How to save the world during a pandemic event. A case study of frugal innovation

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COVID-19 has been the most important pandemic that hit the world in the last century. An overwhelming number of initiatives aimed to save lives and protect humanity came out especially at the beginning of the health crisis, following an outside the box approach to address relevant R&D problems. Digital makers, not surprisingly, have been part of the game. Being masters in using digital technologies for customized products, and being strategically fitted to cope with the imperative to be fast, many of the players on the front line to fight the pandemic have looked at them as the ‘providers next to the door’ able to offer fast solutions to critical problems. Based on these premises and adopting frugal innovation as theoretical base, the aim of the study is to analyze how digital makers have taken part in R&D processes to find solutions to the problems created by an exogenous and unexpected sanitary problem. Through an in-depth case study, we provide insights on if and how frugal approach to innovation is adapt to cope with the extraordinary pressure coming from event like the COVID-19. The results of the study highlight the power of connecting frugal innovation principles, agile mindset of makers and open innovation strategies in providing effective solutions on a local scale and eventually exploit their potential global impact. Furthermore, we highlight implications and pathways for future researches.

1. Introduction

COVID-19 has been the most important pandemic that hit the world since a century, after the so-called ‘Spanish Flou’ (1918/1919). While the two pandemics share the same biological trigger, luckily the technological base of humanity today is not comparable to that of early 20th century. Thanks to the astonishing progress in Information and Communication Technologies (ICT), society and economy has entered the ‘Digital Era’, where speed and breadth of exchanging ideas, information and knowledge is increasing and more and more important in innovation processes (Del Vecchio et al., 2018; Hsieh and Wu, 2019).

COVID-19 has been a significant stress test for scientist, innovators, entrepreneurs and managers looking for new solutions to an unexpected problem. The good news is that we have seen an overwhelming number of initiatives that applied an outside the
Digital makers, the new craftsmen of the digital era, have been taking their stake in the challenge to face the pandemic, providing their local communities with devices for individual safety and emergency equipment for hospitals (Engineering.com, 2020). Thanks to their ability in using digital technologies and 3D printing devices (Anderson, 2012; Hatch, 2014), a new manufacturing technology enabling the making of products with a particular type of equipment (printer) not restricted to corporate facilities, many of the players on the front line to fight the pandemic have looked at them as the ‘providers next to the door’ capable to offer fast solutions to solve critical problems. Digital makers around the world have played a key role in designing effective and immediate solutions to support doctors in the front line in the fight against Coronavirus (https://www.nytimes.com/2020/03/31/science/coronavirus-masks-equipmentcrowdsourced.html).

Given the fact that production chains were broken because of limitations in movements of people and goods, and under time constraints in which they had to develop new solutions to unforeseen problems, they were forced to exploit their ingenuity counting only on the resources available at that moment in that place. And they did.

Starting from these premises the objective of the paper is to analyze how digital makers have been taking part in R&D processes to find solutions to the problems created by an exogenous and unexpected emergency on a local scale but yet with potential global impact.

To answer the research question, this study theoretically refers to the managerial practices of innovation observed when the imperative is of ‘doing more with less’ and that have been studied and reported as cases of jugaad or frugal innovation (Radjou et al., 2012; Radjou and Prabhu, 2015). A qualitative methodology presenting and discussing an in-depth exploratory case study (Yin, 2003; De Massis and Kotlar, 2014) has been adopted. The case is that of Isinnova, a small and young innovation services company, located in the city of Brescia (Lombardia, Italy), whose contribution to save lives especially in the very first, and most difficult, phase of the pandemic has been recognized by media all over the world, including Forbes and CNN (https://www.isinova.it/press/).

The study has theoretical and practical implications. From a theoretical point of view, the study contributes to the literature on the frugal innovation approach, providing insights about how it has been adapted to cope with an extraordinary and rapidly spreading events such as COVID-19. From a practical point of view, the paper highlights how an innovation intended to give relief to local community can be scaled up rapidly at global level. Further, the study provides indications about actions that policy makers and firms should consider in preparing our society for future challenges like COVID-19.

2. Theoretical background

2.1. Frugal innovation

Frugal Innovation is a concept originally developed in the context of emerging economies where the Hindi term jugaad was used to describe a bottom-up innovation process able to develop effective and low cost solutions (Radjou et al., 2012). In this context, the frugality in innovation originates from the necessity to satisfy the basic needs of resource-constrained customers, the so-called Bottom of the Pyramid (Pralahad, 2005; Radjou et al., 2012).

Frugal innovation has recently attracted a lot of attention in advanced economies too not only as a specific typology, but also as philosophy of innovation that makes possible to develop affordable, sustainable from the economic point of view, and high-quality products and services with the use of minimal resources and in less time (Radjou and Prabhu, 2015; Nesta, 2016; Tiwari et al., 2016). Weyrauch and Herstatt (2016), arguing in favor of a more general application of frugal innovation approach, identified three drivers to define frugal innovation: substantial cost reduction, concentration on core functionalities and optimized performance level. Along the time, frugal innovation concept has been analyzed from different perspectives. The mainstream approach sees frugal innovation as a specific kind of innovation practice (Pisoni et al., 2018) defined by a coherent set of principles (Tiwari and Herstatt, 2012; Rao, 2013). Some scholars emphasize the cognitive aspect of frugal innovation, considering it as an approach (Brem and Wolfram, 2014; Prabhu and Jain, 2015).
a mindset (Soni and Krishnan, 2014) or a management philosophy of innovation processes (Gupta, 2011).

Radjou and Prabhu (2015) state that frugal innovation is an approach that refers to the whole innovation process or product/service characteristics and that could be applied to different typologies of innovation.

In this perspective, frugal innovation is considered an alternative mindset to the new product development process (Prhalad, 2012; Radjou and Prabhu, 2015) and to the process through which innovation is ‘conceived of, executed and delivered’ (Petrick and Juntiwasarakij, 2011, p. 24) in which the limitations of resources is considered an opportunity and not a threat.

To develop and apply a similar kind of approach, Radjou and Prabhu (2015) identify six key principles: engage and iterate, flex your assets, create economic sustainable solutions, shape customer behavior, co-create value with prosumers, make innovative friends.

From one side, they highlight the necessity for firm to increase internal flexibility and agility in managing innovation process. On the other side, they sustain the importance for firm to access external knowledge in developing new products, fully implementing the practice of open innovation (Chesbrough, 2003). External knowledge that can be brought from organizations as well as individuals (Brabham, 2008; Cappa et al., 2020).

While the basic idea of frugal innovation of doing more with less (Radjou and Prabhu, 2015), contains in itself the strategic driver of being fast and parsimonious in a constraint-based situation (Agarwal et al., 2017), frugal innovation principles have never had the opportunity to be tested in a worldwide stress condition like the COVID-19.

2.2. Digital makers: definition, theory, and principles of action

The frugal innovation approach has already been associated to the so called maker movement that identify local communities of digital craftsmen (Anderson, 2012), and a growing global movement (Browder et al., 2019) which impact on economy has been considered as the next industrial revolution (Anderson, 2012; Hatch, 2014). As highlighted by some scholars, given their ideological philosophy based on the idea of knowledge exchange (Maric et al., 2016), their distinctive culture based on experimentation (Shah, 2005; Furnari, 2014), and thanks to the new digital technologies like 3D print (Rayna and Striukova, 2016), makers could be considered a fertile arena for the implementation of frugal innovation principles (Radjou and Prabhu, 2015).

Their mindset, defined as an orientation of doing and experimenting by itself characterized by self-efficacy, motivation, and interest, has been studied in educational studies and proposed as an educational model for youth (Chu et al., 2015). The sense of being a community between them is very high and new digital technologies like internet and some event formats like the Maker Faires have added a new level of potentiality for aggregation of the movement (Dougherty, 2012). The specific culture of digital makers (Mortara and Parisot, 2016), their peculiar ideology based on cooperation and open source sharing (Pieri and Domeniconi, 2016), let them to work easily according to the paradigm of collaborative innovation. It has been reported that in the maker communities, knowledge diversity and the crowd wisdom that emerges in collaborations between different individuals, generate advantages for the innovation process and innovation capability of the community itself (Franzoni and Sauermann, 2014; García Martínez and Walton, 2014; Cappa et al., 2019).

The role of digital makers in R&D management processes has been initially acknowledged with respect to user-centered innovation (Franke and Piller, 2003), or even in mass customization strategies based on digital toolkits (Hienerth et al., 2014). More recently their role has been studied with respect to the open approach to innovation, a model of innovation that replaces the old vertical integrated innovation process and focuses on the idea of collaborations with external subjects (Chesbrough, 2003; Fabrizio and Di Minin, 2008), which impact on innovation capabilities of the firms has been demonstrated (Cammarano et al., 2019).

3. Research design

3.1. Research methodology

The aim of this study is to illustrate how a digital maker has managed R&D process and its flows to deliver effective solutions to face an unforeseen emergency due to a pandemic crisis. The authors conducted an in-depth exploratory case study (Yin, 2003) adopting a narrative approach (Hjorth and Steyaert, 2004; Hamilton, 2006a, 2006b; Larty and Hamilton, 2011). The exploratory case study fits particularly the way to answer correctly the
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3.2. Research setting

The case study is that of Isinnova, an innovation services firm and digital maker based in Lombardia, a region sadly known for having the highest COVID-19 infection rate in Italy. Isinnova was selected for several reasons. First, the firm can be considered an insightful example of a firm which business is to offer innovation services using digital technologies. Isinnova has contributed to the development of many new ideas of products and services in collaboration with more than 350 innovators (www.isinnova.it). Second, the firm has been worldwide recognized as a multiple innovation success cases during this pandemic. Therefore, this case was chosen as it offers a unique and peculiar setting to examine the phenomenon under investigation. More specifically, it represents a perfect example of frugal innovation (Radjou and Prabhu, 2015), that well matches it represents a perfect example of frugal innovation in Winkler’s model that are cost reduction, concentration on core functionalities, and optimized performance level (Winkler et al., 2019).

3.3. Data collection and method

Information was collected through six direct interviews to Isinnova team and other players involved in the R&D process, selected using a snowball sampling strategy (Patton, 1990) and triangulated with other sources of data (Gibbert et al., 2008), such as the analysis of some archival documentation and web sites. The interviews were conducted in Italian language via mobile phone due to legal pandemic restriction, by one of the Italian authors with the support of an assistant who manages the recording of interviews and takes notes. They lasted between half an hour and one hour and were recorded (except one) and later transcribed. The interviews were focused on the firm’s R&D process and the role of all the players involved in the development of the new products. Data on the firm’s processes were collected in multiple stages between April 24th 2020 and May 06th 2020. These data allowed to identify the R&D process, the difficulties encountered during the development stage and how Isinnova was able to overpass these. A list of the interviewees’ roles is provided in Appendix A. Regarding the interview protocol, this study used a combination of life-story interview approaches (Atkinson, 1998, 2002) and phenomenological interviews (Thompson et al., 1989). Researchers did not use set scripts – as occurred successfully in a number of study depicting stories of entrepreneurs, inventors and other characters (Cohen and Mallon, 2001; Cope, 2005) – letting the questions to ‘flow from the course of the dialogue’, being the aim of the interview to acquire the person own description and interpretation of the R&D event. The adoption of life-story interviews represents a way through interviewer and respondent ‘jointly construct narrative and meaning’, and thus, ‘render events and experiences meaningful’ (Riessman, 2008, p. 23), being both active participants of the narrative. In this sense, each of the participants told their stories in different ways: thus, some needed more prompting by the interviewers than others.

3.4. Data analysis

In data analysis, this study adopted the approach suggested by Larty and Hamilton (2011) combining a structuralist approach with the two-following steps of contextualization and further in-depth analysis. Structuralist approaches investigate primarily the role of plot, the role of the narrator and characters, how events were pieced together, and the aim of the story. The second stage of contextualization means to consider the ‘embedded nature of stories and storytelling’ (Larty and Hamilton, 2011, p. 231) as well as the role of researcher in inducing the storytelling. Finally, in the third stage emerging key concepts have been linked with theories of R&D management. Passing to the analysis of data, the second and the third authors individually conducted an analysis of the interviews to identify the key emerging themes, discussed these themes and agreed on representative labels. Thereafter, the authors undertook a new analysis to identify the deeper patterns in the data, leading to secondary themes, and iterated between theoretical abstractions related to R&D process and the contextual situation (namely, pandemic crisis). An example is the ‘effectuation’ theme as a theory of reference with regard to agile entrepreneurial thinking. From the analysis of quotations and the
identification of first-order concepts, it emerged that the informants directly mentioned the term of agile thinking and the capability to ‘see over the bush’ where opportunities can be seen in adapting existing products to new meanings. Consequently, the authors searched the literature that deal with these concepts and associate it to the domain of ‘effectuation’ (Sarasvathy, 2001). This iterative process between theory and evidence allowed the identification of some issues in the R&D process during a pandemic crisis as well as several entrepreneurial capabilities, constituting secondary themes and first-order concepts.

4. The Isinnova case

The case covers 18 days, from the first product developed by Isinnova during the pandemic to give an answer to the urgent needs of its local community, till the launch of a project aimed to scale up world way the technologies developed by Isinnova and its partners.

The description of the case has been split in chapters, each covering distinct steps. Narrative style chosen echoes the drama style of screenplays with the explicit intent to render to the reader the accelerated pulse of the facts that were extraordinary from many points of views.

4.1. Chapter A – ‘Alert: an invisible enemy is among us and its force is beyond our capabilities’

Days 0–2

Step: The replacement of the Venturi’s valves.

Players:

• **Chiari Hospital (Brescia):** The City of Brescia (Lombardia Region) was one of the hotspots for the spread of the Coronavirus in Italy. The Chiari Hospital, during the first part of March, was literally submerged by an overwhelming number of people affected by coronavirus and showing very important pulmonary symptoms.

• **Giornale di Brescia Newspaper:** The Brescia’s Local Newspaper covers the news of the pandemic in the City and gives voice to the SOS launched by the Chiari Hospital about shortage of medical devices.

• **Isinnova Team:** An innovation service company, located in Brescia whose core business is to support companies and organizations in exploiting their innovation capabilities, and to develop and make prototypes of new products. At the end of the month of March major global newspaper and media, including New York Times and CNN, would features news speaking about them.

In the mid of March 2020 the Chiari Hospital of Brescia, as many other Hospitals in the Lombardia Region, were under tremendous pressure for the pandemic. Among many other problems, the shortage of medical devices put the lives of hundreds of Covid patients at risk. The Head of technological unit of the Hospital was worried about the shortage of some disposable devices, and in particular the Venturi’s valve, a disposable respiratory support device. Sadly, the OEMs (manufacturers) of the Venturi’s valve were not able to respond to the requests. The Hospital had a 3D printing machine but was unfit to produce the Venturi’s valve. The last (almost desperate) chance considered was to ask the Local Newspaper to launch an SOS to whomever can be of help.

As a result, on the day of March 13 Cristian Fracassi, the founder of Isinnova, and his small team was at Chiari Hospital to collect a sample of the Venturi’s valve. At the end of the day, a prototype was produced by their 3D printing machine. The day after in the Chiari Hospital the Venturi’s replica was tested on a member of the Isinnova team who offered himself as a volunteer. The test was perfect.

Days 2–4

Step: Venturi’s Valves production facilities ready to be scaled up

Players:

• **Isinnova Team**

• **Lonati Co.:** a Corporation located in Brescia. They are leader in the production of equipment for textiles and for many other industries. They are shareholder of Isinnova and by chance they have bought at the beginning of January 2020 a very sophisticated state-of-the-art 3D printing machine: *Audentis fortuna iuvat* (an old Latin motto, that means: fortune help the braves).

The replica of the Venturi’s valve was ready, but the Hospital needed at least 100 units soon. The necessity to produce this huge number of valves with high level of quality-induced Isinnova to call Lonati group for help. By the end of day March 14, the file for high precision 3D printing was ready and on 16th in the morning, the first lot of 100 Venturi’s valve was consigned to the Hospital. The news reached other Hospitals in the area, and they sent urgent requests for thousands of more valves. At that point, Lonati was not able to keep up with the entire production with its 3D machine. They...
made the decision to share their printing file with other companies in the area that have the same kind of 3D printing machines, to respond quickly and positively to the many requests.

4.2. Chapter B: ‘Our hands and our boldness are not enough. We need to see beyond the bush’

Days 6–7

Step: The transformation of a snorkeling mask in a medical device

Players:
- Dr. Favero: Retired Head of Intensive Unit of a Hospital in the area of Brescia. He has a deep knowledge of the infrastructures needed to help patients with respiratory problems. He loves to do things and to re-adapt old things to a new use.
- Isinnova Team
- Decathlon Italia: Among the thousands of articles sold by this famous sports retailer, the snorkeling mask was well known by swimmers.
- Chiari Hospital

In the same days Dr. Favero, was thinking about how to be helpful in that moment of distress. In his previous clinic experience, he noted the rough similarity of devices used in intensive care and the Decathlon snorkeling mask. Now that observation can become useful (need sharpens ingenuity). He procured a snorkeling mask from a friend and set out to disassemble it. He rapidly understood that some of the valves can be easily readjusted according to the functioning mechanism of a ventilator device, but the one that substitutes for the snorkel (the tube that let you breath air from the surface while swimming) was a little bit more complicated. While its original function was to allow water accidently leaking in the mask to go outside, the valve of a ventilator device must have the opposite function, not to leak air outside the mask. For a while, he considers producing the new valves by himself, but because of the precise technical requirements of a pulmonary mask, this hypothesis was discarded. It was during lunch that his wife mentioned she had read (again on the Giornale di Brescia) the name of the Isinnova as the company that has made the Venturi’s replica. Thanks to a phone call, an appointment was arranged, and the day after Dr. Favero was in the Isinnova Labs giving instructions to the team about the way a respiratory device should function and about how to modify the snorkeling mask he had with himself. Decathlon Italy was informed and it graciously offered help in the matter of hours making available technical design of the mask. By the evening of the second day, the prototype of the new adapted mask was tested successfully at the Chiari Hospital. Charlotte and Dave were the two names chosen for the new valves produced by Isinnova’s 3D printing machine.

4.3. Chapter C: ‘This is not mine but ours’

Days 8–18

Step: The logistics for scaling up production and making the new valves available to Hospitals throughout the world

Players:
- Isinnova Team
- Dr. Favero
- Decathlon
- Oldrati: An industrial group with headquarter in Bergamo, and plants in Italy and abroad. They produce a wide range of plastic products, including snorkeling mask for Decathlon.
- Makers Community: Thousands of makers all around the world that have been part of the game, working for the benefit of their communities.

As soon as the new mask was ready, the decision was made by Isinnova and Dr. Favero to have an open source not for profit approach to the production. An urgent request for a new patent of Charlotte and Dave valves was filed and a web section of the Isinnova website dedicated to EASY-COVID was made public, with technical design and files of the two valves ready to be downloaded and replicated for free by any makers wanting to do this.

Decathlon on its side declared to be open to give for free up to 10,000 snorkeling masks, to anyone interested to use. Compared to the Venturi’s valve, Charlotte and Dave, are more easily to replicate and any makers with the help of files and tutorials posted on the Isinnova website can do it by themselves. In the first days request from Lombardia were high, and makers from outside were asked to contribute to the production of the valves for the need of Region. In parallel with the makers community, a company specialized in plastic products (Oldrati), started to work with Isinnova to develop a plastic injection process to scale up production of the two valves. In less than 10 days, the new production process of the valves was ready and the first lot of 17,000 valves was ready to be donated to the hospitals requiring them.

The results were impressive. In about 15 days, 3,000 makers were involved in the project, hundreds of thousands of files of the valves were downloaded, about 150,000 valves were produced all over the
world, including less developed countries, and above all, many lives were saved.

5. Discussion: Lesson learned on the innovation process under severe constraints looking for local solutions and global applications

The Isinnova case, with the innovative and creative solutions developed under constraints of time and resources imposed by a pandemic crisis, well expresses and represents many of the features and spirit of frugal innovation: the search for innovative solutions that are not sophisticated but create high value at a lower cost and with limited resources. In the Isinnova case, those strategic drivers presented their own peculiarities. While these solutions are not sophisticated, they are very demanding from the engineering point of view: The caliber of the new valves is critical, it must adapt perfectly to the mask (Dr. Favero). The value created is not a monetary one but a social one: we decided, from the first meeting, that we would not ask for money, because the project had a value that surely went beyond work, beyond the professional, we enter the sphere of ethics (Mr. Abeni of Isinnova and Dr. Favero). The real impetus was not to reach a defined goal with limited budget, but to work with the ‘ingredients you have in the cupboard’, to follow the metaphor used by Sarasvathy to explain the concept of effectuation (Sarasvathy, 2001): I remembered the similarity of the Decathlon mask with some devices we used in the Hospital. Decathlon shop was closed, but one of my close friends had a Decathlon Mask (Dr. Favero).

In the way the R&D process was managed, we can find the application of many managerial principles associated to frugal innovation. Let us expound three of them.

1. Engagement with end users and rapid iteration of solutions: the fast modification of solutions developed on the basis of feedback provided by end users, represents one of the success’ factor of this case: As soon as I knew about these guys of Isinnova I gave a call to my friend in the Chiari Hospital asking to put me in touch with them, and the following morning I was in their lab with the Decathlon mask (Dr. Favero). The role of Doctor Favero was first of all to have had the intuition, he also explained to us in a very exhaustive way how the lungs and the respiratory system work to make us understand how to modify the snorkelling mask so it can work as a suitable ventilation mask (Mr. Abeni of Isinnova). As soon as the valves were ready, in the same day we tested the valves in our Hospital, monitoring their functioning according to our standards (Ing. Cirimbelli Head technicians of Chiari Hospital).

2. Capability to flex existing resources: repurposing and sharing resources in a larger network and making strategic choices to integrate manufacturing and logistics have been key in the success. In the very first phase, for the Venturi’s valve we involved one of our partners, the Lonati group, which made itself available to 3D-print the pieces at a larger scale. 3D printing of Venturi’s valves requires high precision printers, which Lonati is equipped with. The hospital needed around 100 pieces. In 24 hours, 100 valves were delivered to the hospital (Mr. Abeni of Isinnova). Flexibility was applied by Lonati itself: we have produced 400-500 Venturi valves, then, we asked for support from the companies that were nearby and had the opportunity to 3D print, because we couldn’t keep up with everything, of course. We therefore had the support of companies that had the exact same 3D machine as we have. We gave them the instructions for setup, I manually cleaned the valves, at the end to have the valve working (Ing. Faini of Lonati group). For the design and production of the modified mask, flexibility was even more important, thanks to a collaborative network in which Decathlon played a special role. We contacted the local Decathlon store, which put us in contact with the Decathlon Italia management, with whom we continued to interface. In a matter of hours they shared with us the details needed to design the new valves for their snorkeling mask (Mr. Abeni of Isinnova). In the subsequent phase of mass production Oldrati (an OEM of Decathlon) played a key role. We contacted them (referring to Isinnova) on the day when they made the design public, it was the week-end of March 22nd. We took their generic 3D design and at that point we said: nice design but we have to make sure that the product can be used in different contexts … whoever prints it has different materials and printers, there was the risk of sending uneven products to hospitals among them, fragile, who risked breaking. We made ourselves available to make an injection mold. On Monday 23rd we began to design the mold, on Saturday 28th, the mold was ready … in agreement with Isinnova, we said: we print and donate the injection-molded valves. We made 400-500 Venturi valves, then, we asked for support from the companies that were nearby and had the opportunity to 3D print, because we couldn’t keep up with everything, of course. We therefore had the support of companies that had the exact same 3D machine as we have. We gave them the instructions for setup, I manually cleaned the valves, at the end to have the valve working (Ing. Faini of Lonati group).

3. Repurposing of an existing production line: when we wanted to produce high-quality products for hospitals among them, fragile, who risked breaking, we made ourselves available to make an injection mold. On Monday 23rd we began to design the mold, on Saturday 28th, the mold was ready … in agreement with Isinnova, we said: we print and donate the injection-molded valves. We made 400-500 Venturi valves, then, we asked for support from the companies that were nearby and had the opportunity to 3D print, because we couldn’t keep up with everything, of course. We therefore had the support of companies that had the exact same 3D machine as we have. We gave them the instructions for setup, I manually cleaned the valves, at the end to have the valve working (Ing. Faini of Lonati group).
3. Co-creating value with communities: The makers community made a great contribution by co-creating value with their members. We could not cope with a huge demand from all over Italy and from abroad, so we created a dedicated area on our website where we made the design file freely downloadable. The file has been downloaded throughout Italy and abroad and massive production has started, of the pieces for the fittings by all the makers (Mr. Abeni of Isinnova).

The process that comes into play is an exceptional collaborative network in which many innovative people and firms work together to come up with an idea and co-produce a solution with great social impact. It represents a demonstration of the power of frugal innovation and agile thinking in the context of an ecosystem open to sharing knowledge and critical assets (Crupi et al. 2020) to solve a social crisis.

To date, thousands of Venturi’s valves and about 150,000 valves for the snorkeling mask have been produced all over the world. Some of the players, and notably Decathlon were already accustomed to the concept of frugal innovation, whose principles fit well with their agile R&D approach and a corporate culture that empowers local Subsidiaries. Doing more with less, favouring local resources, optimising production, thinking about a second life for our products right from the design phase and investing in cutting-edge technologies are just a few of the ways we are making this a reality. These approaches help us create more social value, be active where we are needed, have a positive impact and make Decathlon a sustainable company that innovates responsibly. The innovative ecosystem at Decathlon today is made up of multidisciplinary teams who promote innovation by designing useful, simple and eco-friendly sports solutions (Decathlon, 2020).

On the contrary, the decision-making process of the players in this case can be analyzed from the point of view of how they frame their goals. Here, the differences between effectuation and causation models of thinking can be helpful (Sarasvathy, 2001). Causation way of thinking is ‘effect dependent, that is, the final outcome is fixed but components and technologies can change. Effectuation way of thinking is ‘actor dependent’, that is, the components and the technologies available to reach an end of innovation are fixed and the effect can change. As reported in literature, these two approaches are not interchangeable in the process of developing a new product, but they are in a continuum with hybrid forms emerging in real cases (Ortega et al., 2017). There is certainly much of the Effectuation approach in the innovation process described here: We had 3d printing machine available (Lonati and Isinnova); I know snorkeling masks could be suitable and my friend lend me his Decathlon mask (Dr. Favero). But, we cannot say they were allowed to pursue whatever goal with the given components and technologies available at that moment in that place: the new devices should be fully compatible with existing infrastructures of the Hospitals. No tolerance margin admitted (Ing. Cirimbelli). Therefore, this study suggests a mixed approach that can be defined ‘realization’, i.e.: no choice is allowed between effects (goal to reach) and no choice (or very limited choice) is allowed between components and technologies to be used.

Interesting insights emerged from the interviews about how open innovation can tackle a societal challenge, a topic still in its infancy stage (Ahn et al., 2019). We decided to urgently patent the link valves (Charlotte Valve), to prevent any speculation on the price of the component. We clarify that the patent will remain free to use, because it is in our intention that all hospitals in need could use it if necessary (Mr. Abeni and Dr. Favero). The societal impact provided by Isinnova is evident being referred to significant or lasting changes in people’s lives, brought about by a given action (Roche, 1999, p. 21) delivering medical services to transferring core knowledge to the local communities (Chesbrough and Di Minin, 2014). One aspect that merits a further exploration is IP protection in cases of exceptional social challenges (Manzini and Lazzarotti, 2016). Here, the development of the Venturi’s valve (a product already on the market protected from a patent) and the development of the new valves for the Decathlon mask represents both stress tests for IP policies.

6. Implications

From the in-depth analysis of the case, we can draw some theoretical and practical implications.

First, the Isinnova case enlarges the theoretical body of frugal innovation underlining the relevance of a less studied concept, that is, that of frugal innovation as a personal mindset of key players (Soni and Krishnan, 2014). During COVID-19 crisis, there were many frugal innovation initiatives worldwide to make ventilators. Examples are the MIT initiative (http://news.mit.edu/2020/ventilator-covid-deployment-open-source-low-cost-0326) and the MakAir initiative (https://drone dj.com/2020/04/20/parrot-donate-5000-motor
s-for-ventilators/) in France. All these initiatives aimed at creating a new product from scratch and these ventilators were still costly ($100 to $1,000). But, Favero and Isinnova used their frugal mindset to see the potentialities of an existing and available product and exploiting the potential of 3D printing to transform them, at a very low cost.

Second, another relevant enlargement of frugal innovation theory is represented by the way by which frugal innovation principles and open innovation strategies interact each other's. While concept and prototype of the products developed by Isinnova, well fit with the principles of frugal innovation, their success on larger scale was due to a collective effort to share and to adapt the innovation with external partners, that is, applying an open innovation strategy. To scale up production Isinnova was able to connect with classic mass production companies (Oldrati and Lonati, luckily located in the same area of Isinnova) that were involved in transferring and adapting the technology on a more sophisticated level and with a different production scale.

Third, the paper provides some implications and indications on the impact of digital makers in the innovation process and for actions to prepare humane society for future challenges like COVID-19. Isinnova case shows that even if makers have a local dimension, thanks to the power of Internet, they easily can diffuse their innovation all over the world. To strengthen the makers' network is an effective strategy to respond flexibly to unexpected problems and to fully exploit the potential of wisdom of crowd. To connect the network of makers to local industrial systems for any rapid scale up is another important element in order to support innovation processes. This could be realized through the promotion of the culture of 3D printing in manufacturing companies.

Fourth, implications for intellectual property management also emerges from the case. More specifically, Isinnova case shows the necessity to reconsider the IP rules of the game in conditions where replicating IP protected products is essential because of temporarily unavailable products.

Fifth, another important implication coming from the role of Dr. Favero is about the opportunity to encourage experimentation and 'tinkering' in hospitals (frugal engineering can act as an 'antibody' during crises) and the importance to diffuse innovation culture/familiarity with technological aspects also in a clinical or medical context. Finally, recognizing the role of local media in mobilizing and connecting local actors is another important implication in terms of 'to do action' for boosting R&D process in a stressful condition, that derive from the study.

7. Conclusions, limitations, and future research

The article offers a real-life case study to analyze how digital makers have taken part in innovation processes to find fast and effective solutions during a pandemic event. The results of our study provide insights on how frugal approach to innovation is suitable to cope with an unexpected and extraordinary event like the COVID-19. More specifically, our paper sheds light on the way in which frugal innovation principles can interact with agile makers’ mindset and open innovation strategies in providing effective solutions on a local scale but with a potential global impact.

Following the quest for more contingency-based studies on open innovation and R&D performances, the study of action of makers during the pandemic has added thoughtful insights on the role and interconnections between individuals, communities, and organizations (Bogers et al., 2017). From this point of view, the study intercept at least three perspectives needed to further develop the theory of open innovation: User-center innovation perspective; Digital tools perspective; Institutional perspective (Gassmann et al., 2010). The present work is not without limitations that represent opportunities for future research. First, the paper suffers the limitation of a single case study concerning the generalizability of results. Further empirical studies should be necessary in order to analyze how frugal innovation approach is applied in different contexts and situations.

Moreover, the paper considers a specific crisis event that is the COVID-19 pandemic. Further research could consider how frugal innovation could be applied to face other kind of crisis and to study which role frugal innovation could have in post pandemic.

Acknowledgments

The authors are very grateful to Erika Naponiello for comments on paper and research support.

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APPENDIX A

Table A1. Interviewee roles

| Interviewee   | Role                                           | No. of interviews |
|---------------|------------------------------------------------|-------------------|
| Lorenzo Abeni | Senior Consultant at Isinnova                   | 2                 |
| Davide Cirimbelli | ICT and Biomedical Technologies Department – ASST Franciacorta | 1                 |
| Michele Faini | Designer at Lonati S.p.A.                       | 1                 |
| Renato Favero | Retired Head of Intensive Unit of the Gardone Val Trompia Hospital | 1                 |
| Renato Mutti  | Operations director at Oldrati Group            | 1                 |