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Free innovation in online communities: the case of tech4COVID19

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Abstract

Virtual innovation communities provide an online platform for users to join in free innovation activities, communicate product experiences, and cooperate with each other. The innovations created in these community interactions take years to be developed, allowing extended periods of communication, gradual community creation, and innovation diffusion. Other communities are being established to respond to demands during an emergency, in which time spans, motivations, and diffusion mechanisms might be different from the usual communities, with a prime example being the current COVID-19 pandemic. In the existing studies, there is a lack of analysis of these communities thus in this dissertation the previous knowledge about virtual communities and their innovation processes were tested and confirmed whether it is applicable in this pandemic circumstance and what differences could exist. So, the aim of this study was to understand how and why virtual hybrid communities innovate with the purpose to deal with urgent societal issues. To achieve this goal, an in-depth case study was selected, the tech4COVID19 community, and three embedded case studies that were explored. Interviews with community initiators and participants were conducted, a podcast was analysed and a "netnographic" approach was applied in the online community. Based on this data, the motivations of participants were mainly centred on self-rewards with no short-term profit ambitions. Moreover, the knowledge diffusion freely occurred only through virtual platforms and virtual meetings, reducing the impact of physical and relational distance. These new forms of interaction allowed projects and innovations to be developed, reducing a possible impact of the absence of face-to-face interactions. But this type of community presented differences compared to the usual hybrid online communities, for instance, the shorter response time/sharing of ideas, participants' identification, the fast allocation of volunteers to projects and tasks and the participation in the community was connected to the area of participants' entrepreneurial for-profit activities. All these divergent characteristics are justifiable by the urgent character of the analysed community.

Resumo

As comunidades de inovação virtual constituem plataformas online que permitem aos utilizadores participar em atividades de inovação, partilhar as suas experiências com o produto e cooperar uns com os outros. As inovações criadas nessas interações levam anos a serem desenvolvidas, permitindo longos períodos de comunicação, a criação gradual da comunidade e difusão da inovação. Outras comunidades estão a ser estabelecidas para responder às necessidades que surgem durante uma emergência, em que intervalos de tempo, motivações e mecanismos de difusão podem ser diferentes das comunidades habituais, sendo a atual pandemia COVID-19 um excelente exemplo de situação urgente. Nos estudos existentes, a análise das comunidades com caracter urgente está em falta, portanto nesta dissertação os conhecimentos prévios sobre comunidades virtuais e seus processos de inovação foram testados nesta situação pandémica. Assim, o objetivo deste estudo foi compreender como e porque as comunidades híbridas virtuais inovam para superar questões sociais urgentes. Para atingir esse objetivo, selecionámos um estudo de caso aprofundado, a comunidade tech4COVID19, e três estudos de caso incorporados. Foram realizadas entrevistas aos iniciadores e participantes da comunidade, o podcast da comunidade foi analisado e uma abordagem "netnográfica" foi aplicada na comunidade online. Com base nestes dados, verificou-se que a motivação dos participantes era centrada em benefícios pessoais. Além disso, a difusão do conhecimento ocorreu por meio de plataformas virtuais, que reduziram o impacto da distância física e relacional. A reduzida interação pessoal mostrou-se com pouco impacto. Ademais, a participação na comunidade estava ligada à área das atividades empresariais com fins lucrativos dos participantes. Mas este tipo de comunidade apresentou diferenças em comparação com as comunidades online híbridas tradicionais, por exemplo, apresenta inferior tempo de resposta/partilha de ideias e conta com a identificação e alocação de voluntários para projetos e tarefas. Todas as características divergentes justificam-se pelo caráter urgente da comunidade.

Códigos JEL: L39, O31, O33, O36, 039

Palavras-chave: Inovação livre; Comunidades híbridas virtuais; inovação de utilizador; COVID-19; tech4COVID19

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1. Introduction

Since the beginning of 2020, we have been facing the COVID-19 pandemic that has affected all countries in the world. This pandemic highlighted the importance of knowledge and innovation to deal with fast-paced and extreme events (which are likely to keep occurring in the future) (Friedman, 2020; Ross, Crowe, & Tyndall, 2015). Knowledge production escalated (Mendes & Carvalho, 2020) and previous technologies and competencies were recombined, in partnerships that crossed the world. The most popular example is perhaps the development of vaccines, but there are many more – including projects to develop open-source ventilators (Mok, 2020; Pearce, 2020), prevention solutions, humanitarian assistance, digital platforms to connect patients, vulnerable groups, and all sorts of providers, data analysis, goods delivery solutions, among others (Budd et al., 2020; Renu, 2021; Wang, Su, Zhang, & Li, 2021).

The way innovation occurs for vaccine development, pharmaceuticals, and medical-related innovation is well understood in innovation economics and innovation studies (the actors, the incentives, the processes, the knowledge protection methods, the ways of reaping profit, etc.) (Bianchi, Cavaliere, Chiaroni, Frattini, & Chiesa, 2011; Malerba & Orsenigo, 2015). However, the process is unclear for other sorts of innovations, in which innovators may have wider motivations than profit, experts and amateurs, which are geographically dispersed, interact and organize in virtual communities (von Hippel, 2017b).

In the literature, there are studies analysing how the knowledge exchange and collaboration practices in online communities lead to valuable knowledge that result in innovations, namely in the so-called virtual hybrid communities (Grabher & Ibert, 2014), encompassing professional and lay users around issues of common interest. These communities appear to create relevant knowledge even in the absence of physical or relational proximity between participants, actually making "distance an asset" (Brinks & Ibert, 2015). Moreover, these communities are valuable to make knowledge circulate, and innovation diffuse (Meelen, Truffer, & Schwanen, 2019).

Yet, to our knowledge, no study has yet addressed how virtual communities of users and innovators are organized in emergency cases. Usually, users interact and develop valuable knowledge on the basis of their long-term personal interests (Meelen et al., 2019)

but when there are urgent societal needs such as those caused by the COVID-19 pandemic, the interaction between users must be fast-paced for solutions to be found and quickly solve the need. Such a context may have implications in the organization and management of the community, the actors involved, and it is unclear whether there may be advantages or hurdles related to online communication in the absence of (physical and relational) proximity. Moreover, how innovation projects articulate with other for-profit ventures of their proponents is still unclear as well as the implications associated (positive for diffusion or negative).

This dissertation aims at exploring this literature gap and understand how and why virtual hybrid communities innovate with the purpose to deal with urgent societal issues. It seeks to analyse the extent to which previous literature findings apply in a new context, and what are the differences when the innovation setting changes from a long-term (purpose and engagement) towards an urgent societal issue, requiring fast solutions. Therefore, it explored: i) the (profit and non-profit) motivation of participants to engage in this type of virtual communities and innovation projects; ii) the types of knowledge produced and learning dynamics taking place in these communities; and iii) how and why users combine their participation with other eventual entrepreneurial for-profit projects. Understanding these issues is important not only for the literature but to understand the conditions under which these types of communities fail or succeed in developing and diffusing innovations.

To achieve these aims, the tech4COVID19 community was selected to be analysed. The tech4COVID19 (tech4covid19.org) was a Portuguese community created by a group of founders of technology start-ups and has been joined by nearly 4.000 organizations, and more than 5.000 volunteers who gathered to respond to various needs that emerged during the fight of COVID-19 pandemic. It was active from March to December 2020. The founders were mostly from the Porto region but, the community had members (professionals and amateurs) from many other places, including from outside Portugal. Several initiatives were developed by these volunteers, including new apps and support or prevention services.

The present work is structured as follows. The next section reviews the literature on "free innovation" (vs. "producer" innovation) and virtual communities. In Section 3

the research methodology is described. Then, in Section 4, the discussion of the results is presented. Finally, in Section 5, the conclusions that result from this work are presented as well as future work.

2. Literature Review

2.1. Free innovation

Virtual communities can be a platform for users to contribute to innovation processes, share their product experiences, and cooperate with each other. The types of innovation originated in these communities resemble what von Hippel called free innovation, in contrast to the so-called producer innovation, that derives from the Schumpeterian tradition (von Hippel, 2017a; Yang, 2020).

Free innovation is the designation assigned to new functionally products, processes, or services that:

(1) have been developed by users, who assume all costs, during their unpaid free time (i.e., who have not been paid for this);

(2) are not protected and therefore can be acquired by anyone without payment (for free).

Thus, free innovations are all innovations designed by users, who developed them to use and fulfil a personal or community need and not for the purpose of selling and profiting from them. User-led innovation has increasingly shown its importance. Users have an important role in the development and improvement of innovations. In fact, users have been the original source of many innovative ideas which have later been taken up and developed to scale by manufacturers. The idea that users innovate has proved of utmost importance and has helped several types of organizations, such as Valve Corporation, video game development firm, and several bike producing firms, to become more innovative by using the design and ideas of free innovators (de Jong, Gillert, & Stock, 2018; Hopper & Torrance, 2019; Tabarés & Kuittinen, 2020; von Hippel, 2017a).

According to von Hippel (2017), the free innovation paradigm is fundamentally distinct from the traditional Schumpeterian producer innovation paradigm (Figure 1). The

paradigm of free innovation, which is represented in dark grey in Figure 1, begins with "self-rewarded developers" who are pioneer users using their unpaid free time to develop products, processes, or services to solve a personal need (von Hippel, 2017a). Users turn out to be one of the most important sources of innovation in many organizations. With the introduction of this kind of innovation, the traditional mode suffers changes and consequently, leads to more competitive advantages (Antorini & Muniz, 2013; Fuchs & Schreier, 2011; Gambardella, Raasch, & von Hippel, 2016). The contribution of users is especially important in the stages of product creative thinking and prototyping because they can support and accelerate these phases (Chang & Taylor, 2016).

As shown at the centre of the free innovation paradigm arrow, users can contribute to improvements in the initial design (interaction with the producer innovation paradigm). Free innovations can complement the innovations designed in the producer innovation paradigm being valuable not only to users but also to producers. A textbook example reported by von Hippel (2017) is the Nightscout project, which is an open-source software, that monitors blood sugar levels during the night, created by parents of children with type 1 diabetes. This project has continued to be developed, maintained, and supported by volunteers that joined the project's initiators (Nightscout, 2016; von Hippel, 2017a, 2017b). Moreover, a free innovator may have a more essential role since its developed design can *spill over* to a producer and become the basis for a product with better revenue (de Jong et al., 2018).

At the right end of the free innovation paradigm arrow, arises the free diffusion of unprotected designs and knowledge via peer-to-peer that can reach "free riders", who are the individuals that benefit from an innovation but do not contribute to developing it. This pattern of diffusion to "free riders" was also identified in the Nightscout project, and in many others. Nowadays it is common to find free innovations and product designs widespread often via the Internet. In the case of Nightscout innovations, these were transferred outside of markets via Internet-based free modes. Other open-source software and hardware, such as Steam Workshop – an online repository where player-created content and tools for games can be found –, have been diffused in the same way (Hopper & Torrance, 2019; von Hippel, 2017a).
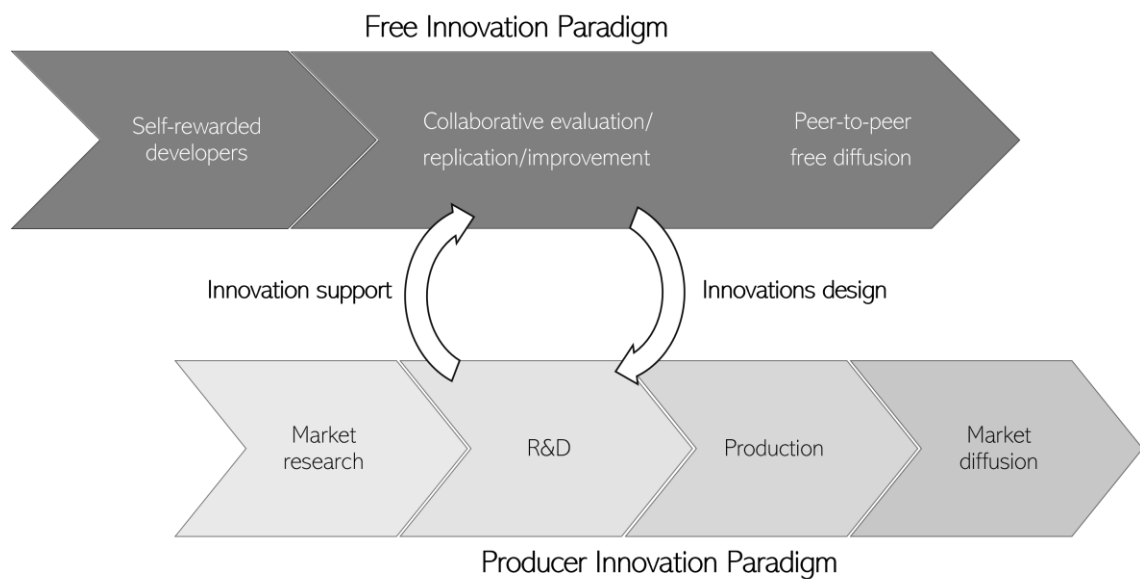
Figure 1. Interaction between the free innovation paradigm and the Schumpeterian producer innovation paradigm. Adapted from (von Hippel, 2017a).

Currently, there is a substantial number of free innovations in modern economies. Eric von Hippel studied six countries and showed that ten million individuals in the household sector – consumers/users – collectively apply ten billion dollars annually to create or improve products for personal use (Chen, Su, de Jong, & von Hippel, 2020; von Hippel, 2017a, 2017b). There are examples of these innovations in various areas such as medical, sports, computing, and gaming (von Hippel, 2017a).

Interactions with producer innovation paradigm

In opposition, in the traditional Schumpeterian producer innovation paradigm, the development and dissemination of innovation are carried out by entrepreneurs and paid employees, who are remunerated depending on the profit. As shown in the light grey arrow in Figure 1, producer development projects begin with the identification of a potentially profitable market by exploring unmet needs (demand-pull). Subsequently, there is the investment in R&D to develop a new product, process, or service that is the solution to the identified need. Finally, there is the production of innovation and its protection and diffusion in the market (Hopper & Torrance, 2019; von Hippel, 2017a).

This paradigm may yet interact with the paradigm of free innovation (upward-pointing arrow at the centre of Figure 1) since producers can provide valuable information and support free innovators for example through technological environments, knowledge, toolkits, and innovation contests (von Hippel, 2017a). There is also a potential link between the free innovation paradigm and the producer innovation paradigm (downward-pointing arrow at the centre of Figure 1). The spill over of free projects information (developed by the users) to producers can occur. In this situation, producers can freely use the designs they consider profitable and commercialize them, as illustrated above, in the textbook cases of bike design and videogames. Research shows that these spillovers can be extremely advantageous notably by increasing the value of the company, increasing sales revenues, and increasing product lifecycles (von Hippel, 2017a).

2.2.   Virtual communities: user and hybrid communities

Recently, many free innovations have emerged from virtual user communities, where these innovators share their experiences and opinions, express their needs, and cooperate with each other to find solutions. Being in the Internet age, the share among community participants has been facilitated. Online sharing is thus easy, fast and allows users to reach many other geographically dispersed participants.

Online user innovation communities, or virtual user communities, are being established as online informal groups of individuals that when interacting with each other, manage to create knowledge and improvements' ideas (Brinks & Ibert, 2015; de Jong & Flowers, 2018; Grabher & Ibert, 2014; Janzik, Herstatt, & Ieee, 2008; Yang, 2020). Additionally, another type of virtual community has been classified as a promising tool: hybrid virtual communities. This type of community is distinguished because it includes not only users but also semi-professionals and experts (Grabher & Ibert, 2014). Examples from the literature are the "Sandboarder Forum" which brings together sandboarders, "Nikonians" which brings together photographers with Nikon camera equipment (Brinks & Ibert, 2015), and "Tesla Motors Club Forum", where people interested in electric vehicles share their experiences and doubts (Meelen et al., 2019).

Within the community, users freely express their needs/problems or solutions already created, encouraging others to reflect on their own experiences and build

solutions. Although not-for-profit-orientated, there is evidence that innovative solutions and products and relevant knowledge can be created in these communities (Brinks & Ibert, 2015; de Jong & Flowers, 2018; Janzik et al., 2008; Yang, 2020). According to Grabher and Ibert (2014), the types of product-related knowledge shared and created in these communities can be from different domains, but the three most common are procedural knowledge, usage knowledge and design knowledge. Procedural knowledge refers to the users' ability to find, for example, new ways to organize and store data for joint use, ways to overcome software incompatibilities, among others. In the case of usage knowledge, this refers to the knowledge gained after using a certain product for some time, for example, a photographer can share his knowledge in a community of a certain camera after having photographed a lot with it. Finally, design knowledge is the type of knowledge that may require more product know-how from users. This knowledge requires the participant to know well how the product works, for example, a platform, to know how its constituent acts and what its purpose is. All these types of knowledge can be transmitted to integrated newcomers, who are guided by more experienced members who share their expertise freely. While not primarily target with that aim, these communities can yet generate economic growth since members can found businesses and create new jobs or commercial profit (Brinks & Ibert, 2015). From users' interactions in the community, collective knowledge is developed which can be accessed by any user and organizations' employees. In contrast, in traditionally innovative organizations, the available knowledge is generally only accessed by the product development teams of those organizations.

The potential of some virtual communities for innovation and knowledge diffusion has been recently studied in a community for users of electric vehicles. Meelen et al. (2019) showed that this hybrid community had distinct characteristics such as strong community sense, a wide diversity of participants ranging from hobbyists to professionals, and different levels of knowledge about electric cars. Community members were able to contribute through different mechanisms. Digital technologies have facilitated knowledge-related activities as well as their sharing by the community. Moreover, users contributed to the development of shared rules, for example in the way vehicles should be used, and to the upscaling process. These contributions result in empowering users and stimulate the creation of more ideas what can become a challenge

among members. Some users of this community have even contributed to the development of infrastructures, namely by lobbying for chargers when individuals go on holidays (Meelen et al., 2019).

The (geographical and relational) distance of community members

An interesting aspect about these communities is that contrarily to other (place-based) innovation ecosystems for long described in the literature (Moulaert & Sekia, 2003), participants often never met personally and are geographical and relationally distant (Grabher & Ibert, 2014). Community members may be dispersed across different geographical areas and so an important question was raised regarding the way these communities could collaboratively create new knowledge when their members are often physically separated. Proximity has been recognized as the most advantageous condition for knowledge collaboration (Brinks & Ibert, 2015; Meelen et al., 2019). However, these collaborative activities are not dependent on permanent physical proximity, because knowledge has also been produced in conditions where there is no proximity at all, whether physical or relational (Grabher & Ibert, 2014). Distance could indeed be a factor affecting the knowledge transfer between members, but the Internet and social media can still enable the connection of like-minded individuals across significant geographical distances (Brinks & Ibert, 2015; Meelen et al., 2019). This easy virtual interaction is suggested as a promising way to overcome some limitations of traditional local innovation communities (such as the limited collaboration with other product users who may have relevant and solvable ideas and suggestions).

Grabher and Ibert (2014) go as far as to suggest that the condition of distance in these online communities – i.e persons that do not interact face-to-face and never socialized before – can even be seen as an "asset" for innovation. This is due to unique qualities such as:

(1) members of virtual communities are quasi-anonymous (i.e., members have the possibility to maintain a private identity). This status is only suspended at the user's will. Thus, contributions are valuable per se, regardless of whether the anonymous user has professional expertise or not in the topic discussed;

(2) Online interactions are characterized as being simpler than face-to-face communications. Moreover, relationships between users are often informational only, that is, interact only with the purpose of developing innovation and share experiences to convert into knowledge;

(3) The participation of users in the community occurs in a cumulative way. Discussions between members remain in the forum for years, and it is possible to consult these topics electronically and trace backlogs of discussions;

(4) The mind-liked participants interact in the long term and have the opportunity to deeply discuss several issues over a considerable period. This time allows "reflective reframing" processes that do not happen in most face-to-face encounters. Additionally, the response time is usually long ("asynchronicity"), giving participants the possibility to reflect on the responses and apply the suggested modifications before answering (Grabher & Ibert, 2014).

Community members' motivations and expertise

Generally, virtual communities participants have different expertise and different product usage experiences, so the topics in which they participate can be distinct (Brinks & Ibert, 2015; Yang, 2020). Users collaborate on topics that they think their expertise is useful for finding the solution. In most communities usually, there are individuals with professional expertise and ordinary users, enthusiasts, and hobbyists (Grabher & Ibert, 2014). Community participants who contribute intensively often receive compensation through gratitude, peer recognition, network reputation, and others (Grabher & Ibert, 2014; von Hippel, 2017a).

Hybrid communities can be divided into different types: communities supported by organizations, communities related to organizations, and independent communities. The first is initiated and ensured by professional producers of organizations. These are responsible for the establishment of an online forum, set interaction rules, and request feedback. Organization-related communities are groups in which interaction guidelines are established by members, however, these communities continue to be dependent on professional producers. These communities are focused on specific products or brands and members share their daily experiences with them. Finally, the last communities arise

without any impulse or assistance from organizations. Members interact only according to their motivations and aspirations (Grabher & Ibert, 2014).

Participants in virtual communities have motivations very similar to those of so-called free innovators. They are mostly motivated by *self-rewards*, i.e., personal non-monetary benefits. These benefits can be enjoyment, learning, self-fulfilment, the feeling of helping others, etc. (Shah, 2006; von Hippel, 2017a). According to the surveys done by von Hippel (2017a), the desire to sell and make money from free innovations is not a motivation for most participants: only 2% consider this a core motivation. (von Hippel, 2017a).

The literature suggests that many community members only intend to share their knowledge with fellow peers not expecting any reciprocal benefits (Brinks & Ibert, 2015). However, there is also evidence that participation may be based on different motives, such as product improvement or its experiences. In addition to self-rewards, the most common motivation for community innovators is to achieve the highest value of a product's experience (Brinks & Ibert, 2015). Although some innovations are ultimately commercialized, as said, this is not the core motivation of most users to participate in virtual communities (Grabher & Ibert, 2014; von Hippel, 2017a).

2.3. Objectives: a summarized view

In most classic entrepreneurship studies, online hybrid communities had a minor role. However, over the years, the contributions of these communities are being increasingly considered. Moreover, as the aforementioned studies suggest, innovation in hybrid communities is still a relatively emergent area of research. Innovations that arise from online hybrid community interactions take years to develop, allowing long periods of interaction, gradual community formation, and innovation diffusion. Nevertheless, other communities are being created to respond to needs in emergency situations, in which time spans, motivations and diffusion mechanisms may differ from the ones previously assessed, with a prime example being the current COVID-19 pandemic.

Beyond vaccines, many innovations are being presented to address other needs that have arisen. In fact, virtual communities have been created with several volunteers with different backgrounds who jointly seek to discover a quick solution (Mok, 2020;

Pearce, 2020). However, there are still no studies to our knowledge that show how these communities with an urgency character are organized, act, what motivates volunteers and what types of knowledge are actually produced. Therefore, this dissertation sets to test the previous knowledge about online hybrid communities and their innovation processes and verify whether they also apply in a fast-paced innovation context and what differences may exist. Furthermore, to our knowledge, this is one of the first explicit studies on free innovation in Portugal. Based on the existing literature, and in the literature gap, this dissertation seeks answers to the following research questions, which can now be underpinned by a set of theoretical expectations:

- o What are the (profit and non-profit) motivations of participants to engage in virtual communities for fast-paced innovation projects?

In literature, it is suggested that the main motivations are personal non-monetary benefits, like learning, enjoyment, self-fulfilment and the feeling of helping others. Given the urgent nature of the projects, we expect participants to be primarily motivated by enjoyment, self-fulfilment and the feeling of helping others. Learning is not expected to be one of the main motivations since the remaining motivations are the most aroused during an emergency situation. Moreover, due to the speed of the development process, much time to learn new skills is not expected.

- o Which types of knowledge and learning dynamics take place in these communities? How does physical and relational distance favors (or hampers) innovation?

Due to the urgency of the community, it is expected that some of the knowledge creation processes that require more time to mature will not take place. On the other hand, the creation of knowledge that leads to relevant innovations is expected to turn out to be more selective and it needs interaction modalities similar to face-to-face methods. Furthermore, the collective knowledge is expected to be available to every participant in the community (the ability to absorb it being, naturally, dependent on their previous knowledge and competencies).

- How and why free innovators combine their participation with other entrepreneurial for-profit activities?

As the innovation objectives had to be quickly achieved, members are expected to participate in the areas in which they feel most comfortable/which they dominate. This being so, community members would not "waste" time learning new skills and could develop technological innovations in a shorter period. Thus, a connection between participation in the community and for-profit/professional activity of the participants can be expected Moreover, innovation activities may awaken the entrepreneurial spirit of the participants and trigger new partnerships and new for-profit ventures.

3. Research setting and research design

3.1.   Research setting: the tech4COVID19 community

For exploring this literature gap and better understand the motives and the ways virtual hybrid communities innovate to deal with urgent societal issues, this dissertation conducted an in-depth case study, focused on the tech4COVID19 community and on three specific innovation projects within. There are several advantages associated with this method for the purpose of this research. Namely, and according to scholars such as George & Bennett (2005), it provides great potential to achieve high conceptual validity, allows to explore under-researched and contemporary phenomena and understand the motivations, processes and causation mechanisms that explain the phenomenon in question (free innovation) (George & Bennett, 2005).

In-depth case study: tech4COVID19

We have selected a specific online community to be our in-depth case study: the tech4COVID19 community (tech4covid19.org), which is strongly representative of the phenomena under analysis (Durães, 2020). This community was created by a group of entrepreneurs from Founders Founders, which is a community of entrepreneurs organized to share office space in the city of Porto and common services that promote the development of start-ups in the digital area, peer-to-peer help and the circulation of knowledge among entrepreneurs of fast-growing companies. They intended to put their skills at the service of meeting the various urgent needs that have arisen since March 2020 in the fight against the COVID-19 pandemic, and thus launched tech4COVID19 community. This community brought together 5.628 volunteers (Figure 2), mainly Portuguese, who were engineers, scientists, designers, marketers, health professionals, among many other specialties (Figure 3), motivated to develop technological solutions that could help the world population overcome the challenges posed by COVID-19 and all its societal consequences.
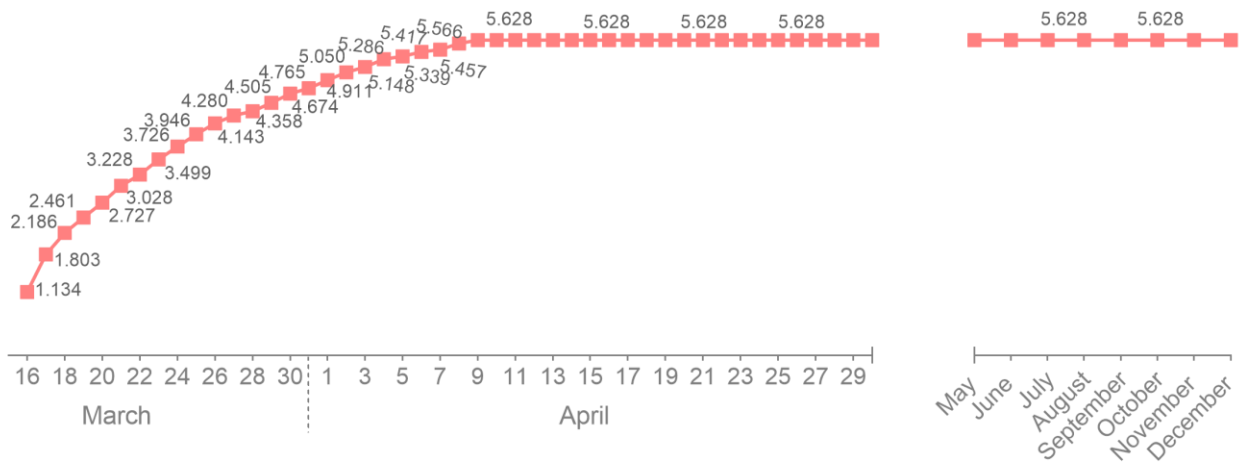
Figure 2. Evolution of the number of volunteers in the tech4COVID19 community between March 16 and December 2020.
Source: tech4COVID19 community website.

Anyone who wanted to participate could join the community through the website or be invited by volunteers who have already been members of the community. Within the community, the new volunteer was allocated to a particular project depending on their background, skills, and needs of the project. This allocation of volunteers to different projects was carried out by a group of initiators designated as "Coordination". Already integrated in a project, the newcomer could volunteer for any of the tasks in progress.

Due to the (physical and relational) distance between the participants, "Slack" was chosen as the communication platform. "Slack" is a software, which has been increasingly used worldwide as a business communication platform, developed by American software company Slack Technologies. This platform was selected because it not only allowed the virtual communication and sharing of ideas among volunteers but also allowed the creation and management of the several projects and allocation of volunteers.

Figure 3. Competences of the participants of the tech4COVID19 community. This is a result of a survey, which was created by the Coordination, in which newcomers had to select competences he/she believed to have. The category selected by most participants was "Project Management/Generalist/Project Management", which includes the organization of projects in companies and management of product-related issues. It also includes the more general skills such as communication, leadership, critical thinking, problem solving, among others.

Source: tech4COVID19 community website.

New projects, at an initial stage, were classified as "prospects", i.e., they were the beginning of an idea to solve a problem. The idea presented by one of the volunteers, who was later considered the "initiator", was jointly discussed and evaluated by several community members with interest in participating in the project. After this initial discussion, if the idea was considered with potential, a developing team was organized. The idea and initial team were later presented to the Coordination and if they considered it a good solution to the problem, the group received approval and was considered a "project" in development. These projects were later developed in record time and when ready to be used, they were presented to the public through the social media of the tech4COVID19 community.

The community ended in December 2020 but from this community, 33 solid projects emerged, resulted from the more than 600.000 online messages exchanged among members. In addition, the tech4COVID19 community included the participation of 3.882 organizations.

This group of organizations already includes companies/institutions associated with volunteers (e.g., where community participants work), which were about 250 different organizations, including Farfetch, Siemens, University of Minho, among others (Figure 4). The organizational origin of the participants was known as, over a period, the registration form included a question to determine the company where the volunteers work.
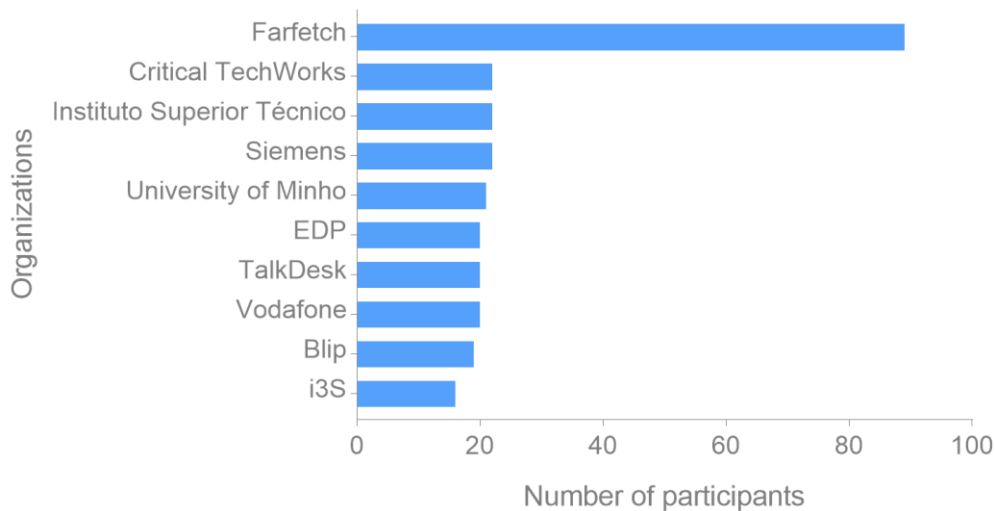
Figure 4. Organizations with more workers participating in the tech4COVID19 community.

Source: tech4COVID19 community website.

Moreover, all messages, material, designs, logos, etc were left available and editable by everyone.

Considering all its features, the tech4COVID19 is classified as a virtual hybrid community since its form of communication was mainly mediated by communication tools provided by the Internet and encompasses professional experts in technologies, laypersons, and enthusiasts, working around common objectives. Furthermore, this was an independent community since it started and evolved without the impulse or support of professional or commercial organizations. Although the initiators at the genesis of tech4COVID19 belonged to a formalized community of entrepreneurs, it did not support explicitly or institutionally, nor were the discussions related to the specific issues of that community.

As shown in Figure 2, there was a large increase in the number of volunteers in the community at the beginning of its creation, then gradually increasing up to 5.628 volunteers, where it stagnated. This value was reached on April 11, 2020, almost a month after the creation of the community. From mid-April, the number of volunteers was no longer counted as the community started to have less demand and fewer COVID-related problems to solve. The initial rapid growth was due to the urgent character of the community and early enthusiasm, i.e., there was a need for rapid creation of technological solutions to the various new problems raised by COVID-19 (e.g., medical support; food delivery; education from home; quarantines; lockdowns) so at this stage, many of the new members were invited by the already members of the community. This invitation was due to the need for people with certain abilities, and community members who knew people with these abilities made the invitation.

The community decided to formally end when its objectives were achieved, i.e., when there were fewer pandemic-related issues to be solved and/or when the solutions developed were no longer in demand and the enthusiasm petered out. Conversations on the platform are still online, and it is still possible to add new conversations, but the community is no longer managed. It was officially registered as an Association and, at the time of this research, the process of official termination of the association was being finalized.

3.2. Research design: embedded case studies and methodological procedures

The community launched 33 projects (Figure 5 and Table S1, SI appendix), many of which were successful, i.e., were developed, reached the public and helped to overcome a specific problem. Here, a project´s success is not assessed through profit, but it is considered successful if the innovation solves the problem presented, that is, if other people consider it useful and use the solution. Hence, within the broad community, and in order to deepen and strengthen the analysis, we selected two of these successful projects and one unsuccessful project that were analysed in-depth (embedded case studies). The separate, comparative analysis of the projects was not intended, but instead, we consider all the information together to shed light and explore the issues raised in the

research questions. Following an initial exploration of a set of community projects, projects were chosen according to the following criteria:

(1) They were finalized or close to completion, i.e., a viable solution has already been developed and diffused to the public outside the community.

(2) They allow the analysis of the desired dimensions under study.

(3) Projects have a considerable number of contributors, which were the community members in the project, from different backgrounds. It should be noted that we are aware that only considering two successful projects and one unsuccessful project can be a limitation in the work.
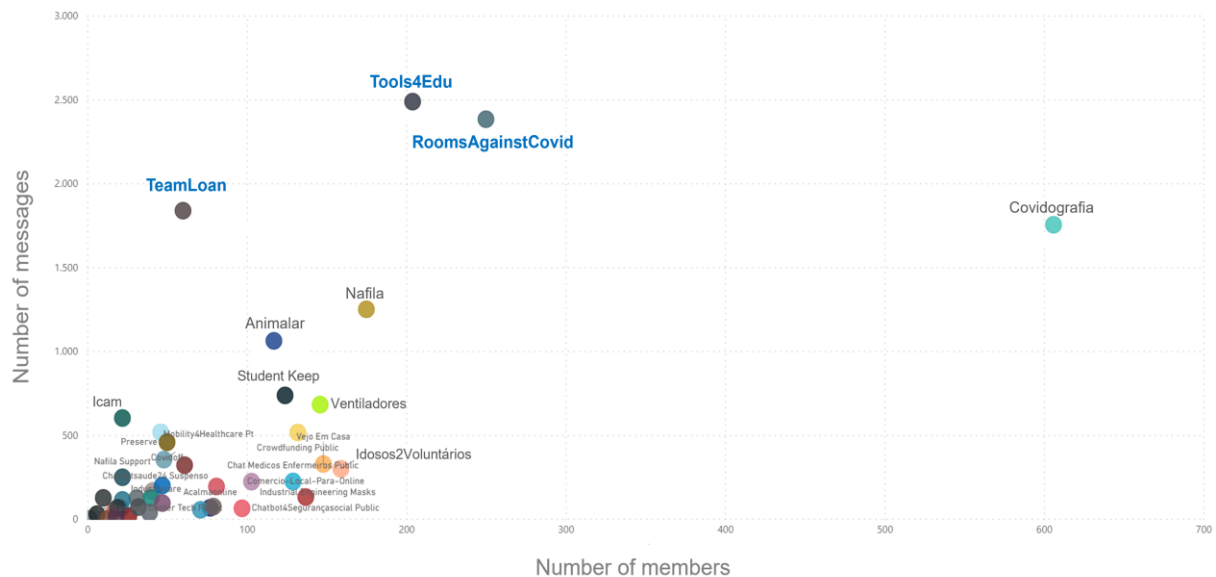
Figure 5. Relation between the number of messages present in the project channels and the number of volunteers in the project. The projects analysed are identified in bold and blue.

Source: tech4COVID19 community website.

Project 1: RoomsAgainstCovid

The first project to be made available to the public from the tech4COVID19 community was RoomsAgainstCovid (roomsagainstcovid.com). In this project, a booking engine was developed to allow health professionals to book hotel rooms or other touristic accommodations. In this way professionals could stay free in their rooms and thus safeguard their families, not putting them at risk. On the other hand, hotels and

hostels received funding and cleaning of their facilities through this project. This project was initiated by an individual from a start-up in the accommodation field and it was supported by several entities in the tourism sector, such as the Association of Local Accommodation in Portugal (ALEP), Association of hotels, restaurants and similar in Portugal (AHRESP) and Turismo de Portugal that contributed to its dissemination. This digital platform, developed in 8 days, has already been decommissioned in Portugal at the time of this writing but managed to gather more than four thousand rooms and ensured more than 17.000 nights in several parts of the country. RoomsAgainstCovid's success was ensured by the 250 volunteers involved from different countries and with different skills that exchanged 2.382 messages (Figure 5 and Table 1). These volunteers were distributed among the different tasks according to their abilities, taking advantage of these to develop the project quickly. Based on Figure 3, the participants had many different abilities, which was beneficial for the whole process. Volunteers were all responsible for creating the online platform that automatically matched the healthcare professional in need with the accommodation available to him/her. There were several sub-teams; for instance, there was a sub-team responsible for developing the platform, another for designing the logo, and then everyone contributed to the innovation's dissemination in the country, through social media, television channels, among others.

Table 1. Projects selected for the analysis with the number of members on the "Slack" channel and the number of messages exchanged on the channel between March and May.

Project	Members	No. of messages
Roomsagainstcovid	250	2.382
Tools4Edu	204	2.487
Teamloan	60	1.837

Source: tech4COVID19 community website.

This turned out to be one of the most successful projects of the tech4COVID19 movement, having been in the Forbes' news (Bosilkovski, 2020).

In recognition of its success, and as Brazil was dealing with a similar problem, this technological solution spread its wings and reached the other side of the Atlantic Ocean. The Portuguese team in cooperation with the tech4COVID19 Brazil movement implemented this same platform in Brazil, having guaranteed more than 18 thousand nights in hotels and accommodation for Brazilian health professionals. The tech4COVID19 Brazil movement (tech4covid19.org.br) was created by Brazilian volunteers who followed in the footsteps of the Portuguese movement and wanted to be part of the tech4COVID19 movement. As in Portugal, the RoomsAgainstCovid Br project was successful but also ceased activity.

This new online platform, developed by community members during their free time, was not protected and can be acquired by any interested entity. Furthermore, the contributors did not receive any payment for the development and application of this innovation. Therefore, this product can be classified as free innovation. Moreover, due to the success of this finalized solution, its dissemination to the Brazilian community and its considerable number of participants, this project was chosen because it allowed the analysis of the desired dimensions under study.

Project 2: Tools4Edu

At the beginning of the tech4COVID19 movement, another launched project was presented through social media, the Tools4Edu. This project arose to fill an urgent need that occurred with the lockdown abruptly implemented in the first wave of the pandemic. As schools closed, students were left with no alternative to continuing their learning process from home. Digital media emerged as the solution to this problem, however, most students, parents and teachers did not know how to use digital tools and platforms. To solve this problem, community members developed Tools4Edu, a platform to support the Educational Community facilitating the understanding and use of digital tools. Its initial mission was to help make the most of technology to recreate, even at a distance, a productive, rewarding and motivating remote learning experience for learners and educators.

The project was initiated by a Portuguese consultant from an international company who was responsible to organize a team of participants. The team conducted a

national survey to identify imminent needs and started producing tutorial videos about the most used free platforms such as "Zoom", "Teams", "Google Classroom" and "Webex". After that, volunteers, for example with skills in design and in education, continued to explore various digital tools that allow more interactive, creative, and enriching lessons. This project had the participation of about 200 volunteers total who shared 2.487 messages on the project's "Slack" channel (Figure 5 and Table 1) and, unlike the other projects chosen, it is still active. This project remains active because volunteers believe the pandemic is still without definitive control and that the needs of the school community continue to exist. That is why even though Tools4Edu fulfilled its initial mission still within the tech4COVID19 community, the project continues its development to serve the educational community. Nowadays, this still is a very dynamic project, now with 10 volunteers, that promotes mutual help between teachers and tries to increase support for students and guardians. The group of participants has no planned end to the project, and they are still open to the entry of new volunteers with innovative ideas. As with RoomsAgainstCovid, this new online platform is being developed by participants during their free time and it is not protected. Furthermore, the contributors do not receive any direct payment for the development and application of the innovation.

Project 3: TeamLoan

The third project chosen for analysis was TeamLoan. This project consisted of a digital marketplace that was created to minimize the impact of the country's state of emergency, allowing companies to temporarily trade/loan a working team. This was the solution created for several companies dealing with lay-off and unemployment situations, together with companies that have seen their work multiply, without the capacity to respond. TeamLoan was a platform that could serve all companies, of all sizes, regions and all activity sectors affected by the COVID-19 pandemic, such as food and non-food retail, accommodation and restaurants, passenger and goods transport, entertainment, health, and social services, among many others. This platform was initiated by a Portuguese freelance consultant, and it had the support of partners like Morais Leitão, which is a law firm that assumed the role of Legal Partner of the project, contributing to its legal operation. It also had the active participation of entities such as the Tourism

Innovation Centre, the Lisbon City Council, the Confederation of Farmers from Portugal, the Federation of the Portuguese Agro-Food Industry, the National Association of Public Road Transport of Goods, and the Braga Commercial Association, among others. As in the previous projects, all the development of this platform was done in "Slack" and by video call. The project was even presented at the Global Legal Hackathon, a promotional initiative organized by the Financial Times, deserving international prominence. Its replication in other countries was considered as well as its use over an extended period after the end of the pandemic. However, the project ceased in Portugal, but it had more than 30 businesses formally registered and more than 40 employees available to be hired. Despite the great interest, unfortunately, there was no exchange effectively carried out, even one major national retail company was initially engaged, close to initiating a loan and then dropped out.

This project differs from the previous ones because it had fewer volunteers participating in the development, around 60 volunteers, but, nevertheless, it was one of the projects that showed higher participation in its "Slack" channel with 1.837 messages (Figure 5 and Table 1). This high level of participation may be due to the greater interest of volunteers and also due to the various challenges they had to overcome, namely the legal issues. Due to this active participation and as it is complete, this project was chosen for analysis as well. Although this project was developed and made available to society, no trades were registered so we consider this project as not successful for this analysis.

Methodological procedures

General information about the community was available online, so this general data was collected directly from the website developed to support the initiative. This data allowed us to better understand the scope, the projects, the initiators, the geographical dispersion of participants, the results, among others. To a better analysis, we also joined the community to access the discussion forums in "Slack", which are available, and cover, on average, several months of discussion.

The core of empirical data consists of 12 qualitative interviews conducted with community initiators, project founders or co-founders and participants, carried out between May and July 2021. The interviews took on average 30 min. All interviews were

done via telephone, recorded, and transcribed verbatim. This form of interview can have methodological limitations such as low freedom to explore the issues, something that in a more personal interaction would not affect in the same way. Moreover, all interviews were conducted in Portuguese and organized around the core domains of the research (motivations; the role of distance; the relation between free vs. for-profit initiatives), and followed standard methodological procedures (Rapley, 2001). The interview script is featured in the Supporting Information (SI) appendix.

In addition, to understand the motivations for engaging and initiating this type of online community, and how participants combine their participation in projects with other for-profit entrepreneurial activities, beyond the semi-structured interviews with community initiators, four episodes of the voice4COVID19 podcast were analysed. This was the podcast of the tech4COVID19 movement, created by community volunteers from the audio-visual area, and served for initiators or volunteers to join and talk about the story of the projects and their development. In addition, it was another way to spread the several innovations created by the community. Four of the episodes were analysed and transcribed, namely #1: The beginning of the Portuguese technological movement against the pandemic; #2: Rooms Against Covid; #5: Digitize Portuguese education and #7: TeamLoan: The innovative temporary team sharing solution. The episodes last on average 30 min and were conducted in Portuguese by other members of the community. Episodes are available on Spotify. Based on the insight of the interviews to the community initiators, podcast episodes and the analysis of existing project logs, three projects were chosen, and their initiators and most active participants were interviewed.

Due to the high relevance of virtual communication tools in the tech4COVID19 community, we decided to incorporate "netnographic" elements into our research design. Netnography is a research method that allows the conduction of traditional ethnography techniques over the Internet. This qualitative approach is based on the observation and participation in the activity and discussion, for instance, in online forums, in order to understand how participants (inter) act, share experiences, doubts, etc. (Kozinets, 2010). Moreover, in order to analyse the types of knowledge and learning dynamics that occur in the community and the role of distance among participants, a "netnographic" analysis was performed on the selected projects (embedded case studies). In this dissertation, the threads and subsequent discussions in each forum were collected and afterwards codified

and analysed using NVivo 12 software (Figure S1, SI appendix). This software was applied to centralize data from multiple sources and formats, such as interviews, research results, forums discussions, articles, and to make deeper analyses. Also, this software allowed to deepen the analysis (coding, queries, visualization) and identify differences, similarities, and connections between collected data. As recorded in studies on other online communities, in quantitative terms, most community members (about 80%) only read what is going on in online forums (Grabher & Ibert, 2014). Participants were informed of the researcher's presence and our intentions to explore the community through contact with the community Coordination. For the purpose of this research, the personal information of all the users was anonymised.

The collected data (both from interviews, online forums, and podcast episodes) was coded and analysed along the dimensions of interest: types of motivations; advantages of distance; relations between free and for-profit innovation – departing from categories identified in the literature. It sought to verify if the theory also applied in this community with an urgent purpose. Insights and evidence from interviews to initiators and participants, logs from "Slack" channels and interviews from the podcast are cited according to the abbreviation in Table 2. For example, an interview (I) to a participant (P) of TeamLoan (TL) project is mentioned as IPTL, with the adjacent number (for instance IPTL2) corresponding to the sequential order of the interview within the whole set.

Table 2. Types of data analyzed.

Data source	Coordination team (C)	RoomsAgainstCovid (R)		Tools4Edu (TE)		TeamLoan (TL)	
		Initiators (I)	Participants (P)	Initiators (I)	Participants (P)	Initiators (I)	Participants (P)
Interview (I)	3	1	2	1	2	1	2
Logs (L)	-	2.382		2.487		1.837	
Podcast (PD)	1	1		1		1	

Source: Own elaboration based on fieldwork.

4. Empirical results and analyses

4.1. Motivations of community members

To identify the types of motivation of community members, interviews were essential. All interviewed participants declared and explained that their participation was strongly driven by intrinsic motivations. As for other online communities (Brinks & Ibert, 2015), these motivations were considered self-rewards that included the feeling of helping others, self-fulfilment, and enjoyment. None of the expressed motivations included for-profit reasons. All participants were also proud and happy with their collaboration for the overall achievement. These motivations are also similar to those identified in other communities.

> "We feel that we were useful and that we helped with something, to be able to develop the platforms or whatever, which are solutions to different problems. It's a very good thing, I feel I helped, and I also think we all helped." [IIR1]

> "We never wanted to create anything for money, we just wanted to help, feel useful to society and help fight the pandemic in any way we could." [IC2]

However, despite the community Coordination team always denoted that the main objective was to mobilize professionals on an exclusively voluntary basis, they also showed that if the participants created partnerships or new professional opportunities, the Coordination would be very satisfied. This can be identified in the community podcast interview:

> "[…] this is voluntary and no, you won't earn money. But look, if because of the initiatives you network and then new businesses are born, we would be happy for you." [PDC1]

The members interviewed did not show that they have made commercial-oriented partnerships yet, but they are open to the possibility. However, participants highlighted that the movement was very important for networking, having met many people from different areas.

"[…] networking was also huge. I met a lot of people and some I still keep in touch for work reasons." [IITL1]

"[…] from time to time I call them with questions to see if they can help me and I can partner in the future." [IC2]

This demonstrates the hybrid character of the tech4COVID19 community's motivations. In addition to motivations based on self-rewards, which are the dominant ones, there is also the prospect of possible future collaborations. Despite the voluntary character, this shows the community's willingness to boost the job market, networking and entrepreneurial spirit among the participants.

As in other hybrid virtual communities, it was also possible to recognize that community participants who contributed above-average received compensation in the form of peer recognition and network reputation (Grabher & Ibert, 2014; von Hippel, 2017a). For example, a graph with the participants who shared the most messages is available on the tech4COVID19 community website. This is a form of acknowledgment of participation, and, in addition, these participants were the most mentioned to help in other project channels. Participation was a window for the volunteer to show their skills and knowledge and the most actives were added more often to different projects, allowing them to work with different people and having more networking.

Apart from the shared enthusiasm, this community appeared to be heterogeneous in terms of professional backgrounds and training (Figure 3). This personal information was revealed because, unlike other online communities, quasi-anonymous was not registered in this community. The coordination promoted users' identification in the "Slack" asking them to have a username like "Name_Work Title_Company/Project" and

use a photograph instead of other types of avatars. The use of this type of identification is necessary since in this type of community in an emergency context, where there is no time dedicated to learning new skills, the main focus was the fast development of the idealized platform, making it reach the public and solving the issue. So, the assignment of tasks to skilled people has to be quick, and the identification of the participants helps this process.

4.2.   Knowledge dynamics and the role of distance

Due to the rising popularity of the community's activities, their size increased and reached maturity in a rather short time (Figure 2), increasing the heterogeny of the social composition of the community. At the beginning of the community, this was formed by a group of entrepreneurs who knew each other, but over time and due to the needs of the projects, members from other areas such as health and education were invited to join the projects and contribute with their knowledge and ideas. In addition, other members voluntarily signed up, having no relationship whatsoever with the already members. That is, the initial relationships were strong and based on past cooperation and socialization, but this started to dissolve, giving rise to physical and relational distance. According to the interviewed participants, this gap ended up not having an impact on the capacity to develop innovation projects.

> "I don't think there was any stress from working with people I didn't know, at least on my part, because people were all there to help, they weren't there to get in the way. And that was a very beautiful thing, as long as there is motivation, that's the most important thing." [IIR1]

> "We had a lot of meetings in Zoom, every day or so. […] It was a good way to shorten the distance between us. It was also possible to work with people from other parts of the country and from Spain and England." [IC3]

Moreover, the volunteer's identification allows community members to quickly understand who the other participants are and the capabilities they have and can use to contribute. This also allows the volunteers' allocation to the projects and tasks in progress. During project development, when tasks related for example with design came up, participants could easily search in the "Slack" platform for designers and add them to the project. Furthermore, identification of the institution can be essential for the partnerships' formation for institutional support.

All projects, when integrating newcomers, guarantee that they are guided by experienced members who freely share their expertise and all the knowledge developed until that time. The members of the tech4COVID19 community demonstrated to be willing to "share" their knowledge freely with fellow peers. So, they contributed to the common pool of knowledge without expecting reciprocal benefits.

"[…] I said «Hello guys, I'm here and I'm from Marketing. I can help with whatever it takes», and suddenly I was a little overwhelmed with all the information and people started sharing with me what they were doing and what they were defining. And ok, «you're in Marketing, so you're going to do Marketing here for the movement»." [PDC1]

"I didn't know anyone, but when I joined, everyone introduced themselves and gave me all the information about the project." [IPTE1]

We explored the kind of knowledge that is shared within the community, namely in the "Slack" channels of selected projects (Table 1). Although our sample's domain of knowledge is diverse, there were three forms of knowledge that appealed to all projects, yet in different degrees: usage knowledge, design knowledge and procedural knowledge (Table 3).

Table 3. Knowledge forms (percentage of posts containing the respective type of knowledge in project "Slack" channels).

	Projects		
	RoomsAgainstCovid	Tools4Edu	TeamLoan
Usage	12	11	9
Design	3	2	2
Procedural	45	33	41

Source: Percentages elaborated based on fieldwork.

Usage knowledge: Gained using a product; Design knowledge: Understanding the constituents and their functions; Procedural knowledge: Finding new ways to do some processes

In a total of 6.706 posts, 3.568 posts (53% of all posts) revealed some form of knowledge being conveyed. As Table 3 shows, the predominant type of knowledge was procedural, which can be due to the fact that these projects were based on the development of new technological platforms. Besides all the programming work, the development also includes the solution of software incompatibilities, new forms of storage, etc. This type of knowledge was mainly identified between March and May 2020.

"We create an app for health professionals to make bookings and another for the hotel industry, just say if they are available or not, the number of rooms available, etc." [LR3]

"[…] I can create a chatbot to automate bookings" [LR17]

"WhatsApp is not going to be enough […] we need to develop a website for sorting and matching, we also have to see how to improve the storage of information. Anyone who knows this part?" [LTL23]

On the other hand, usage knowledge started to emerge later on as it requires the use of the product or solution for some time.

"[…] I've already used technological solutions from the tech4COVID movement, ok? To evaluate my shopping trip and the truth is that it was spot on. I used the application to find out if I can go to the supermarket, if there weren't a lot of queues and there weren't, nobody was there. I thought «This is amazing» […]" [PDC1]

"I was just testing it and it looks great to me, it's working fine and it's matching automatically, but is it missing the filter or not?" [LTL450]

As Table 3 further illustrates, design knowledge was the least registered form of knowledge in "Slack" channels. This can be due to the need for strong foundations of product architecture, that is, it's crucial to know the constituents of a particular product and its functions. However, design knowledge is not restricted to expert members; in fact, this knowledge is often expressed by lay participants. Many of these users ended up acquiring this knowledge through participation, although this was not likely their primary motivation (see section 4.1.). Despite this, results obtained differ from those in the literature, which may be due to the different stages of the projects and the urgent character (Grabher & Ibert, 2014). This character does not allow for a long period to learn and improve skills by community participants. Thus, as participation time spans are short, design knowledge was more restricted among community designers.

"This chatbot on the platform helps to manage all the contacts we receive and allows to give an automatic response to everyone who asks for help., I think it's important to keep it on the platform." [LR70]

"The website is directly linked to the tutorial videos, so just click and open directly" [LTE93]

However, unlike other hybrid virtual communities (Grabher & Ibert, 2014), discussion threads were fast and with low asynchronicity. As this community was initiated to solve an urgent problem, the momentum was fast since the goal was to rapidly develop the needed technological solutions. In general, interaction within the observed forums is characterized by short response times. On average, across all the analysed threads, community members took about 3 minutes for reacting to fellow peer's posts. Although the discussions about a topic ended in 1-2 days maximum, the messages were stored and kept being available in "Slack". This response velocity worked well for participants to develop the virtual platforms, but interaction with partner entities was slightly longer. This is due to the institution's intrinsic routines and culture, but as the participants knew people from these institutions, they were always able to speed up the process.

"Waiting for a response, but I can escalate to admin if he doesn't respond. I have the contact" [LR202]

This short development time can influence the success of a project. Projects that require longer development and improvement times may not be feasible in fast-paced communities. It may also have been the reason for the failure of TeamLoan project. Compared to the other projects analysed, TeamLoan was the project that required overcoming more legal issues, which can be a long process. As mentioned before, this project reached the public, but ended up not solving the need. This project was based on the exchange of teams of employees between companies, with a lot of associated labour legislation. It also implied negotiations with large companies that do not follow distance (physical and relational) models. Also, a first confirmed trade would end up giving legitimacy to the project and show that it was possible.

Regarding community members' origin, they were from various locations in Portugal and there were also participants from Spain and England, meaning that the tech4COVID19 community is constituted by spatially fragmented and socially distanced collaborators. However, in the age of the Internet, distance is a factor that has a minimized impact. In fact, communication platforms allowed to maintain some social interaction, mainly because they allow video and audio, widening and deepening communication possibilities.

"I think the video calls were essential so that the lack of contact was not felt so much. It doesn't replace, of course, but it's good for maintaining a social level." [IPTE1]

"It was very strange at first, especially since most people neither knew nor had ever seen each other. But it didn't hinder the development of the project […] we were focused and all with the same motivation, with the same desire to find innovative solutions." [IPTL2]

However, there were some meetings through the communication platforms that ended up not being fruitful, having dispersed to other topics. Similar to what happens in many face-to-face meetings.

"[…] we had Teams or Zoom meetings almost every day so there was no problem with that. Some meetings turned out to be very tiring and we were already tired of work, […] it started to disperse a bit." [IC2]

Virtual tools, especially the communication platforms "Slack" and "Zoom", showed to be very important in the community for sharing ideas, work management and organization across distance. The interviewed participants shared that, thanks to the daily meetings and to the numerous messages exchanged between members (Table 1 and 2 and Figure 5), through these platforms, projects accomplished demanding collective goals,

and social interaction was not missed. However, the need to resort to meetings by "Zoom", with the option of voice and camera shows that there was a need for richer contacts at the "social level", i.e. the exchange of messages between the participants was not enough and requested an increase in relational proximity even though through the "Zoom" platform. So, this new relational proximity was needed in the production of useful collaborative knowledge.

"[…] we are from different parts of the country, which is also funny. It was difficult not to have interaction, but Slack and meetings by Zoom allowed everything to go well." [IITE1]

Furthermore, distance (physical and relational) was not an obstacle to the migration of the RoomsAgainstCovid project to Brazil. Despite the great distance between members of the Portuguese community and the Brazilian community, it was possible to have innovation and transfer of technological innovation. Again, this knowledge transfer was facilitated by communication platforms such as "Zoom".

"[…] we were able to take the project to Brazil, to help them too. We already had the platform practically developed so we gave everything to them. Thus, they saved development time, just applied the codes and form of organization that we developed in Portugal. I think our help was very good as they saved time and could find accommodation more quickly." [IPR2]

"It was certainly more complicated than with the participants from Portugal, especially because of the time difference. But everything was possible!" [IPR2]

It was also registered a variation in the number of messages exchanged in the corresponding "Slack" channel to each project (Figure 6). As the RoomsAgainstCovid project was one of the first to start (mid-March 2020), it had a large number of posts on

its channel and then gradually began to decline. On the other hand, Tools4Edu and TeamLoan only started in the last week of March, so they had their peaks of activity in the "Slack" channel in April and then followed by a gradual decrease. This peak of activity recorded near the beginning of the project is because community members, after identifying the need, sought to develop a solution in the shortest period possible. It should also be noted that Tools4Edu recorded a decrease in the number of messages shared on "Slack" as they moved to another communication platform, where they continue to develop and evolve the project. Contrary to what is registered in other online communities, in the tech4COVID19 community there were cases of boom-and-bust. That is, the projects, namely RoomsAgainstCovid and TeamLoan, attracted a lot of interest at the beginning and then, with the advance of the pandemic, the platforms were no longer in such demand. In the case of the Tools4Edu project, the level of interest was not so affected by the progress of the pandemic and the changes it caused. The team ended up choosing to migrate from the "Slack" platform to a simpler and more intimate form of communication, which includes personal calls and messages, "WhatsApp" conversations and "Zoom" sessions. These modes of communication allow to maintain the connection between volunteers but in a more mature way, with a smaller and more fixed team than when present in the tech4COVID19 community.
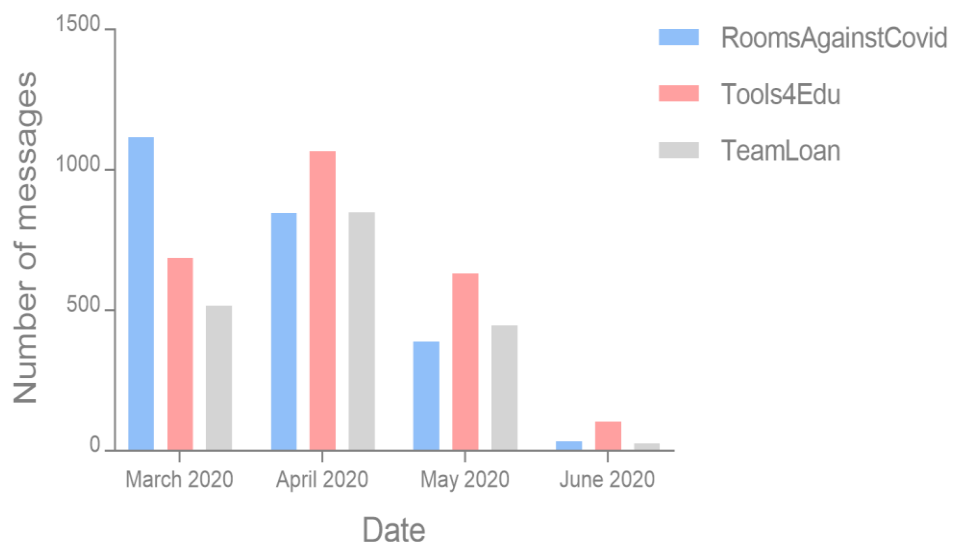

Figure 6. Variation in the number of messages exchanged in the channels of selected projects, on "Slack", between March and June 2020.

In addition to the reduction in the number of messages, it was also possible to identify a decrease in the number of project participants. The best case to analyse this event was in the Tools4Edu project since it is still active. This project, which had 204 participants (Table 1), currently has 10 members. This reduction can be justified by the decrease of the imminent need, reduction of availability that can be due to the resumption of in-person or hybrid work plans, among other possible specific causes. Although a higher number of participants has many advantages, such as more suggestions and ideas, it becomes more difficult to manage in the long term. Thus, a smaller number of volunteers can be more suited to the development of innovations as it turns out to be easier to manage.

"I think the core challenge faced by the movement, from a more operational point of view, is precisely the fact that: 1) there are a lot of people and 2) there are a lot of people who are a volunteer." [PDC1]

4.3. The link between free innovation and entrepreneurial activity

As seen, despite the voluntary and non-profit character of the tech4COVID19 movement, many new solutions emerged from this community. The core element of the community is that members freely invest in the joint development of solutions as they all share the same goal, which is the development of technological solutions to the challenges that arose with the pandemic. The knowledge created in the community had the main objective of helping those in need and participants were not interested in developing virtual platforms to make a profit.

This knowledge pool turned out to be quite rich as it had contributions from volunteers from different areas. But also, most of the initiators ended up developing projects in the same area of their start-ups, for example, the case of the RoomsAgainstCovid project, which was started by an entrepreneur with a technological start-up applied to accommodation. This shows that although the short-term goal is always the rapid development of free innovations that help during the COVID-19 pandemic, there may be, in the short-medium term, a link between projects and start-ups (or other for-profit initiatives) of its initiators.

"[…] the development of this Platform was good for networking and improving collaboration and management work. In addition, the possibility to work closely with people I admire, from other start-ups, and see how they manage their own projects and see how coordination members delegate tasks to people. These were things I implemented in my own company. I learned it one day and the next day I applied it to my own project. Learn to delegate well and empower; set the agenda well for a meeting; set goals…. These were minimal things, but they make all the difference in the daily management of a start-up." [IIR1]

The connection between start-ups and projects in the same or similar areas was also very important as the start-up's collaborators could quickly support the project and support the innovation process. They could also benefit from more technical knowledge by collaborating with experts from other start-ups.

"And I assigned people from my team, from my company, to dedicate themselves 100% to the Movement." [IC1]

In addition to the connection to the movements' entrepreneurial activities, many of the projects ended up boosting the entrepreneurial spirit of the volunteers. Although there were no official partnerships between former members of the community, during the project development process there were several ideas for using the innovations for future activities after the end of the pandemic.

"Super interesting idea. Even after quarantine, the circular economy will become a more settled reality and there will be peaks of need. This is almost like setting up an outsourcing company and there are several legal aspects to consider." [LTL39]

5. Conclusions and implications

5.1. Conclusions and discussion

In this work, we seek to understand how innovations emerge from hybrid online communities in emergency contexts. In particular, we sought to understand what characteristics are different from online communities in a regular situation, namely changes in time spans, motivations and diffusion mechanisms. The pandemic situation that we are still facing seemed ideal as an urgent context and thus, the tech4COVID19 community presented itself as a great case to explore the divergences, how they are organized, act, the motivations and what types of knowledge are shared among volunteers. Thus, this work allowed not only to study these characteristics in a fast-paced online hybrid community but also to compare them with the existing knowledge about online hybrid communities and their innovation processes.

As a first result of our research, it was possible to verify that, similarly to what happens in other hybrid online communities, the main motivation of community members was based on self-rewards. Moreover, as expected, learning was not one of the main motivations. Although the learning of new skills was recorded in some cases, the urgent nature of the community did not have much time to be devoted to this maturation process.

Second, it was seen that the knowledge in urgent online hybrid communities is freely transmitted among users and newcomers by more experienced members and available to every participant in the community. Regarding the physical and relational distance between users, as expected, the existence of many new communication platforms that allow "shortening" the distance between like-minded individuals (such as videoconferencing) was pivotal to facilitate innovation. The predominant knowledge present in the projects' "Slack" channels was procedural knowledge mostly associated with the software and platforms in the projects under development. All the created knowledge can be used by all community participants, who can apply it in their companies and transfer it to others. The successful transfer of knowledge even allowed one of the projects to be implemented in Brazil. However, contrary to what could be expected, the absence of face-to-face interaction did not have impact on the innovation process. But we should consider that digitally mediated communication through e.g., a

"Zoom" platform is not a total absence of face-to-face interaction, and some of its properties remain. This type of interaction is more complex than a simple exchange of messages and with the possibility of using a camera, in addition to a microphone, it allows an interaction similar to the traditional face-to-face interaction (e.g., in terms of speed or partner verification). Thus, although it does not completely replace face-to-face interaction, e.g., in the socialization sphere, the interactions by "Zoom" acted as the possible substitute in the innovation process, mitigating some of the hurdles implied with the physical but essentially relational distance among participants. In all projects analysed, this type of interaction was quite recurrent and despite the participants, preferring the traditional personal interaction, ended up adapting to the new reality and proceeded with the development of technologies. As shown earlier by Grabher and Ibert (2014), distance can be an important "asset" for innovation ecosystems, namely in virtual communities, due to proprieties as anonymity, asynchrony, informational character, long maturation times, among others. In this study, given the urgent nature of the virtual community analysed, some of these properties are not present, such as anonymity, asynchrony and maturation periods. Since the community intended to quickly find solutions to COVID19 pandemic-related problems, these are characteristics that the community evidently could not have. As such, with these properties totally absent and physical and relational distance between the participants, there was a need to resort to other complementary modes of interaction, for example using the "Zoom" platform, to create and exchange relevant knowledge that would lead to innovation.

Furthermore, it was noted that participants collaborated more in the areas they are dedicated to in their entrepreneurial for-profit activities. This is because, as there was a need for fast innovations, volunteers were quickly allocated to projects, depending on their capabilities, and were responsible for the tasks in their areas. In this way, it was possible to save time in the development of platforms and thus more quickly reached the target audience. Therefore, it confirmed the expected link between members' participation and their entrepreneurial activities outside the community. In addition, it was possible to identify cases in which the entrepreneurial spirit was highlighted with a view to implementing projects after the pandemic. Although no partnership between the members is registered, this possibility has not been ruled out and could happen in the future. It should also be noted that the innovations found in this community are similar to the free

innovations described by von Hippel (2017), in the sense that: 1) were developed by volunteer participants who used their free time to develop the platforms and 2) are not protected and can be freely acquired.

Finally, the tech4COVID19 community was a proof that, when there is a common goal, innovation projects can be developed from scratch and reach the public in record time. It was an example of union and collaboration between several people that initially did not know each other. This type of community, created during a pandemic phase, proved to be effective in creating new technologies that could solve specific needs at the time. However, there were many projects that were never developed. As in other areas, the percentage of projects that reach society is much lower than the number of existing prospects, these could need more time for sharing ideas and for development. And this can be a problem associated with the fast-paced communities, because in these there is not much time to process ideas, review opinions and ideas of the other members and finally, develop or improve the products. They have to be fast-developing solutions. In common hybrid online communities, as they have more time, they can improve the developed product, use it for longer and suggest improvements after use.

The short development time may also have had impact in the TeamLoan project. Despite the active users' participation (messages exchanged on the "Slack" channel), similar to the other successful projects analysed, this project required overcoming multiple issues associated with labour legislation, which can be a lengthy process. Furthermore, it also implied negotiations with large companies that commonly do not follow distance (physical and relational) models. In another context, with more time to mature, the project could have reached society and been successful.

Therefore, communities like tech4COVID19 community are very useful to get innovations quickly, but they may not be their best versions because the time for improvement is reduced, and the main objective is just to create something functional and that solves the need quickly. In the most common hybrid online communities, there is time to improve products and, for example, provide a better experience for the platform user.

5.2. Suggestions for further research

For future research, we suggest exploring a prospect that did not reach the project classification, in order to understand what failed. It is also possible to explore whether the motivations, the mode of action and the form of communication were identical to the projects analysed in this work. The inclusion of this new case will allow us to gain a new perspective of analysis.

Moreover, we also suggest analysing whether, after the end of the urgency character, the properties suggested by Grabher and Ibert (2014) begin to manifest, that is, the inclusion of time for maturation, use of past messages for the creation of new knowledge, among others, or if the community is effectively diluted. Additionally, in other communities, it will also be possible to analyse whether, given the new context of the use of "Zoom", "Teams" and others, if these modes will manage to facilitate the relational proximity necessary for innovation.

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Supporting Information

Project	No. of member	No. of messages
Covidografia	606	1.753
RoomsAgainstCovid	250	2.382
Tools4Edu	204	2.487
Nafila	175	1.249
Idosos2Voluntários	159	298
Vejo em casa	148	327
Ventiladores	146	681
Comercio-Local-Para-Online	137	130
Crowdfunding	132	515
Student Keep	124	736
Animalar	117	1.061
Industrial Engineering Masks	103	222
Chatbot4SegurançaSocial	97	63
Chatbotsaude 24	81	193
Openchallenge	79	73
Acalmaonline	77	66
Mobility4Healthcare	76	595
Covidapp	71	54
Posso-ir	61	320
TeamLoan	60	1.837
Covidoff	50	456
Preserve	50	457
Telemed	47	199
Icam	46	517
Interajuda	41	166
Knok4Good	40	125
Wemovit	39	37
Covid19Eu	26	16
Industrycare	22	113
Call Center Tech	21	63
SOSCovid	18	15
Covindex	17	52
Senhas4Covid	13	2
Preventive Test	10	125
E-fitas	1	0

Table S1. Projects developed in the tech4COVID19 community, with the number of volunteer members in each project and with the number of messages exchanged in the respective channel in "Slack".
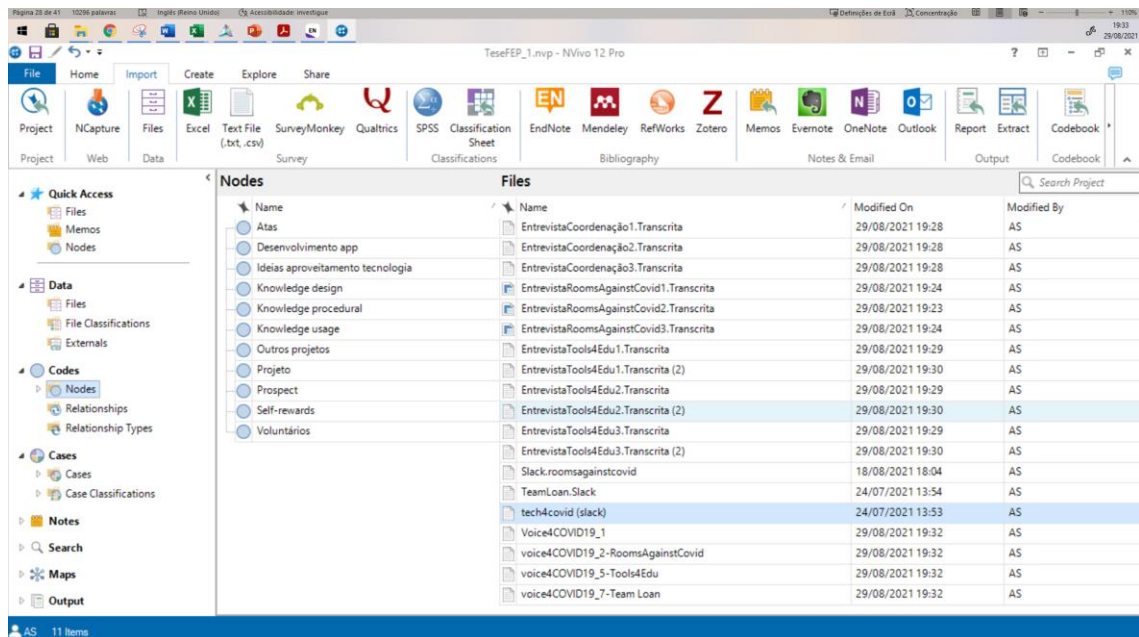
Figure S1. Nvivo software was used to analyse the interviews conducted by the authors and those available on the voice4COVID19 podcast, and discussion forums (the project's "Slack" channel) All this data is in the Files column. In the column to the left of this, there are some of the nodes used, which were the codes used to identify messages that presented, for example, the types of knowledge shared and the motivations of volunteers.

<u>Interviews scripts</u>

    o **<u>Coordination team</u>**

- What were the reasons that led you to start the tech4COVID community? How did the idea come about and who was involved?

- Any monetary motivation (for-profit) or just others (non-profit)?

- Who founded and how is tech4covid managed? Why create an association vs. keep it informal?

- What are the motivations of the projects' initiators?

- In practice, do the participants know each other personally (from experiences and past socialization)?

- How does someone gain status in sub-communities?

- How do you assess what has happened so far? Did it exceed expectations? What concerted solutions have been developed and are they operational? Which solutions gained the most traction and why?

- Can you give examples of projects and communities that worked very well and less well, and explain why?

- How did the user involvement change over the 1st and 2nd/3rd covid wave? Was the enthusiasm of the 1st wave in participation maintained?

- In addition to participating in this community, do you have other professional activities?

- How do you combine them?

- Can you use the knowledge and development that happens in the community in your professional activity? If yes, how? And on the contrary – what resources from your professional activity (network of contacts, technology, infrastructure, financing) do you mobilize for the initiative?

- Initiated which projects?

- How was/is it to deal with the distance between the participants? Do you feel it affects you positively or negatively?

- What is the future of the tech4covid initiative? How do you see it in 2 years? Will it dissolve once the urgency of intervention has passed?

- Why is it important to "formally" dissolve the movement?

- Are there similar experiences of dissolution of this type of online community?

- How will the process of dissolution of the Movement be? What steps will you take?

- What will happen to the website and social networks (Facebook, Slack)?

- Will the information developed remain with the leaders/companies responsible for the development?

- Are the relationships and networks that have been created in the meantime expected to dissolve? What will "stay"? (New business contacts? New partnerships?)

- o **Community members**

- What were the reasons that led you to join the tech4COVID community?

- Any monetary motivation (profit) or just others (non-profit)?

- Have you contributed/helped in the development of how many projects?

- How do you feel after contributing? Did you feel it helped?

- In addition to participating in this online community, do you usually participate in others? If yes, which ones? (Including online forums)

- Do you have other professional activities?

- Can you use the knowledge you acquire in the community in your professional activity? If yes, how?

- Can you use this knowledge in your day-to-day? (Non-professional context)

- How was/is dealing with the physical/social distance between the participants (compared to other types of "Face to face" interactions, or with people you know previously)? What are the advantages and disadvantages and why?