose: they empower stakeholders to share best practices, data and protocols (Brasseur and Gallardo, 2016; Larosa and Perrels, 2017), contributing so to expanding the available knowledge stock.

2.2. Climate services as sustainable knowledge-intensive business services

Climate services can be seen as a form of sustainable innovation which "takes into account environmental, social and economic considerations in their development and use" (Larson, 2007). Business models are critical for the success of climate services (Long et al., 2017). Sustainable innovations can be technological, organisational and social (Boons and Lüdeke-Freund, 2013). Business models shape the internal organisational processes, supporting effectiveness in linking providers and users. Also, they help maximising the collective utility achieving social maxima through technological transformations. The analysis of existing literature suggests that business models act as signals and mediators within a given market, often leaving the revenue model behind, while positively impacting on society (Boons and Lüdeke-Freund, 2013; Doganova and Eyquem-Renault, 2009).

Climate services are a special type of knowledge-intensive business service (KIBS), i.e. non-financial, knowledge-intense services characterised by high human capital density (Brenner et al., 2017; Koschatzky et al., 2001). They are intangible and difficult to standardise (Miles, 1995). Progressive shift from industrial to service-dominated economies (tertiarization) has favoured knowledge industries and climate services are part of this transformation (Baró, 2008). KIBS do not just generate new products and services, they also support co-production of innovation (Amara et al., 2008). They have in common three features:

- Knowledge is both input and output of knowledge-intensive services. Knowledge comprises a whole "stock of expertise" (Starbuck, 1992), including context-specific judgements and choices. This is why standardisation of KIBS is difficult.
- Services are products of close and multiple interactions between providers and clients, implicit to co-creation process (Xu et al., 2016), and final services are tailor- and custom-made to the specific knowledge demand of customers (Koschatzky et al., 2001).
- Systemic understanding of innovation include product/service development, marketing strategies and innovative work practices (Flikkema et al., 2007)

Climate services include these features and incorporate them in business models (Larosa and Perrels, 2017). However, literature revealed three main barriers:

- Co-development of climate services need to be cultivated, and the added value of services explored from the beginning (Vaughan et al., 2016; Service and Commission, 2014)
- Business models are often ineffective and not adapted to profit-oriented and private sector's culture (Brasseur and Gallardo, 2016)
- Asymmetries in benefits and gains across separate groups must be tackled in order to equally understand the implications of providing timely and accurate climate information to society (Vaughan and Dessai, 2014)

Mitigation practices found a relatively successful window of opportunities so far (Brasseur and Gallardo, 2016), while the market for adaptation is also promising at the early stage of development. A variety of actors and organisations are supplying climate services (Medri et al., 2012) for a wide spectrum of economic and policy sectors. The uptake of climate services is driven not just by the knowledge product itself. Clear identification of the value-proposition (advantages gained by users) is equally important. Finally, service providers can be simultaneously suppliers and users of climate services, making the identification of stakeholders difficult (Cortekar, 2017).

2.3. The business model Canvas

We adopt the Business Model Canvas (Osterwalder & Pigneur, 2010) as a framework for analysis. Business Model Canvas (BMC) is described by nine components (Fig. 1). The left side of the 'canvas' reflects the product-related components, whereas the right side is focused on the customers' side. Value proposition, characterized as "the bundle of products and services" (Osterwalder et al., 2005) aimed at satisfying users' needs and creating value, is located in-between.

The BMC has found widespread application (Long et al., 2017; Dijkman et al., 2015; Universalia, 2013) and generally positive experience (Long et al., 2017; Ching and Fauvel, 2013; Eppler et al., 2011) but also some criticisms. BMC underscores how a company's value network operates. A value network (Fig. 2) allows to share information, data, good practices and protocols, as well as to sell and buy products and services. It is defined as business ecosystem in which each member has a precise role and is continuously affected by interactions with other members (Allee, 2000; Clarysse et al., 2014). Value is generated as a cumulative result of each participant's effort.

The value network (Fig. 2) is composed by supply/provider (Fig. 2, on the right) and demand/customer sides (Fig. 2, on the left). **Partners** entail all stakeholders, suppliers and providers that 'make the business model work'. Successful partnerships are forged as strategic alliances, are embedded in contingent risk strategies helping businesses to cope with market uncertainties. Partnerships are developed as non-competitive agreements, but they also include provider-user relationships. Operational **activities** deliver the value proposition and reach target users in the most cost-effective way. They encompass all development phases: from design to marketing. Key **resources** are the physical, intellectual, financial and human inputs required to trigger activities and ultimately deliver the value proposition. They respond to a logic of business sustainability: a careful planning is required to ensure they will not be depleted before the completion of the set of activities.

Customer segments entail different groups of actors potentially interested in climate services' value proposition. Each cluster may have separate needs: the market segmentation supports their characterisation and defines priorities. Groups are separate if they react differently to the value generated by the service, if they use different channels to interact with the service providers and even if they are willing to pay different prices. The dichotomy between mass and niche markets is an example of this heterogeneity. **Relationships**, as much as customer segments, are also highly differentiated and adapted to the needs of target users. They may be fully automated or personal and they support the client acquisition, development and scaling-up phases of every climate service. Relationships entail the way users live the experience and engage with the provider. Examples of this block are provided by personal assistance features, learning opportunities and value co-creation process. **Channels** are the tools any service uses to communicate with and relate to its segments. They may work on– and off-line through inhouse or outsourced infrastructures. Channels raise awareness about the service's mission and values; they support the evaluation of the activities offered and they guide customers through the purchase steps.

Each member of the value network may offer tangible (priced products, components or services) and/or intangible values. While the tangible values are actual exchanges between partners and they normally involve Memorandum of Understandings (MoUs), contracts, invoices and requests for proposals, the set of intangible values can be further sub-categorised in knowledge and benefits. While knowledge includes information, competences and skills, benefits comprise reputation factors and prestige. The value network analysis is a mandatory step when dealing with the customer segment: the set of the target users and interested stakeholders shape the activities required to deliver the value proposition and provides boundary conditions to the available resources (Osterwalder et al., 2005).

3. Data and methods

3.1. The theoretical framework: the grounded theory method

Qualitative analysis is a scientific method of observation of properties and patterns using non-numerical data (Babbie, 2011). Qualitative market studies (Flick, 2010; Seemann, 2012) typically employs focus groups, expert surveys and interviews. here, we use a cross-case approach (Miles and Huberman, 1994) to uncover emerging patterns across different climate services typologies (cases).

Using the Grounded Theory Method (Glaser and Strauss, 1967), researchers collect, store and analyse data that will be used as building blocks of a theory. The interview technique is one of the possible tools used to observe a phenomenon. An interview is "an interchange in which one person… attempts to elicit information or expressions of opinion or belief from another person or persons" (MacCoby and Maccoby, 1954). The process of interviewing generates mutual learning between those involved and creates primary data that can be then analysed and interpreted (Fontana and Frey, 1994). In order for interviews to be effectively used, some key steps must be followed, crucially split in three classes: design, data collection and data analysis. A clear identification of the research question creates the conditions to understand if and how interviews are the most appropriate tool to solve the problem. Structured interviews follow a predetermined script, that cannot be adapted to different actors or situations. Conversely, unstructured interviews are based on the answers of the respondents.

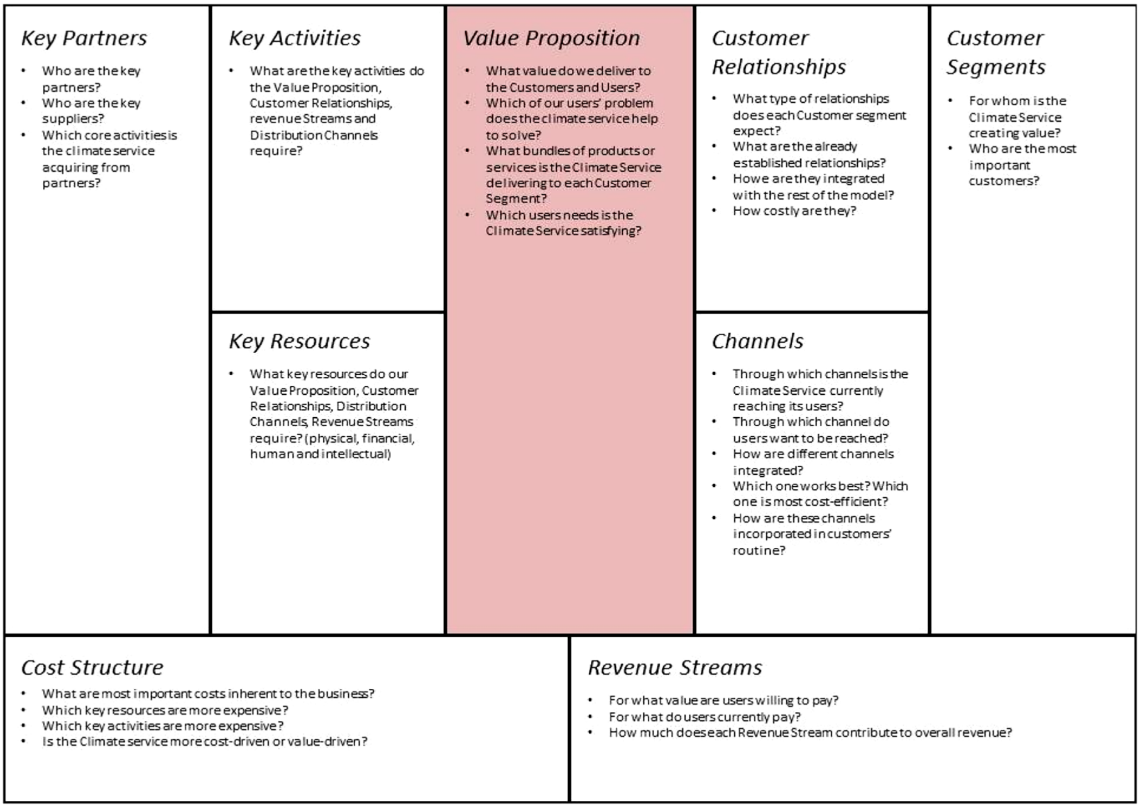

Fig. 1. Business Model Canvas.

Questions are spontaneous and are shaped by the direction the discussion. In semi-structured interviews the interviewer asks a pre-defined set of questions but is also free to ask more and more in-depth depending on the direction of the conversation. The elaboration of an initial set of questions serves as basis to further proceed in the grounded theory method. This represents an initial attempt to frame the problem and may not be exhaustive: revisions and edits are often required (Fig. 3).

Data collection starts with identification of a sample of interviewees. A range of sampling strategies exist, including (i) snowball, that uses initially identified informants to contact relevant others; (ii) representative sampling, where the number of selected participants are representative of the total population; (iii) random sampling, where selected informants are interviewed randomly (Young, 2018). Pilot interviews should ideally refine and test the effectiveness of the questions. Analysis of interviews involves "coding", that is placing "tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study" (Miles and Huberman, 1994). Coding allows the classification of pieces of data and transformation of non-numerical to numerical data. Codes might have been previously set, which is the typical case for structured interviews, or may instead be chosen using an "open coding" procedure. Codes are units organized in "concepts", which are regroupings of the available data to reach more analytical conclusions. Throughout the coding procedure, memoing is essential (Babbie, 2011): the act of writing memos and notes related to (i) codes; (ii) the theory behind the process; and (iii) all relevant methodological issues. The so-collected reflections enrich the analysis and support the writing phase.

Interviews include some subjective considerations before, during and after data collection (Babbie, 2011; Young, 2018). The choices the researcher makes can affect the outcomes of the process. However, the cross-case grounded theory method allows for identification of emerging patterns that can be very useful for exploratory research.

3.2. Sampling climate services provision

Given the heterogeneity of definitions, typologies and contexts, a comprehensive catalogue of climate services is not available. Besides, climate services are developing by a wide variety of public and private actors that implement research and innovation actions, as well as for-

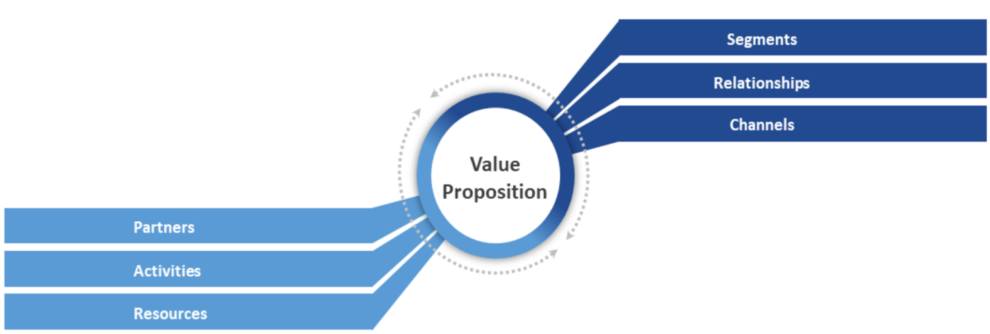

Fig. 2. Defining the value network.

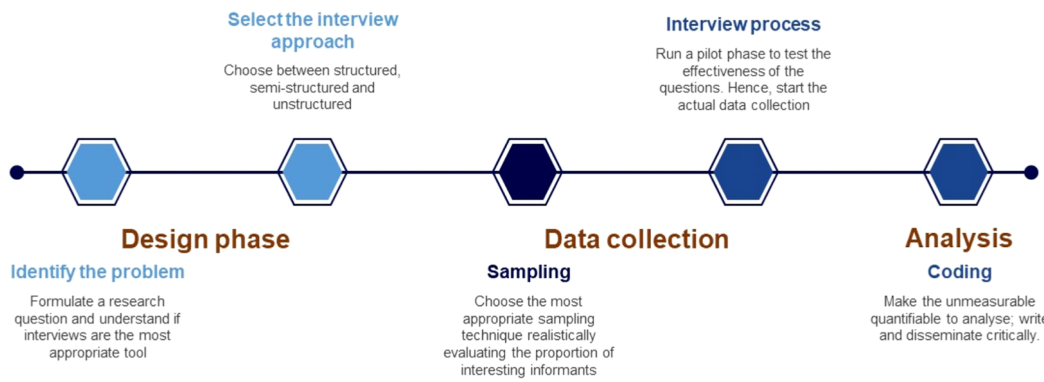

Fig. 3. The key steps of an interview process.

profit commercial activities differently. Research institutes are involved in the provision of climate innovations: they are rarely working under for-profit logics, but create value for society as a whole. Therefore, the application of a business framework to these entities may be controversial (Universalia, 2013).

Public actors (such as meteorological organisations and research performing institutes) were the first to value the climatic information and to extend their services beyond pure weather applications (World Meteorological Organisation, 2009). However, a range of incumbent players is widening the spectrum of available activities and actions. This variety has implications on the business model they use to perform their activities. To allow a more precise identification of the building blocks of business model for climate services, we first distinguished between three forms of climate services discriminating the funding source of their activities: (i) Ongoing publicly-funded projects; (ii) Completed projects; (iii) Private firms.

For (i) and (ii), we focused on European projects operating in a twelve-year period (2005–2017) and funded under different strategic programs managed by the European Commission. We consulted the Community Research and Development Information Service (CORDIS) platform and we launched multiple queries using a combination of keywords[1] under any program, domain and country[2]. The choice of keywords potentially affects the sample included in the research. In particular, hydro-meteorological and weather services may respond to the set of fundamental characteristics climate services have. Despite this limitation, we opted for the institutionalized keywords as they are shared by the three most relevant frameworks at European and global level: the definition of climate services (Barron, 2001), the Global Framework for Climate Services (Directorate-General for Research and Innovation, 2015) and the European Roadmap for Climate Services (Krippendorff, 2004).

Our query in CORDIS reported 153 results. We restricted our interest to programs dedicated to the development of an actual service or application. This includes practical, open-access tools and innovations, platforms, training activities aimed at increasing public and private stakeholders' engagement in this type of services. We did not include individual grants (e.g.: Marie Skłodowska-Curie Research Fellowship Programmes) and purely theoretical initiatives. We also consulted two other major information sources: the Copernicus Climate Change Service (C3S) and the Climate-ADAPT database. Regarding the former, we focused on the section dedicated to "providers", while for the latter, we used "climate service" as key word to perform the research. Successively we contacted scientific managers of identified initiative and conducted eight interviews. We used the same interview protocol to interview 14 climate services developed in the context of the European funded project CLARA ("Climate forecast enabled knowledge services"). We conducted additional 22 interviews: 14 ongoing publicly-funded climate service provisions and 8 completed projects.

For the private firms we used a snowball sampling technique. We asked the Scientific Managers of each publicly-funded initiative included in the sample to mention private entities working on climate services or providing any form of climate service. This non-probability sampling technique presents some limitations: (i) it does not pretend to be representative of the population of interest; and (ii) it may suffer of a selection bias. However, managers interviewed are experts in the field and their judgement allowed us to reach innovative for-profit actions. Overall, we conducted 32 interviews.

3.3. The interview process

We conducted semi-structured interviews with project managers of each climate service provision. Interviews were conducted – whenever possible – as in-person discussion, by telephone otherwise. The interview lasted approximately one hour.

We first presented the objectives of our research and fostered a shared understanding of what climate services are. Then, we explained the framework used to collect and analyse the interviews: the Business Model Canvas. We did not specify every building block of the BMC, but explained our intention to detecting the value proposition, the value network and the financial structure of each service. Finally, we asked the interviewees to highlight the main barriers and potential opportunities in the design, development and eventual launch of the service. Therefore, we reviewed the standard BMC, adding two additional sections that span across the different building blocks. The first looks at "Opportunities", while the second deals with "Barriers". Our revised version of the BMC (Fig. 4) puts emphasis on the bottlenecks and gains that climate service provision generates. The two aspects are particularly relevant in the context of disruptive products because they identify where gaps are and try to foresee potential concerns.

Interviews were semi-structured: we followed a pre-determined protocol of 17 questions (see Supplementary Material), leaving freedom to deepen some aspects of the conversation. The order of the questions was not pre-defined on purpose: the interviewee was left free to jump from one topic to another autonomously. This flexibility provides the core methodological input for a linguistic and content analysis. In fact, it is not just the content that matters, but also the order in which an informant mentions key concepts. The process of building a narrative clarifies and complements the talk. Furthermore, it supports qualitative and critical reflections. Hence, the pre-defined set of questions has to be perceived as a roadmap, a protocol that facilitates the allocation of questions, rather than the identification of answers.

3.4. A quali-quantitative approach

We used codes and labels as the building bricks of a quali-

[1] "climate services" AND "Climate Services" AND "Climate Service*".

[2] The query was performed in March 2017.

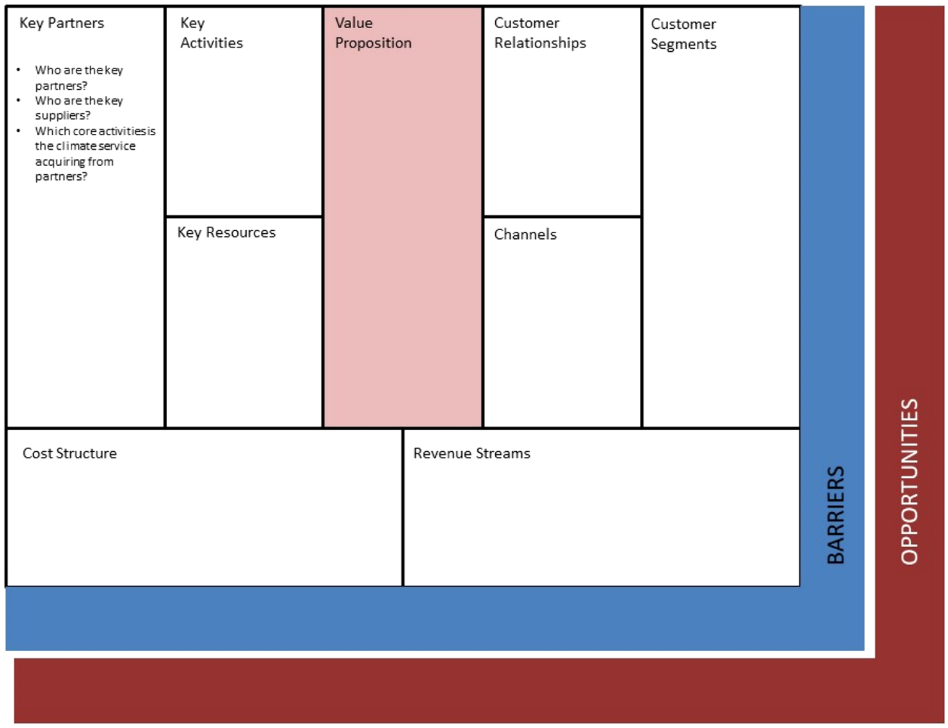

Fig. 4. Extended Business Model Canvas.

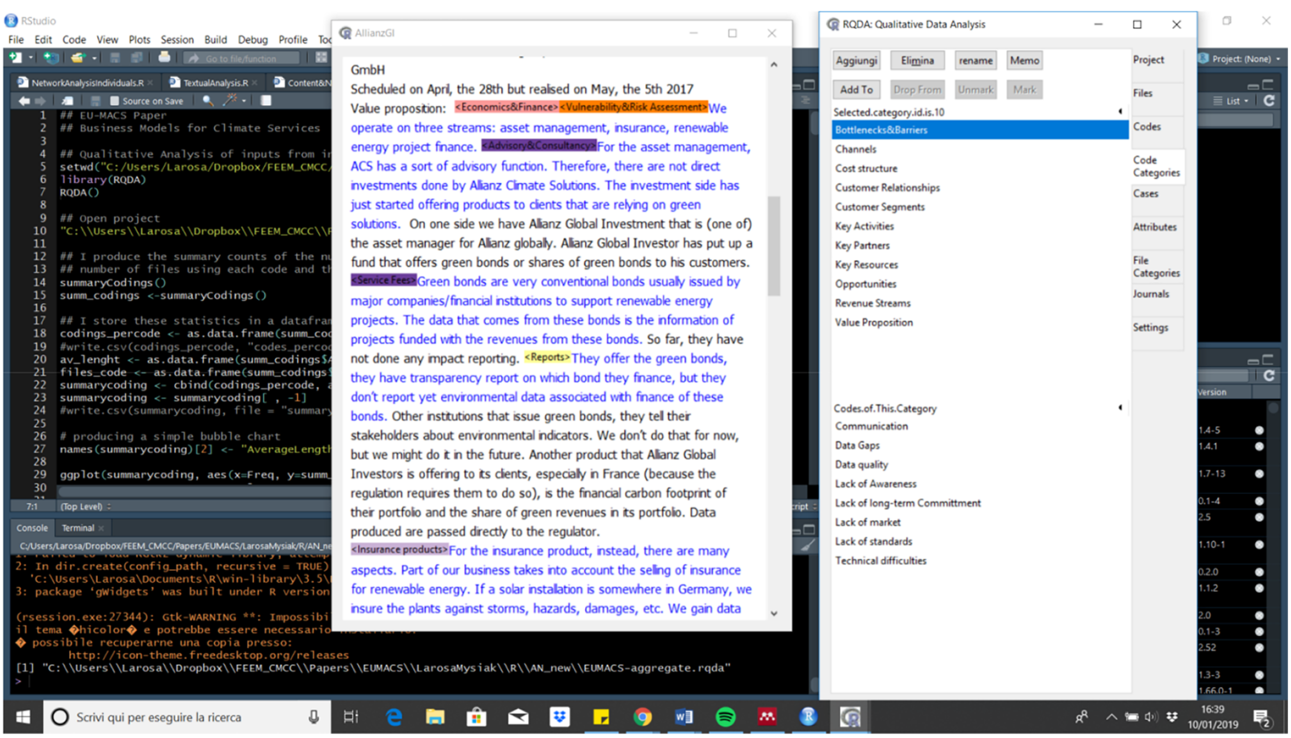

Fig. 5. The RQDA package of R software.

quantitative approach: we combined Content Analysis with Network Analysis to visualise, analyse and interpret the outcome of the interview process. Content Analysis responds to the need of systematically analysing bodies of texts, visuals and matters, without including personal judgements and perspectives (Pashakhanlou, 2017). It allows the identification of patterns throughout the text by transforming qualitative information into quantitative ones. It uses labels and codes to perform statistical evaluations using textual information. Outputs of this approach comprise word frequencies and descriptive statistics of the interviews' recording under study. By treating words as data gives researchers the freedom to quantitatively assess the latent and manifest meanings in the text (Otte and Rousseau, 2002).

Content Analysis can also uncover the relationships between different tokens of texts and codes. However, it is not sufficient per sé to characterise alone is not sufficient to rank or characterise the properties of these networks. That is why we complement our methodological framework with Network Analysis (Boccaletti et al., 2006), capable of detecting and characterising links between individual nodes to derive generally valid considerations about a group of agents (Pokorny, 2018). Networks (N) are constituted by vertices – or nodes, V(N) linked together by edges – or links, E(N). Whenever the direction of the relationship between two nodes matter, networks are represented as directed or undirected graphs (Boccaletti et al., 2006). We opted NA to characterise the complexity behind the codes assigned through Content Analysis. This approach supports both the visualisation and analysis of textual information, by efficiently representing the links between concepts and by computing statistical evaluations through centrality analysis. Analysis of networks' characteristics provides an insightful overview of the general features of the environment in which nodes move. Furthermore, the study of nodes highlights the influential poles of action, uncovering where central, neutral or marginal actors stay in a quantitative way. The computation of centrality measures is important to understand the role of certain vertices in driving and spreading information efficiently.

We organised the notes taken during the interviews and we grouped them according to the type of provision (ongoing projects, completed projects and private firms). We coded the text through RQDA, the qualitative analysis package of R software (Fig. 5), a free and open-source tool typically used in statistical analysis. We assigned codes to portions of text (tokens) through an open coding procedure. We then iteratively proceeded through axial coding, a technique that involves a regrouping of the data to move from simple codes to more analytic concepts (Babbie, 2011). Concepts are grouped in code categories, that represent a component of the revised Business Model Canvas.

We coded texts using 70 codes (see Supplementary Materials). We performed a Content Analysis on codes to highlight the most relevant concepts mentioned through the interview process with different types of climate services provision. Then, we used codes to build a graph and explore the complexity of the storyline and ultimately of the business model of each initiative in the sample. Networks were constructed in R and exported in Gephi: an open-access network visualisation software.

The 32 interviews form a directed network of 70 nodes (the codes) and 1892 weighted links. The direction of the links is provided by the order in which project managers presented their narrative around their business model. Edges of the network are weighted according to the frequency of the connection between the two codes. This approach builds upon a consideration around the way informants structure their narrative: the chronological location of codes matters in the formation of the directed graph, as well as the proximity of two codes throughout the text. This is allowed by the use of semi-structured interviews that gave freedom during the conversation to jump from one topic to another without losing focus on the core script. This approach (Bodin, 2012) allows to retrieve information on how certain codes relate to each other within a token. It has been proved successful in education empirical research (Paranyushkin, 2012) and in theoretical works (Paranyushkin, 2011; Carlson and Wilmot, 2006). Hence, the network of codes becomes a map defined both across time and space that describes not just the content, but also the relationship between different concepts, as provided by the informant. When building our network, we mixed the proximity approach (Carlson and Wilmot, 2006) with the chronological order of appearance of concepts throughout the interview (Paranyushkin, 2012), allowing for non-mutually exclusive codes to interact in a directed, weighted graph. Given that two codes may actually overlap, the relationship between them can be either bidirectional (if they are overlapping) or unidirectional otherwise. The isolation of a given node implies that the token of text deals with a single topic, expressed by a node. We computed descriptive statistics at network and node level to uncover the structural properties of the graph and to quantitatively assess the relationships between the different Business Model Canvas sections. Network analysis is providing insightful information and complements the Content Analysis because it looks at central codes relating them to the others and within their network. Concepts are not central per sé, but only when and if they are related to others. Therefore, the role of relationships acquires significance and moves the analysis further both methodologically and content-wise. To achieve this goal, we computed the size of the nodes as equivalent to the PageRank centrality. This is an eigenvector-based algorithm. The score assigned to each node can be interpreted as a fraction of the time "spent" on that given node. Despite its wide use in the World Wide Web domain, PageRank is a suitable centrality measures for networks derived from textual material because high values of PageRank can be due either to (i) multiple codes (other nodes) pointing at the one under scrutiny or (ii) some highly relevant codes pointing at the target one. Once ranked nodes according to their PageRank score, we restricted our analysis to the network's giant component. In network science, this is a connected portion of a random graph, which contains a finite fraction of the whole network's nodes. We used the giant component to extract and interpret considerations around the business model used.

4. Results and discussion

Results from the Content Analysis provide insights on the use and spread of codes across and within interviews. Outcomes of the coding procedure are related to the frequency of specific concepts, which highlight where topics of interest are, rank them and set the grounds for cross-case comparisons. Furthermore, the analysis of the content of our interviews reveals what has not being mentioned. Topics that are often disregarded can be as relevant as mentioned ones.

We found that the relationship between frequency of mention and the number of interviews is quasi-linear (Fig. 6). Therefore, some key concepts seem to be familiar to every type of climate service provision analysed, independently on their public or private nature. When looking at the frequency distribution of codes, the most cited ones belong to the domain of the Value Network, followed by the Value Proposition (Fig. 7). Marketing and business-related activities are mostly disregarded (< 5 mentions), while technical aspects behind the service are stressed by 87.5% of the interviews. Within the domain of Value Proposition, the top cited codes are related to the provision of information about energy production and use. Climate services are also useful to estimate the costs and revenues generated. They use forecasts and climate projections and solid research-grounded products.

Project managers interviewed used the widest portion of their time to cover the requirements of the development phase. Due to the innovation characteristic of climate services, the technical improvements at both methodological and operational level are crucial. The lack of attention to the financials behind the service is an alarming signal and is worth discussing. Ongoing projects tend to consider the Cost and Revenue Stream as a secondary step in their activities (Fig. 8). This is mostly due to the nature of funding they receive from European or

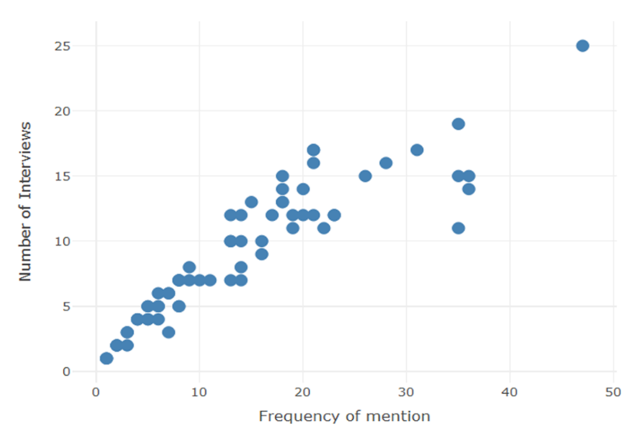

Fig. 6. Frequency of codes vs Number of interviews.

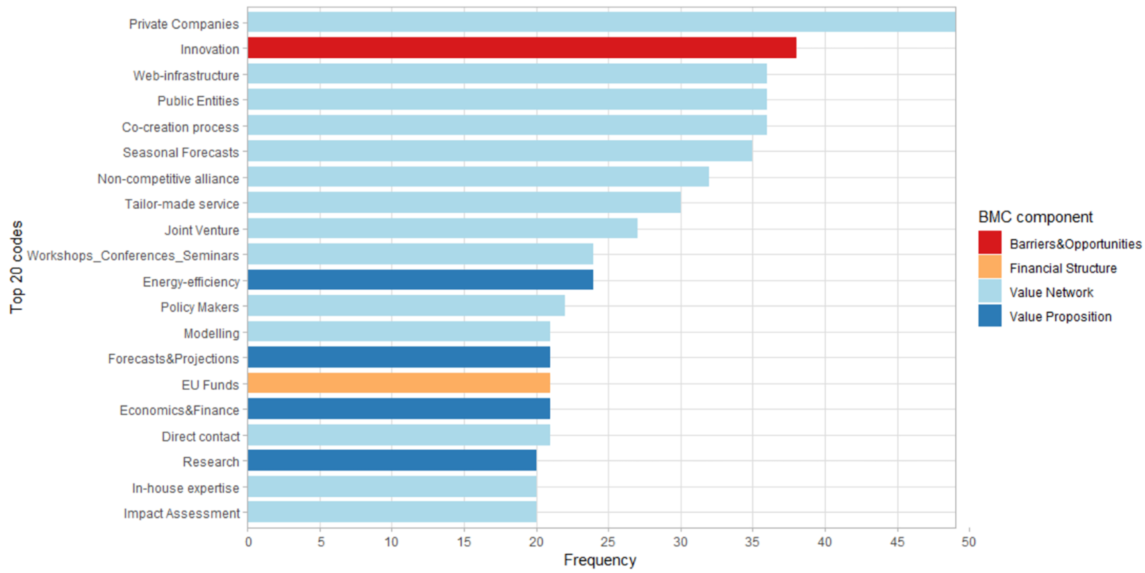

Fig. 7. Most cited codes across interviews.

National bodies. However, considerations around the economic feasibility of the service are essential to launch the product on the market. Potential clients and targeted users may have different willingness to pay and may alter the financial planning if not carefully prepared in advance.

Within the Value Network, we explored the most frequent terms differentiating by code category. Climate service provision is perceived as a tool to generate *innovation* throughout the value network and to boost internal processes, ultimately increasing productivity and effectiveness. Client and stakeholder management is pursued through online (*web-based infrastructure*) and offline (*workshops/conference/seminars* and *direct contact*) interactions. Key activities are delivered via non-competitive alliances or joint ventures between different economic actors. Climate services provision is mostly targeting public entities and policy makers: tailor-made products exploit the in-house knowledge and expertise to provide seasonal forecasts, modelling products and often impact assessments. The qualitative assessment of the interviews reveals that in-house competences and experience are key resources that a consortium of different partners can pool together. Seasonal forecasts, model and research efforts dominate the Key Activities component of the Business Model, while the identified users are equally shared between private and public actors and they are engaged through a co-generation approach to co-develop a "user-friendly" service.

To understand the circumstances in which the Value Network plays a crucial role, we further detailed the analysis discriminating between typology of projects (Fig. 6). As expected, the role of partners and

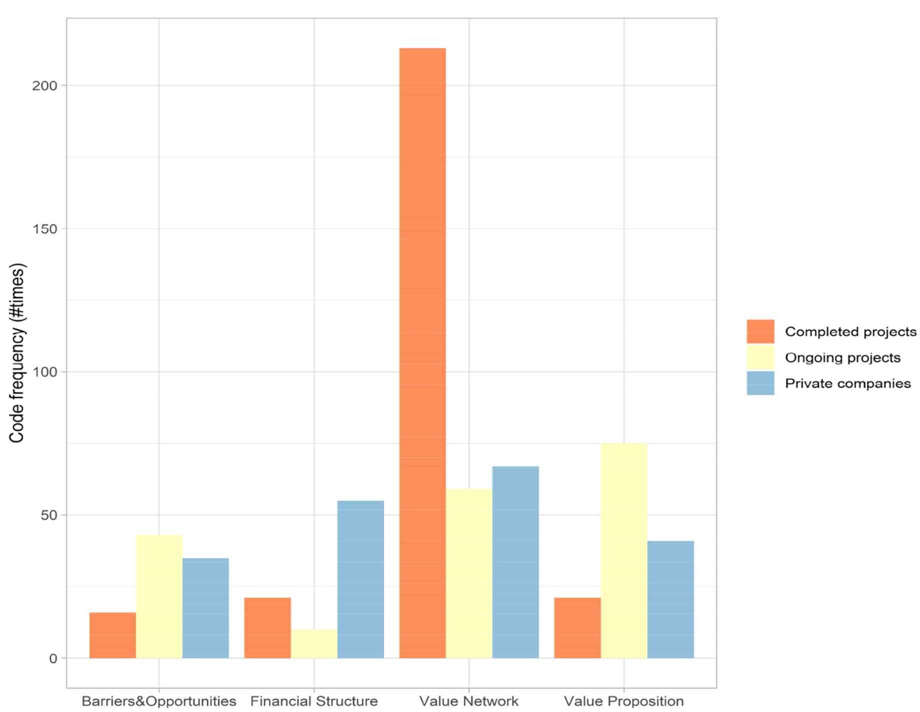

Fig. 8. Most cited BMC components per type of climate services.

stakeholders in providing the adequate resources to perform key business activities is what matters once the service reaches the final prototype stage *("The interchange with other projects has been crucial throughout the duration of the activities and provided mutual learning opportunities while developing the service"*[3]). Instead, given their work in progress activities, ongoing projects extensively use their interview time to cover topics related to the value proposition (*"The aim of the service is to provide users with the opportunity to assess the impacts of future planning scenarios on local urban air pollution levels"*[4]). The punctual definition of the value proposition is a core aspect of success in the case of every innovation (Osterwalder et al., 2005). It provides a careful estimation of the needs, approaches, benefits and competition requirements (NABC) the service provider faces (Albert and Barabási, 2002).

The NABC Framework helps the climate service provider to consider the value proposition by working systematically with the four elements and to identify where competitive advantages lie. A need is related to an important and user-specific issue and can be solved through a disruptive and efficient approach. This should result in the generation of benefits from the customer's perspective. These may range from lower costs to higher performance or decreased risks and must be higher than the ones offered by the competitors. In the design and development phases these considerations must be addressed as preliminary and continuous exercise to overcome barriers and identify opportunities. The definition of a clear value proposition also helps to identify a customer segment, which should be identifiable, reachable, but also stable to ensure sustainability of the planned activities (Osterwalder et al., 2005).

We first computed network-based descriptive statistics at graph level (Boccaletti et al., 2006). Measures of network topology also support the general understanding of network's contents (Bodin, 2012). The number of nodes and links gives the size of a network, together with the average path length and the density. The former depends on the network size and provides a measure of the number of edges included in the mean path (Newman, 2003). It ranges from 0 (minimum value) and the diameter (the maximum possible distance-based value). In the network of codes that we built, the diameter takes value 2, while the average path length is 1.1809. Low values of average path length describe highly interconnected graph. As highlighted in Fig. 9, some codes are strongly interrelated: connections happen especially within the Value Network and mainly link Key Activities and Key Resources with Customers Segments and Key Partners. Across code categories, features of the Value Proposition are mainly paired with Value Network's ones. Among the topological metrics, we also computed the density, which provides an indication of the degree of completeness of a graph and can take values between 0 (fully incomplete) and 1 (theoretically complete). Our network has a density of 0.415, which implies that slightly less than half nodes are connected. This finding is not surprising given that nodes are text-derived codes and not individual agents (e.g. people or organisation). However, the connectedness of more than 40 percent of the total available codes is enough to highlight that some concepts are strictly related to each other.

Once computed the network statistics, we moved towards the characterisation of the individual nodes. The average degree indicates the mean number of links touching a given node. In our case, this is equivalent to 27.82. This metrics provides an innovative visualisation of already existing outputs from the Content Analysis. However, for directed graphs, we can differentiate between in-degree and out-degree node-level metrics. These provide the quantification of – respectively – the links directed towards and outwards a given node (related figures in Supplementary Material). Outcomes of these representations provided insightful information about the temporal mapping of the concepts throughout the interviews: the most cited codes (normally included in the Value Network and interesting Key Activities) acquire relevance in a second moment and they are mentioned after considerations about the Value Proposition and the Barriers encountered to deliver it. Therefore, by following the direction of the relationship, we could assess the chronological order in which concepts were presented by informants. Nodes' colors (Fig. 9) are given by the different Business Model Canvas sections and help visualising the linkages between them, moving towards a comprehensive understanding of the interviews' dynamics.

We computed PageRank centrality to understand the importance of the codes moving beyond the findings of Content Analysis (Fig. 9). Codes are ranked on their PageRank score: the most relevant ones are such both because they were highly mentioned and because they receive inputs and send outputs to other significant nodes. We found that Copernicus, Water Forecasts, Seasonal Forecasts and Early-Warning System are the top ones. We restricted our analysis to the network's giant component where Seasonal Forecasts is the ultimate node of the connected portion (Fig. 10). We observed a tight and strong link between some key concepts: "Co-creation development", "Seasonal Forecasts", "Tailor-made service" and "Web-infrastructure" are not just linked, but they are also frequently mentioned in the same token. Based on the direction of this relationship, we derived useful implications on the role of co-creation: it directly serves as tool to generate the forecasts together with stakeholders and partners, but it is also used as mean for tailor-made final services. Approximately half of the network is connected through the "Co-creation development": 45.58% of the overall edges are pointing towards the node. Interestingly, innovation is conceived as an opportunity and is achieved by both private and public agents. It is tightly connected to energy-efficient technologies, as well as to the provision of forecasts and climate projections. It interests the co-creation process and supports information sharing activities both offline (Workshops/Conference/Seminars) and online (Web-based infrastructure).

Our quali-quantitative methodology provides insightful information on the business model some of these climate services provision use (Fig. 11). On average, climate services included in our sample are mostly working online and use a subscription-based mechanism (e-business model): they supply a constant flow of information and data under the payment of a fixed amount of money, on top of the installation costs. The network analysis also highlighted the most interesting sector of operation: Energy, Water and Disaster Risk Reduction. The web platform is used extensively for seasonal forecasts: both the direction and the thickness of the edge between the two nodes provides an indication of the high frequency of mention within the same piece of narrative. Given the high degree of operability, these services are suitable for both public and private actors, provided that they are tailor-made. Copernicus appears as a central node of our code network and is directly linked within the e-business model structure. This is not surprising: the launch of the Copernicus Climate Change Service (C3S) and the Climate Data Store offered the free access to data and post-processed information, which would have otherwise been difficult to process and use.

The e-business model described by our sample deserves a reflection on the financial sustainability. As by Fig. 11, fixed and variable costs associated with the development of the service are "Infrastructure and Maintenance". These may require a significant initial investment, depending on what is already available in-house. However, the competences of the consortium of partners – when existent – are key resources capable of lowering the instalment expenses. As highlighted during the interview process, in-house competences are enhanced and increased by the exposure to other organisations' expertise *("We combined the models and tools we have been developed in the past years with the data and expertise of our users. Within the consortium we were first exposed to marketing needs and business models. This new knowledge provides us a fresh look on how we could use the in-house resources. The effects of the merge will be long-lasting: we developed new protocols that we intend to*

[3] Extracted from CLIMRUN.

[4] Extracted from the AirCloud service – CLARA project.

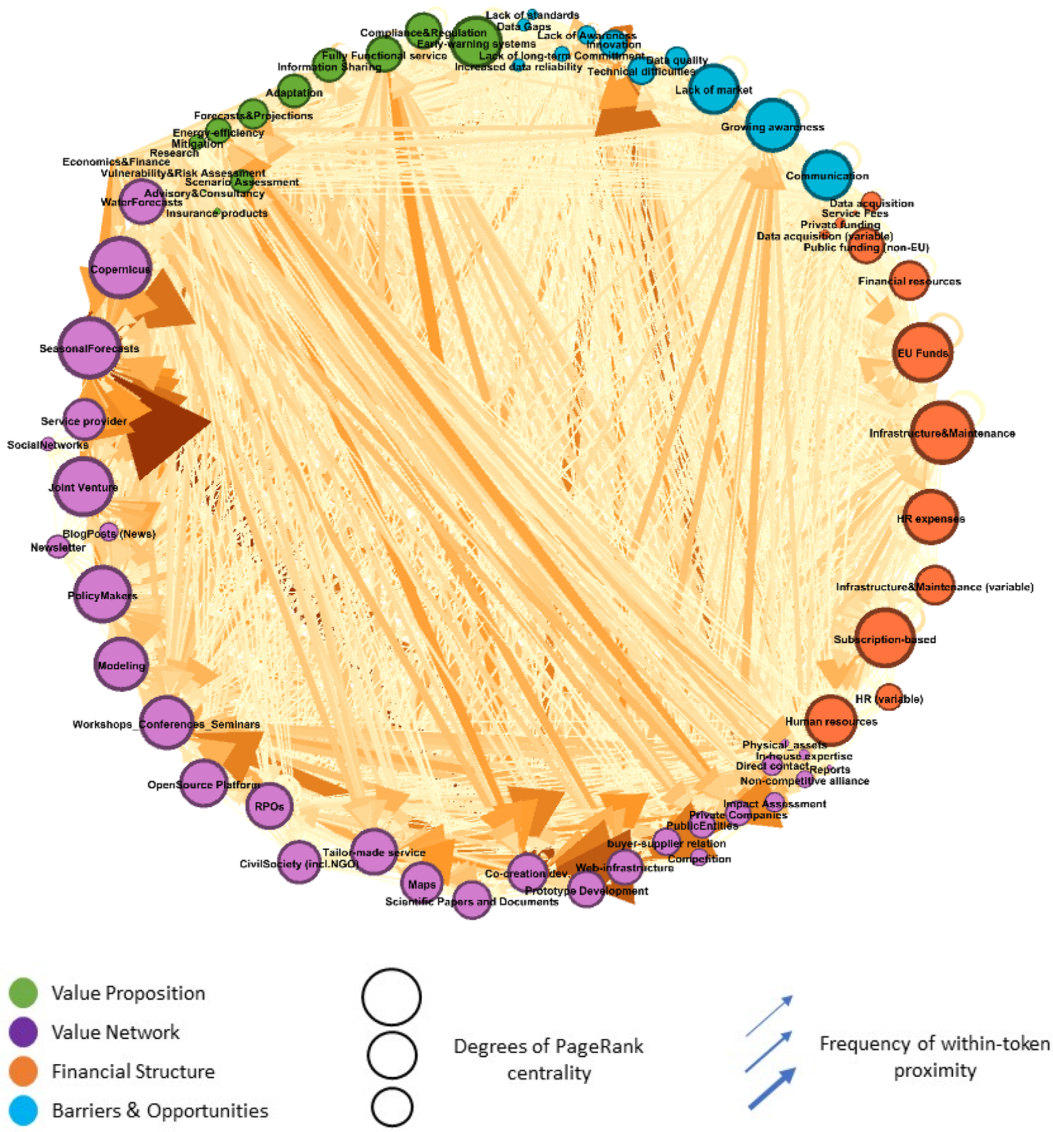

Fig. 9. The network of codes.

apply in the future"[5]). Furthermore, the co-creation process supported a shift towards new actors *("Since the moment we started developing the new indices, we understood there was a massive market potential for these products working hand.in-hand with cutting-edge research organisation, who support the development and back-up the design of these innovations"*[6]).

5. Conclusions

Theoretical and empirical investigation of business models for climate services is important for fostering services' adoption and boosting the market for climate innovation. Business models are firm-specific strategic choices aimed at creating and retaining value for a target user. Therefore, they provide a roadmap that guides the collection, use and dissemination of resources to impact on a specific set of users. In the case of climate services, appropriate business models may act as market signals and provide the most adequate means to overcome future and potential barriers.

We conducted semi-structured interviews with 32 climate services providers in Europe. Our sample is constituted by private firms, consortia members of past and ongoing projects funded under different research and innovation programmes. The semi-structured interviews were guided by a set of predefined questions but service developers were left to unfold their own narratives. We used the Business Model Canvas to frame the analysis and split the text corpus into nine components, grouped in three macro categories: Value Proposition, Value Network and Financial Structure. We revised the standard version of the BMC to include one additional macro category that includes Barriers climate services face and Opportunities they may want to exploit. A quali-quantitative approach was used to (i) analyse the content of the narrative (Content Analysis) and (ii) to assess the role of different concepts in shaping the set of strategic choices managers have been and are doing (Network Analysis). Our paper represents one of the first attempts to explore business models for climate services. We found that, despite the wide contribution of public funding (at European, national and regional level), private actors are those concerned with the financial structure. This highlights a certain lack of sustainability in climate services provision and a relatively short-looking attitude towards the delivery of climate information. Consequences of such a negligence may be relevant when it comes to the sustainability of projects about climate services: a careful business plan is required to support the

[5] Extracted from the interview with WRI.

[6] Extracted from the interview with Amundi.

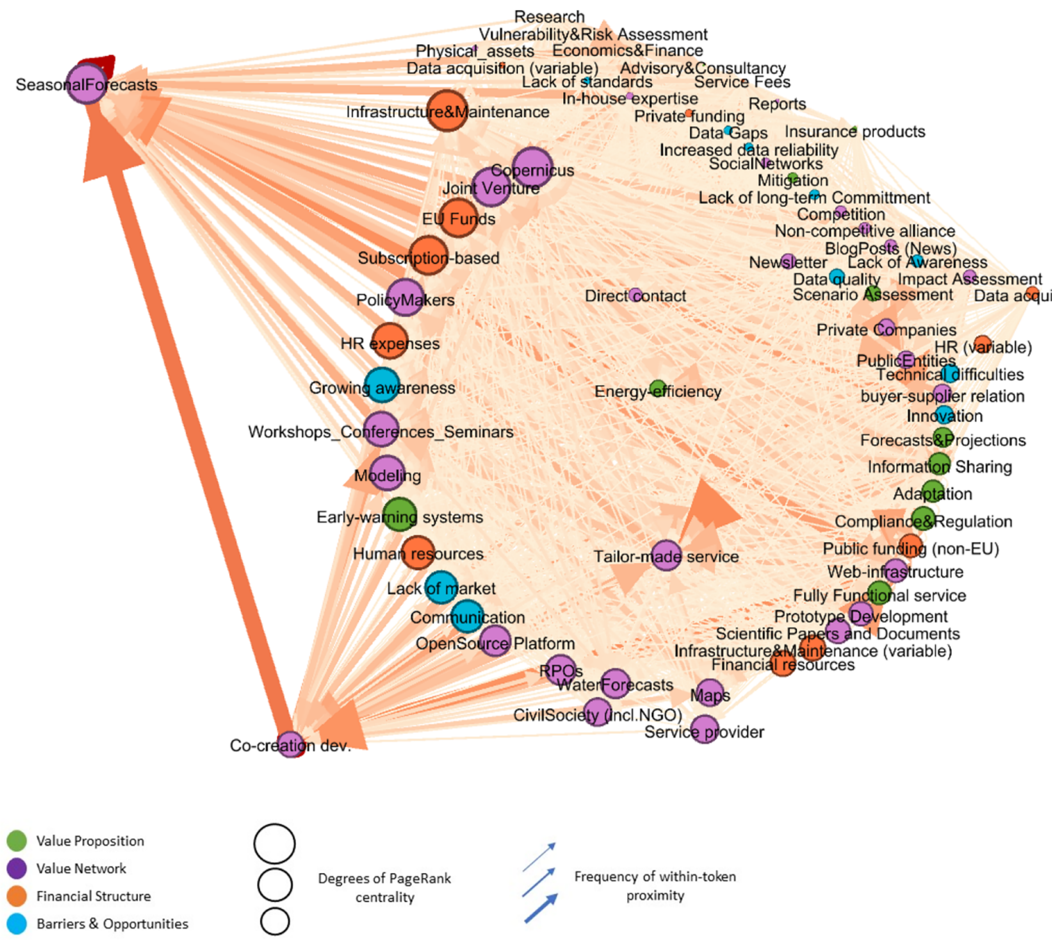

Fig. 10. The giant component.

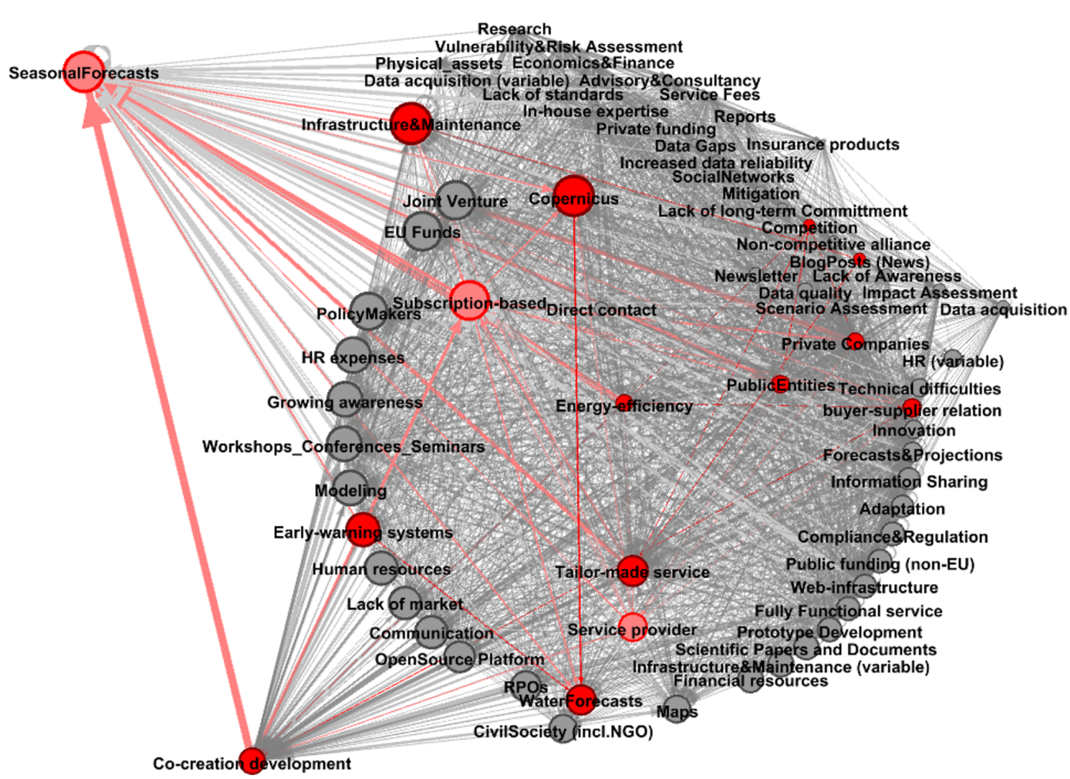

Fig. 11. A subscription-based business model.

research phase. We acknowledge that efforts toward this direction have been made: multiple public funding schemes (such as the European Horizon2020) are now stressing the importance of a business logic when applied to new forms of climate innovations.

We found that, among the components of the BMC, the Value Network received the majority of attention. This includes not just the Customer segment targeted and the Channels used, but also the range of stakeholders involved in every phase of climate services provision. The creation of consortia of partners is essential to enhance the existing in-house resources and to foster innovation: by pooling together competences and expertise, agents can fill their gaps and engage in a mutual learning process. This holds for both research-dominated components (such as modelling and framework creations), as well as for business-related aspects (e.g. marketing and budgeting). Boosting these forms of exchange is key to design, create and spread climate innovation. Interestingly enough, the Value Network plays a significant role for both projects and private firms (Fig. 8).

Our quali-quantitative approach exploited both Content Analysis to extract information about the most mentioned concepts and Network Analysis to provide insights on the links between different codes. By integrating methodological proposal from theoretical (Paranyushkin, 2011; Carlson and Wilmot, 2006) and empirical (Paranyushkin, 2012) research, we offered an innovative approach to analyse qualitative textual information. We elaborated a chronologically-consistent map of codes based on the way they appeared in the transcription of the interviews. Codes formed a directed weighted graph of 70 nodes and 1892 connections. The size of each node was attached to their PageRank score, a measure that builds upon the importance of the code itself and their direct neighbours. Relationships, rather than simple frequency of mention, acquired significance and offered new insights to the Content Analysis.

Results include a tight and direct connection between some crucial concepts. The direction of these relationships provides the opportunity for some policy-relevant and business-related considerations: (i) The role of co-creation in supporting climate services is directly impacting on the generation of seasonal forecasts (by connecting partners within the same consortium), but it also serves as mean to deliver tailor-made final services. Results are widely driven by the sample composition, but climate services projects connected to seasonal forecasts still constitute less than half of the overall interviewees, while findings are strongly indicating the dominance of co-development. We found that – on average – climate services provision is mostly working online through a subscription-based mechanism. This holds particularly for Energy, Water and Disaster Risk Reduction domains and it is a crucial resource when delivering seasonal forecasts. A tailor-made online platform is found to be suitable for both public and private actors, through the direct communication between service provider and target user. In this sense, business models can serve as enablers to overcome barriers and identify opportunities.

Despite the novelty of the approach we hereby proposed, we acknowledge some crucial limitations that leave room for future research. The sample used for this work did not aim at being representative of the population of climate services providers. This is due to a time restriction and to a lack of a comprehensive and detailed database of climate services operating in Europe. However, we tried at the best of our possibilities to interview a set of heterogeneous actors in order to collect the widest possible set of information and capture variety. The sample of climate services provision has the potentiality to alter the results and to drive conclusions. Nonetheless, we do not aim at offering a universally valid characterisation of business models for climate services, but rather some explorative insights to stimulate the debate around this topic. Second, to perform our Content Analysis we employed an "open coding" procedure. This is justified in the case of explorative research but builds upon a subjective judgement that the coder has to take. This open remark may be solved through the consultation of experts in the field, who can revise the chosen codes and suggest alternatives. It is worth mentioning that a certain discretion will always be part of qualitative methodologies, especially in presence of small samples. Finally, the use of Network Analysis is based on the way codes were linked. The methodology has been adapted from insights provided by recent literature (Bodin, 2012; Paranyushkin, 2012; Paranyushkin, 2011; Carlson and Wilmot, 2006). However, it requires further validations and additional checks to reach robustness.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2019.100111.

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