R&D Management at a time of crisis: what are we learning from the initial response to the Covid-19 pandemic?

Letizia Mortara, Raffaella Manzini, Lawrence Dooley, Valentina Lazzarotti, Alberto Di Minin, Andrea Piccaluga

Picking up from where we left (Di Minin et al 2021): a reminder of the nature of this Special issue

"*In the days and weeks ahead, we expect to see the number of cases, the number of deaths, and the number of affected countries climb even higher. WHO has been assessing this outbreak around the clock and we are deeply concerned both by the alarming levels of spread and severity, and by the alarming levels of inaction. We have therefore made the assessment that COVID-19 can be characterized as a pandemic. Pandemic is not a word to use lightly or carelessly. [..] We have never before seen a pandemic sparked by a coronavirus. This is the first pandemic caused by a coronavirus and we have never before seen a pandemic that can be controlled, at the same time.*"

With these words (March 2020), the Covid-19 pandemic was declared by the Director-General of the World Health Organization (WHO). In May 2020 we made the call to the innovation research community for contributions, as we wanted to capture the emergent learning as the innovation machine kicked into action to fight the emergency. We recognised the importance of documenting what was happening as it occurred, so that this and other future grand challenges could be more effectively tackled. The idea was to collect case studies about how different players in society were innovating to face the crisis, and for authors to reflect on what they were learning and how this evidence could inform our academic discipline going forward.

We received 113 submissions from around the world, exceeding any of our initial expectations. These led, through a thorough process of double-blind reviews, to 28 papers published in this special issue, which were made available throughout 2021. Whilst we are conscious that this sample does not represent the complete story of innovation during this time of crisis, and that much is still happening, we have chosen this point to pause for reflection on the contributions captured across the summer and autumn of 2020 in this special issue call.

In reflecting, we attempt to summarise what we learned from these initial responses to the crisis, from the first knee-jerk reaction to the acute phases of the pandemic. While the global dream of a definitive innovation-led solutions to the crisis has not yet been delivered on, initiatives have brought significant value for society and enhanced our knowledge understanding for further developments. Thus, while the world still struggles with the Covid challenge, initiatives to date have generated interesting learning regarding innovation under acute crisis, where players have a 'sense of urgency' and still possess the energy to react and test new approaches.

So now, let us turn our attention to what have we learned about the acute response to the Covid-19 pandemic based on the cases captured in this SI?

Fighting the pandemic: innovation practice under acute crisis

We have grouped the contributions around intertwined themes to discuss the emerging evidence.

Competences vs capabilities

Whilst in many sectors such as hospitality, aerospace and automotive, key competences became suddenly difficult to deploy according to known patterns, many examples in the contemporary press showed the importance of certain core competencies for facing the crisis and the advantage gained by the organizations holding them. It is enough to think about the amazing success of the companies holding the knowledge on the development of mRNA vaccines. Also, *digitalization* competences were not only the basis for the creation of very successful firms (think at the shooting trajectory of "Zoom"), but were also fundamental to all in society, as they provided an alternative channel for social interaction, as strict lockdown became reality. Digital competences facilitated the transfer of organisational processes online, underpinning remote working, and in some instances, even introduced new business models. These competences, together with digital platform infrastructure, allowed the development of many transversal initiatives to enable knowledge sharing between players towards the creation of innovation (e.g. via hackathons, crowdsourcing, communities, and fab-spaces).

However, more than discussing what type of capabilities were fundamental in fighting the crisis, the papers collected in this SI showed that the sources of key *innovation competences to fight a crisis are distributed across a variety of players* in society (Companies, Universities, Individuals). When harnessed, mixed and focused thanks to a compelling and powerful societal goal such that of fighting the pandemic, distributed competences can deliver important contributions. We found evidence that players in all categories were willing to share what they knew and owned to support the development of innovation to counteract the pandemic, even in conjunction with direct competitors (e.g. Marhold, 2021). One of the practices adopted by those owning IP has been to offer it freely to those who could employ it for fighting the pandemic: Antonelli et al. (2021) studied the Open Covid Pledge, subscribed by companies who pledged *"[..] to make [their] intellectual property available free of charge for use in ending the Covid-19 pandemic and minimizing the impact of the disease"*[1]. They found that the competences companies were willing to share are mostly technologies to be used to demand and search contextual information and for creating virus-detecting devices.

Moreover, a variety collaboration formats aimed at mixing competences, was described in the special issue (e.g. crowdsourcing, consortia, hackathons, etc.). These activities were not only initiated by firms, but were also led and deployed by other players with the intent of enabling new mechanisms to derive innovation and produce needed goods. We collected examples, particularly around the design and production of novel medical equipment (such as ventilators and personal protective equipment PPE). The story of the Isinnova mask - originally conceived as a scuba-diving product which was re-designed by makers into an emergency ventilation equipment – featured heavily and showed that competences of individuals could create high impact results through frugal innovation processes, i.e. even in environments where competences are scarce, in both high and low-income countries (Corsini et al., 2021; Vesci et al., 2021). In general, we saw many examples of *less-traditional sources of competences,* leveraged in the initial pandemic response, showing that there was a desire from all sides to engage and be useful to fight the crisis. Fabrication spaces (Abbassi et al., 2021) distinguished themselves as pools of highly reconfigurable innovation and manufacturing competences both in physical and in digital (Vesci et al., 2021) forms. This evidence confirms the role of fab-spaces in catalysing entrepreneurship and innovation (Mortara and Parisot 2018; Mortara and Parisot 2017) and encourages the idea that it would be important to support and maintain such competences and resources beyond the time of crisis, so that they could act as reservoirs of re-deployable competences. Competences were also brought together from universities and

[1] https://opencovidpledge.org

partners to quickly design reliable, cheaply deployable ventilators (e.g. see the story of the Mechanical Ventilators Milan (MVM) (Di Guardo et al., 2021) and in the UK (von Bher et al., 2021).

The discussion into the role of *capabilities* in the fighting of the crisis was however more represented across the SI. Several papers presented results regarding how companies repurposed their competences and were able to use them either to meet the needs of society and/or to remain economically viable (e.g. Hanish et al., 2021; Liu et al., 2021; Ardito et al., 2021; Bergami et al., 2021; Puliga et al., 2021; von Bher et al., 2021; Radziwon et al., 2021; Clauss et al. 2021; Ferrigno et al. 2021). These papers link several concepts present in extant literature (e.g. exaptation, effectuation, agility, lean processes, ecosystems building, open innovation, business model innovation, and exploration and exploitation (Mastrogiorgio and Gilsing, 2016; Berends et al., 2014; Brand et al., 2021; Prajogo et al., 2016; Oh et al., 2016; Chesbrough, 2003; Massa and Tucci, 2013; March, 1991)) to that of dynamic capabilities (Teece et al., 1997; Puliga et al., 2021), showing how firms quickly sensed, seized and were able to reconfigure at the time of crisis. This special issue has reinforced the connection amongst these concepts and confirmed the role of open innovation, and in particular the outbound mode, in the response to a crisis (Di Minin et al., 2010; Ahn et al., 2018). For instance, exaptation (Mastrogiorgio and Gilsing, 2016) allows companies to find new applications for their core competences. This is a dynamic capability, already described and linked to open innovation processes (e.g. Chesbrough and Chen 2015), which has been widely observed by the authors of this SI in a number of companies since the start of the Covid-19 pandemic (e.g. Ardito et al., 2021; Liu et al., 2021). Some companies could be agile to deal with the crisis, leveraging the capability to 'effectuate', to reshuffle their competence, looking for complementary ones, to enact new business models and creating new ecosystems (Radziwon et al., 2021), sometimes even temporarily (Clauss et al., 2021). In sum, it is no surprise that dynamic capabilities are confirmed as antecedents of firms' resilience (Bergami et al., 2021; Soluk et al., 2021), but there was also evidence that governments demonstrated a high level of adaptation (Patrucco et al., 2021), as they revisited their innovation instrument programmes to encourage innovation and open innovation approaches in fighting the crisis.

Bottom up or top down? The importance of coordination capabilities and processes

As we anticipated in our interim editorial (Di Minin et al. 2021), bottom-up solution provisions played an important role in the initial stages of the pandemic. Examples include those brought forward above, whereby innovation emerged from groups of skilled makers, or it was sought through crowdsourcing and hackathon exercises. Other examples highlighted the role of "users" in this phase of the pandemic (e.g. doctors (Park et al., 2021) or patients (Garcia et al., 2022), but also self-organizing entrepreneurial agents (e.g. university students creating apps to identify where face masks are available) (Park et al. 2021). However, the top-down impetus to solve the crisis was not absent in the collection: for example, in the UK, a number of consortia appeared as a result of the government incentives to identify new sources of ventilators (von Behr et al.), whilst Crupi et al., (2021) describe the responses to the Chinese government's call for entrepreneurial firms to embrace the social challenge of delivering medical supplies.

Both directions of innovation had merits and yielded results. However, in particular for the bottom-up solution, the challenge of coordination emerged throughout. For instance, if analysed at a macro level, the act of repurposing innovation to identify ways to contrast the pandemic was characterized by inefficiency and coordination problems (Hanish et al., 2021). These authors analysed the new clinical trials during the initial stages of the pandemic, which

showed that many companies ended up looking into the 'low hanging fruits', replicating efforts in testing the same drugs and leaving other opportunities untapped. Although derived less scientifically, a similar conclusion could be drawn if we consider the number of new ventilators challenges reported in our sample of papers, as many separate initiatives tried to address the same problem around the world.

The SI provided some answers regarding how coordination capabilities have emerged across the bottom-up impetuses: the *role of communities and digital platforms* was clear, in promoting the co-development and distribution of solutions to patients problems (Garcia et al., 2022). For instance, the case of the community-based digital contact tracing in Wuhan (Boeing and Wang, 2021), showed how the platform and the community could mediate between the needs of the government of enforcing a system to monitor the spreading of Covid-19 and the needs of citizens to feel less exposed and that their information was managed ethically. Knowledge management and project management capabilities as well as community-building themes emerged across the SI, both illustrated in the description and role of hackathons and crowdsourcing (Bertello et al., 2021; Vermicelli et al., 2021; Kokshagina, 2021) and within projects across consortia (von Behr et al. 2021; Di Guardo et al. 2021). Other coordination mechanisms were proposed through the uses of tools: Guderian et al., (2021) reminds us of how patent analytics could be applied to detect where key competencies reside, whilst Whal et al. (2021) promote adoption of data mining tools to analyse the landscape of key problems that need solving in a pandemic. It strikes us that if used in combination, these two approaches support the assemble the right competences, around the key problems emerging and could be powerful tools for coordinating efforts.

Internally to firms, the increase of stress generated by the crisis led to an increase of innovation when high knowledge sharing mechanisms were present (Montani and Stagliano, 2021), indicating that knowledge sharing is fundamental coordinating capability to reduce the pain of shocks and to constructively channel the energy into innovation.

Changes in value logics and processes

Unsurprisingly, the desire of providing solutions to the pandemic helped in providing focus to innovators across companies and communities. However, more poignantly, we noticed how companies' and governments' logics shifted in this initial crisis phase from being driven by a traditional, purely economic value paradigm, to a societally-driven one (Ahn et al. 2019). This shift towards a "purpose-led" logic (Ferrigno et al. 2021) was universal across the sample, in both large (e.g. Bergami et al., 2021; von Behr et al., 2021) and small (Battaglia et al., 2021; Clauss et al., 2021) companies. Even very large 'arch-competitor' companies such as Apple and Google joined forces in the name of a societal value logic: developing the standard for bluetooth technology that enabled contact tracing across the world (Marhold, 2021). Further, companies participated in different initiatives to share their knowledge and pledged to license IP for free to those who were going to use them to fight the pandemic (Antonelli et al., 2021). In smaller companies, such as academic spin offs, the need to fulfil a societal need generated by the pandemic became a value to pursue, the catalyst to identify a market where to direct technological capabilities (Battaglia et al., 2021). Also, the societal value imposed from governments acted as a stimulus for entrepreneurial behavior (Crupi et al., 2021), not only addressing Covid-era needs but also generating economic value within their regions. We have seen that the capability of being successfully driven by societal value logics can be useful and potentially may continue helping with fighting Covid-19 further. Going forward we might need to consider how the mechanisms which led to this shift of logics could be redeployed also to counteract the other grand challenge crises that are on the horizon. As we are facing an

increasingly looming scenario of permanent crisis derived by global warming, would the example of using societal values as drivers for innovation and succeeding through these allow firms and markets to recognize and address also these societal challenges more effectively?

The change in behaviour was not just about values, and how companies sought to shift strategically to pursue societal value, but also about how organisations operated. Governments shifted their innovation policies and the intensity of instruments used to encourage Open Innovation (Patrucco et al. 2021). Family firms, traditionally characterized by less flexibility and higher risk aversion, changed behavior (Soluk et al., 2021), increasing cohesion across stakeholders, introducing less rigid mental models, and implementing digital technologies. SMEs managed to introduce temporary business models meant to survive the crisis but not intended as final solutions (Clauss et al., 2021). An interesting trajectory of study into the future might be what will be the long-term consequences of these changes for the venture, its industry and wider society in terms of which will dominate in the long term and why?

Where does this lead us?

Below we conclude with a few thoughts, embracing questions and approaches for future work.

Everyone wants to get involved – what are the consequences?
When an emergency like this arrives, everyone tries to get involved. We have seen how, besides the power of the compelling societal goal, the availability of digital technologies allowed systems to come together very quickly across boundaries, not only to promote designing innovation, but also to facilitate the creation of new manufacturing systems which could produce what was needed, such as PPEs or ventilators. Even if digital platforms, knowledge sharing and communities have been useful for coordinating these efforts, an additional need for coordination has emerged from articles in the SI. Nevertheless, this distributed capability (Srai et al. 2016) has demonstrated its value as a fundamental 'hole plugger' when the well-oiled machines of 'just-in-time supply chains' stop. This example demonstrates the value of redundancy in competences and of a pervasive digital infrastructure. This calls for adopting new rationales in the evaluation of performance in innovation, traditionally geared towards efficiency and effectiveness, to accommodate 'just in case' scenarios.

Further, when crises develop, governments are pushed to take swift action under strong pressure from the public. Many governments reacted at the start of the pandemic shifting to introducing instruments supporting open innovation model. However, as we realized with other types of instruments (Ahn et al., 2020), that different instruments lead to different behavioral consequences and thus we need to verify the effects of such policy changes.

A way forward for innovation management for facing crises: innovation management education, complexity theory and a call for continuing to keep tabs

Overall, the set of case studies reported in this SI brought forth evidence of approaches that in many ways existed prior to the start of the pandemic. Even the IP Pledge mechanism was not per se new, as for instance Tesla has pledged IP since 2014 with the aim of stimulating the development of the electric vehicles market[2]. However, many of the activities developed in this first stage of the pandemic seemed to be stemming organically, and we wonder how much these activities were inspired by the learning our discipline has offered to date. We fear that, although

[2] https://www.tesla.com/blog/all-our-patent-are-belong-you

innovation management models were developed by our discipline, the impact of our research is still weak compared to what it could be. If this is the case and we do not do anything going forward, every crisis will see a repetition of past approaches without the benefit of the hindsight. Hence, we think that encouraging an innovation management education should be paramount. We should spend energy to encompass the basis of the discipline in professional curricula so that physicists, biologists, doctors, and all the specialists, who might play a potential role in innovation, will not have to learn from their own experience in real time when fighting a crisis but instead have theoretical grounding to inform their innovation decisions.

Secondly, a suggestion for innovation management scholars: from what we have seen, innovation contributed to find solutions when actors, structures and infrastructure were able to act as a unique complex and dynamic eco-system. In the covid scenario, this was where patients, institutions, hospitals, doctors, fablabs, universities, small and large innovative companies and individuals with high capacity and resources came together within systems that co-evolved. Such evidence suggests an intuitive connection with complexity theory - originated in the natural sciences by the Nobel Prize winner Prigogine in 1977 - and complex adaptive systems theory (Holland, 1992; Kauffman, 1993; Miller 2009). These theories adopt a research approach in which all systems are composed by actors (agents), among which the boundaries are not clearly defined and in constant state of flux, and among which, non-linear, dynamic, adaptive interactions occur. Complex systems are characterized by non-linear relationships among the agents and with the environment, which is the medium in which all interactions and relations emerge (Poutanen et al., 2016; Cilliers, 2016). Many different actors are able to move as a single, harmonic, integrated system continuously improving its wellbeing and survival. This picture aligns with the systems described and investigated in this special issue, and with how they changed in order to guarantee the survival of agents involved, as the pandemic evolved. Complexity theory and complex adaptive systems theory are starting to be applied in the innovation management field (among others, Battistella et al., 2018, Poutanen, 2016, Dougherty, 2017), where innovation is studied as a complex eco-system, intrinsically open (Poutanen, 2016). These theories seem particularly useful looking forward as we will need to confront the problems emerging from many looming “grand challenges”, such as climate change, energy, water and resource scarcity, poverty, health crises and overpopulation. However, complementing current theories with complexity theories implies some change in the way we - researchers and managers operating in the field of R&D and innovation management – setup our research. For instance, we think that for such problems we should:

- Avoid a strong distinction between micro-meso-macro perspectives of investigation. Innovation and R&D management cannot be studied at the firm level, without considering the companies network in which firms operate, the institutional and policy-making actors, the surrounding societal, cultural, political environment. This means reducing the cognitive and methodological barriers that sometimes separate studies in innovation management, economics of innovation, innovation and industrial policy, organization and organizational behavior.

- Consider ambiguity and emergence as a characteristic of innovation systems, that cannot be (and shouldn’t be) totally eliminated by control systems. Ambiguities, lack of (or reduced) rationality, system redundancies, are characteristics that allow complex systems to dynamically evolve together with the agents in the environment, and to survive in the long run. Controls mechanisms need only to be implemented in order to allow innovation systems to rapidly adapt, as in natural systems.

- Avoid over-simplified models, as complexity cannot be reduced by separating the parts of the system. On the contrary, separating them would have us miss interactions and relations,

which are fundamental parts of complex systems. This means favoring a holistic perspective in studying and practicing innovation.

- Not limit research to hypotheses verification or testing, so as to better deal with the issue of "emergence" within in complex systems. For this, explorative research is fundamental, with both inductive and abductive reasoning applied, i.e. "the process of reasoning in which explanatory hypotheses are formed and evaluated" (Magnani 2001), to deepen our understanding.

Is what observed short-term or long-term innovation?

Finally, what we distilled in this SI needs to be considered very much in Darwinian terms as part of the 'variation' phase of the innovative cycle, before a 'selection' cycle sifts the winning solutions (Nelson and Winter, 1982). Unfortunately, at the end of 2021, despite much innovation helped with fighting against the virus and its economical and societal consequences, we are still wrestling with a new Covid-19 variant strain. As the crisis is continuing, morphing, as the repercussions are still in action, innovation hasn't certainly stopped! Furthermore, questions still need to be answered: we still need to understand which of these approaches has yielded the best results, which has been useful in the short term, which has instead been maintained longer and how have these efforts changed over time. How could we make sure that some of the results and approaches are sustained? Would the dynamic capabilities gained through this crisis be long term or short term? How will they be deployed beyond the crisis? How quickly do actors revert to 'old models' if a new 'normal' is established?

These and many other questions relate to the capabilities of systems to maintain momentum and to be able to use a crisis to build the important capabilities to face what's ahead of us.
We hope that the community will continue taking stock of the lessons we are learning and make them available for the future. While this Covid-19 SI is now formally closed, the R&D Management journal will be pleased to receive further submissions on future learnings from the crisis as the research develops.

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