R&D MANAGEMENT

Exploring the Open COVID Pledge in the fight against COVID-19: a semantic analysis of the Manifesto, the pledgors and the featured patents

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Coronavirus disease-19 (COVID-19) has stimulated urgent innovative responses to tackle the current crisis and unveil new trajectories enabling recovery as early as possible. In the quest for solutions to the pandemic, organizations have been forced to join efforts with an unprecedented number of different stakeholders, including competitors, rising new appropriation-related challenges. To ease these issues and facilitate collaborative efforts, some initiatives have come into being to encourage the release of Intellectual Property (IP) rights to unlock new possibilities from their use and possibly foster the collective innovation process. The Open COVID Pledge (OCP) stands out as the most visible project that has gained momentum at the international level, as it has increasingly involved well-known top-patenting companies, willing to publicly commit to making their IP relevant to COVID-19 freely available. Drawing from all the available information (the World Wide Web, the participating companies' press releases and official websites, and the documents of pledged patents), we propose a research design, applying a semantic method to allow an augmented understanding of the main characteristics of this pledge. Our findings point out that the OCP has got a great media resonance on the overall web, also thanks to the commitment of large top-patenting pledgors; results also show that while the official communications of the participant companies resemble very much the general OCP Manifesto of providing free access to their patent portfolio, the semantic analysis of the pledged patents unveils details on available technologies that mostly refer to the real-time search and analysis of information and devices for the detection of the diffusion of the virus. Overall, this analysis contributes to providing contextual information on the available IP, towards the desired direction of putting the pledge to work and have an impact on follow-on innovation, which represents the underlying rationale of the initiative in the fight against COVID-19.

1. Introduction

The coronavirus disease-19 (COVID-19) pandemic has affected not only countries' health systems but also global economies, depicting times of high uncertainty (Chesbrough, 2020; Coccia, 2020a, 2020b; Wenzel et al., 2020). At the same time, however, the urgency to find means of enabling the recovery has forced and led to exceptional progress in innovation practices (Chesbrough, 2020). Firms have experienced that their survival and success are tied to the ability to navigate new opportunities,[1] embracing a more collaborative attitude to unlock the collective innovation ability (Chesbrough, 2020; McGahan et al., 2021). Governments, scientists, educators and companies of different sectors have therefore committed themselves – sometimes for their first times – to global collaboration on an unprecedented scale to cope with the effects of the pandemic more efficiently and rapidly (Ratten, 2020; Younes et al., 2020). The efforts committed to the development of the *COVID-19 Open Research Dataset*,[2] as well as the crowdsourcing-based industrial reconversion of many manufacturing firms, represent illustrative cases of this trend (Chesbrough, 2020). Overall, this evidence has shown 'how a sense of urgency can truly fuel open innovation' and stimulate the organizations to open their boundaries to jointly tackle societal challenges (Chesbrough and Di Minin, 2014; Chesbrough, 2020; McGahan et al., 2021, p. 55).

Nevertheless, these extraordinary Open Innovation (OI) efforts have brought about new appropriation-related challenges, because organizations have found themselves collaborating with an unprecedented number of different stakeholders, including competitors (Heled et al., 2020; Moerchel et al., 2020a; Tietze et al., 2020a, 2020b). Facing these challenges, and to facilitate these collaborative efforts, organizations have been encouraged 'to adopt an Intellectual Property (IP) perspective on the currently unfolding COVID-19 pandemic' and re-design and increasingly apply IP management practices (Chesbrough, 2020; Tietze et al., 2020a, p. 2).[3] For instance, at the company level, Medtronic[4] has opened its IP rights (i.e. patents) to increase the production of efficient ventilators, and Isinnova[5] patented its Charlotte valve, however, making it freely available to help hospitals. At a collective level, there has been an increasing adoption of patent pledges to make IP relevant to COVID-19 freely available to potential users. Among these, the Open COVID Pledge (OCP)[6] has gained international resonance as it has attracted an increasing number of well-known innovative companies (such as Facebook, Intel, Microsoft and Amazon) that have publicly married the cause. Their commitment has spurred many complementary 'similar programs and initiatives [which] align squarely with those reflected in the Pledge',[7] such as the World Health Organization Access to COVID-19 Tools Accelerator[8] and the Open COVID-19 Declaration[9] signed by a group of Japanese technology companies to allow the free availability of their IP in support of stopping COVID-19 (Chesbrough, 2020; Contreras et al., 2020; Cotè et al., 2020; Heled et al., 2020; Srinivas, 2020; Younes et al., 2020; Tietze et al., 2020a, 2020b).

Albeit patent pledges are not novel IP practices, the COVID pandemic has revitalized their adoption and diffusion, especially for those classified as 'mission-oriented', pursuing philanthropic objectives, such as the growth of social welfare through faster recovery from the crisis (Maggiolino and Montagnani, 2017; Contreras, 2018; Contreras et al., 2020; Tietze et al., 2020a, 2020b). Given the relevance of this large-scale collective pledge, leading scholars and practitioners have stimulated the debate about how to put this pledge to work,[10] towards the desired direction to stimulate follow-on innovations and hence find factual solutions to the pandemic (Contreras et al., 2019; Chesbrough, 2020). In fact, related evidence suggested that simply publishing patent lists seldom results in follow-on innovations in the absence of contextual information on the complex technologies at stake (Contreras et al., 2019).

Inspired by this debate, the paper aims to provide an augmented understanding of OCP's main characteristics, which may inform potential users. Aiming at this, we also contribute to responding to the call for dissemination of these emerging best practice actions to aid current and future efforts in the fight against COVID-19.[11] To do so, by applying the text mining approach and semantic methods to all the available information on the OCP, we pursued a threefold study along the following directions of: (1) understanding how the overall web resonates with the Initiative and the main related concepts (*OCP Manifesto Overview*); (2) comprehending the nature of pledgors' commitment (*OCP Pledgors Overview*); and (3) deep diving on the characteristics and contents of the pledged IP portfolio (*OCP Patents Overview*).

Based on the semantic analysis, we found that the OCP has attracted a huge amount of interest from the overall web and this is also confirmed by the globalization of the movement that has stimulated, and still does, an increased number of complementary efforts all around the globe from different types of organizations.[12] What is also interesting is the bandwagon effect of some of the big companies, such as

Microsoft, Amazon, Seagate and Morgan Stanley, which catalyze most of the relations that have emerged to the surface. Second, our findings reveal that the pledgors' participation statements sound very similar and broad, and the main words that emerged from the semantic analysis are all centered around the OCP Manifesto to make their IP freely available. Hence, the patent analysis has offered richer insights, as it allowed to understand the content of the pledged technologies, which overall seems to be related to the real-time search and analysis of information and devices for the detection of the diffusion of the virus.

The remainder of the paper is organized as follows: Section 2 provides the theoretical background of the study, recalling the extant literature on the OI and IP management practices, with a specific mention to patent pledges, concerning the pandemic. Section 3 introduces the OCP initiative as a setting of our study and describes the applied research methodology. Section 4 presents the discussion of the results of the analysis across the three studies (*OCP Manifesto Overview*; *OCP Pledgors Overview*; and *OCP Patents Overview)*; finally, Section 5 finalizes the paper, highlighting the implications and limitations of the study and putting forward future avenues of research.

2. Theoretical background

As the OI principles are increasingly diffused, firms are more frequently engaged in collaboration activity with external and diverse partners; it, therefore, becomes imperative for them to decide whether and to what extent they should be open but still capable of capturing value from their internal R&D investments. The relevant literature has called this appropriation dilemma the 'Open Innovation paradox', because of the inherent tension between the firms' urgent necessity of sharing and the everlasting need of protecting the source of their competitive advantage (Bogers, 2011; Di Minin and Faems, 2013; Laursen and Salter, 2014; Arora et al., 2016; Leone, 2016).

Besides investigating the conditions under which is more severe, such as in the case of collaboration with universities or research organizations, authors have also suggested how companies could tackle the paradox, through the deployment of ad hoc practices to find the optimal balance and reap the best gains from the collaboration (Bogers, 2011; Di Minin and Faems, 2013; Laursen and Salter, 2014). One above all, the proactive management of IP rights has attracted the interest of scholars and practitioners. In this new perspective, IP rights are deemed to increase the effectiveness of R&D collaborations, enabling safer exchange, through the reduction of opportunistic behaviors (Bogers, 2012; Ritala and Hurmelinna-Laukkanen, 2013; Hagedoorn and Zobel, 2015; Henttonen et al., 2015; Leone, 2016).

This new way of looking at IP rights as knowledge-sharing facilitators, rather than legal tools for exclusion, represents the underlying rationale of the design and adoption of patent pledges,[13] which have recently taken hold in the innovation scene (Contreras and Jacob, 2017; Maggiolino and Montagnani, 2017; Contreras, 2018; Chesbrough, 2020; Kim, 2020). They can be defined as 'a publicly announced intervention by patent owning entities ("pledgers") to out-license active patents to the restricted or unrestricted public free from or bound to certain conditions for a reasonable or no monetary compensation using standardized written or social contracts' (Ehrnsperger and Tietze, 2019a, p. 6). Besides technology-standard setting dynamics and patent asserting behavior to avoid authorities' unfavorable treatments, these voluntary private tools have also served other objectives such as open-source software development, green technologies and biosciences diffusion, and even the collective and philanthropic promotion of the common good (Contreras and Jacob, 2017; Contreras, 2018). An illustrative case is the Eco-Patent Commons,[14] made by big businesses 'to prove their green credentials by sharing environmentally friendly innovations with their competitors […] for mutual and wider social benefit' (WIPO[15]; Contreras, 2018; Contreras et al., 2019). From an OI perspective, hence, patent pledges make the promise to be effective means for diffusing technology and promoting innovation, through sharing (Chien, 2015; Ehrnsperger and Tietze, 2019b).

With the unfolding of the pandemic, a high number of OI initiatives have emerged globally, to 'prevent duplication, reduce redundancy, and create synergies based upon specialization and labor division' (Younes et al., 2020, p. 5), hence, proving the strategic role of openness also – or even especially – in the case of emergency (Chesbrough, 2020; Tietze et al., 2020a, 2020b; Younes et al., 2020). However, in this scenario, the 'paradox of wanting to collaborate but also safeguard one's own interest'[16] (Ratten, 2020, p. 5) has been exacerbated given the time constraints and the multitude of actors involved. Facing these new IP-related challenges, some authors have offered a multi-stakeholders framework to allow for more timely IP considerations (IP ownership, relevance, technological coverage, etc.), during a pandemic, to avoid obstacles in mobilizing resources needed for the development and mass manufacturing of Crisis-Critical Products (Moerchel et al., 2020a, 2020b; Ratten, 2020; Tiezte et al., 2020a, p. 1;

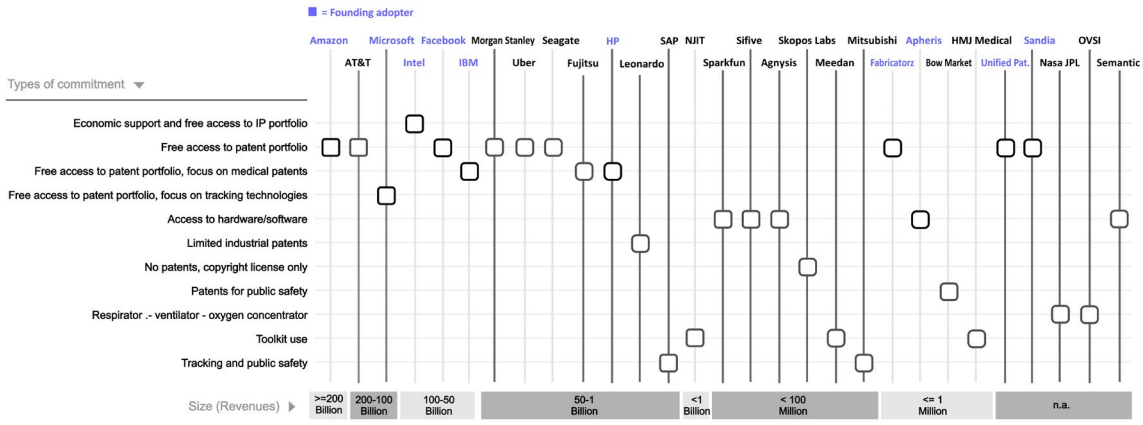

Figure 1. Pledgors type/size and commitment. *Source:* Authors' Elaboration (2021).

2020b). Others have analyzed the voluntary pledges[17] to make IP broadly available, suggesting that they can overcome the hurdles faced by more elaborate legal arrangements such as patent pools and be more widely accepted than governmental compulsory licensing (Contreras et al., 2020). However, the same 'lightweight, self-executing and sometimes broad nature of pledges could, without ongoing stewardship and active assessment of the rights being made available, challenge users seeking to find specific pledged IP' (Contreras et al., 2020, p. 1148). In fact, evidence on the Eco-Patent Common showed that only making available and listing these IPs was not enough to put the pledge to work as potential users needed contextual information and accessible understanding to find applications of the pledged patents (Contreras et al., 2019). Hence, making sense of the huge amount of IP knowledge to allow the potential user to 'learn what IP are available'[18] is paramount to ensure that these large-scale collective pledges have an impact on the follow-on innovation process, based on the dissemination or use of pledged technologies, for the achievement of the societal goal of recovering from the crisis.

3. Research design

3.1. Case selection and description

The OCP initiative was launched in April 2020 with a call 'on organizations around the world to make their patents and copyrights freely available in the fight against the COVID-19 pandemic'.[19] In few months, the OCP has attracted an incredible number of companies, well known for their international reach and mostly for their intense patenting activity, and hence with the capacity to lead the way for other high-tech leaders to join this effort.[20] As a result, it has started a global movement involving an increasing number of complementary initiatives all around the globe (Chesbrough, 2020; Contreras et al., 2020; Tietze et al., 2020a, 2020b; McGahan et al., 2021). The 'openness' of the OCP builds upon four main pillars: first, the pledge is open to all types of organizations who want to contribute to the fighting against COVID-19; second, it addresses the unrestricted public, interested to apply the available IP, but 'solely for the purpose of diagnosing, preventing, containing, and treating COVID-19'[21]; third, the participation scheme encompasses two types of commitment, either as pledgor or supporter. Only in the former case, there is a legal commitment to make the pledge and allow the free use of a portion of internal IP; and fourth, besides some possible personalization,[22] the basic conditions of the pledge claim a 'non-exclusive, royalty free, worldwide, fully paid-up license (without the right to sublicense)' to the potential user.[23]

As a preliminary analysis, we classify pledgors companies according to their size and type of commitment. We collected data on revenues[24] from Orbis and Nexis Uni,[25] and we enucleated firms' statements of participation as taken from their press releases. We identified 11 main categories, ranging from more general statements to more specific ones (related to practice) (Figure 1). First, the picture shows an even distribution in terms of size, albeit many founding adopters[26] are clustered on the left side of the chart representing very large companies. Regarding the type of commitment, most of the companies are clustered in the upper side of the figure, therefore being in line with the general intent of allowing free access to their portfolio relevant to fight COVID-19. This is especially true for the founding adopters, except for Microsoft that has communicated a specific focus on tracking technologies and IBM that focuses on

medical patents; but it also applies to well-known pledgors that have joined later, like AT&T, Uber and Seagate. Different considerations can be brought forward if we look at the lower section of the figure, where we can detect a more specific type of commitment, both in terms of fields (medical, hardware and software) and in terms of applications (tracing, ventilator, toolkit, etc.).

As a second preliminary analysis, we described the 22 pledged patents showcased on the OCP website.[27] We collected the available patent cards and complemented the information with the main patent statistics[28] (IPC[29] technological classes, claims, backward and forward citations) drawn from Google Patents[30] and Espacenet.[31] The table in Appendix A shows that the selected patents belong to four funding adopters (Facebook, Intel, IBM and Sandia National Laboratories) and five additional pledgors (AT&T, Mitsubishi Electric Research Labs, the New Jersey Institute of Technology, Uber and Fujitsu).[32] Most of these patents represent very novel pieces of knowledge (five of them were granted between 2019 and 2020 and six are still pending), and they mostly refer to the G06-Computing; Calculating or Counting[33] (seven patents) and H04-Electric Communication Technique (five patents) IPC classes. Besides, many of them report about 20 claims but show, as expected, a minimum number of forward citations (with some notable exceptions of Intel's pending patent – US20200128006A1 – with 54 citations). On the contrary, most of the patents display an average of 25 citations (with a peak of 133 for AT&T's patent, US7298836B2). This means that, albeit they were filed very recently, those patents do not represent novel knowledge in absolute terms, as they tap into a well-established state of the art, as also demonstrated by the scarce presence of non-patent/scientific literature (except for Sandia's patent – US8163154B1 – with 22 references).

4. Research method

In this study, modern Innovation Management methods are used, according to the recent calls of top journals, to contribute to methodological diversity (Tseng et al., 2007; Choi et al., 2013; Ghazinoory et al., 2013; Lee et al., 2014; Han and Sohn, 2015; Arts et al., 2017; Moehrle et al., 2017; Antons et al., 2020; Faems, 2020; Ritala et al., 2020). More specifically, this study implements semantic methods to leverage the hidden potential of unstructured data to unveil original and novel data insights (Faems, 2020; Ritala et al., 2020). For what concerns the unstructured data related to patents, we applied IP Analytics, with specific references to text mining approaches and semantic methods (Aristodemou & Tietze, 2017, 2018).

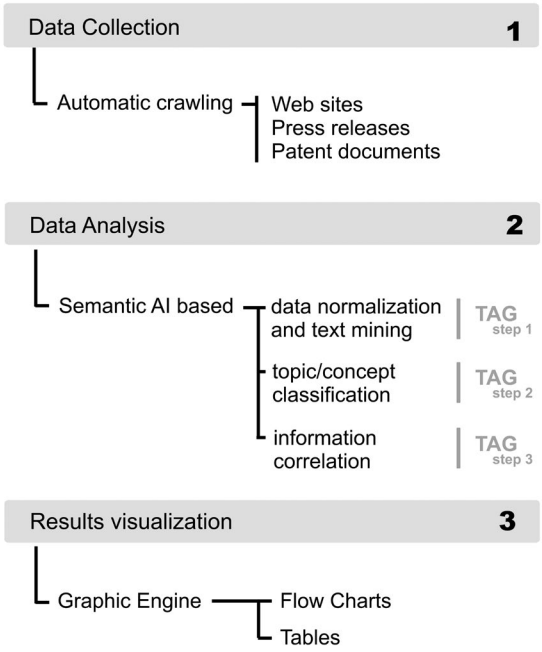

Figure 2. The overall research process. *Source:* Authors' Elaboration (2021).

The overall research method is represented in Figure 2.

4.1. Data collection

We collected data from multiple sources, at different levels (World Wide Web, pledgors companies and pledged patents), to build a comprehensive knowledge base to analyze the OCP initiative. In the first step, the automatic crawling system explored 1974 websites to extract and read their content. The same parsing process has been applied to extract textual contents from press releases and patent title and abstracts. Full details of the data collection sources are embodied in Appendix B.

4.2. Data analysis

We cleaned the information, by lowercasing the text, eliminating punctuation, useless and unrelated words and spelling mistakes; we processed the cleaned data concatenating the title and abstract words. We applied a proprietary semantic tool, named 'TAG', to analyze the information. It first splits all the sentences into periods, eliminates words that are not

significant for semantic interpretation (i.e. adverbs), simplifies the meaning of sentences and tokenizes them into significant words (TAG1). It, hence, selects the most relevant items for the following step, as follows: (1) by combining up to three adjacent significant words (input items); (2) by cross-referencing the input items with the AI-generated Database[34]; (3) by ranking the topics corresponding to the input items, according to their relevance[35]; and (4) by keeping only the relevant topics and the corresponding input items (TAG2). It finally correlates all the relevant input items (hereinafter simply item/words) with one another, based on the number of their links.[36] All the correlations are therefore ranked for their relevance (TAG3).

4.3. Result visualization

We opted to use flow charts that enable us to represent the main links without considering the data with minor relevance. Starting from the main words with the greatest number of inbound links, we can easily visualize the links between them and related items.

5. Results and discussion

5.1. OCP Manifesto overview

In the first study, we investigated how the Web resonated with the OCP initiative by semantically analyzing all the relevant information on the web (1974 sites). The visual representation is shown in Figure 3.

The scanning of the World Wide Web has brought to the surface, as expected, the main word 'Covid' and the top linked words, such as 'news', 'impact', 'response', 'crisis' and 'fight', all in line with the OCP Manifesto (see also Appendix C for the list of the top 20 main words[37]). Very counterintuitive, instead, it is the relevance of the word 'market' (with 1382 inbound links) that appears to be less in line with the aim of the initiative; however, it may foresee some potential trajectories for solutions development. This intuition might explain the evidence of the additional association between the word 'market' with 'electronic automation' and 'electronic design', both referring to possible fields of application of the pledged technologies. As we were interested to know the association between 'covid' and 'patents', we displayed the corresponding relation, which

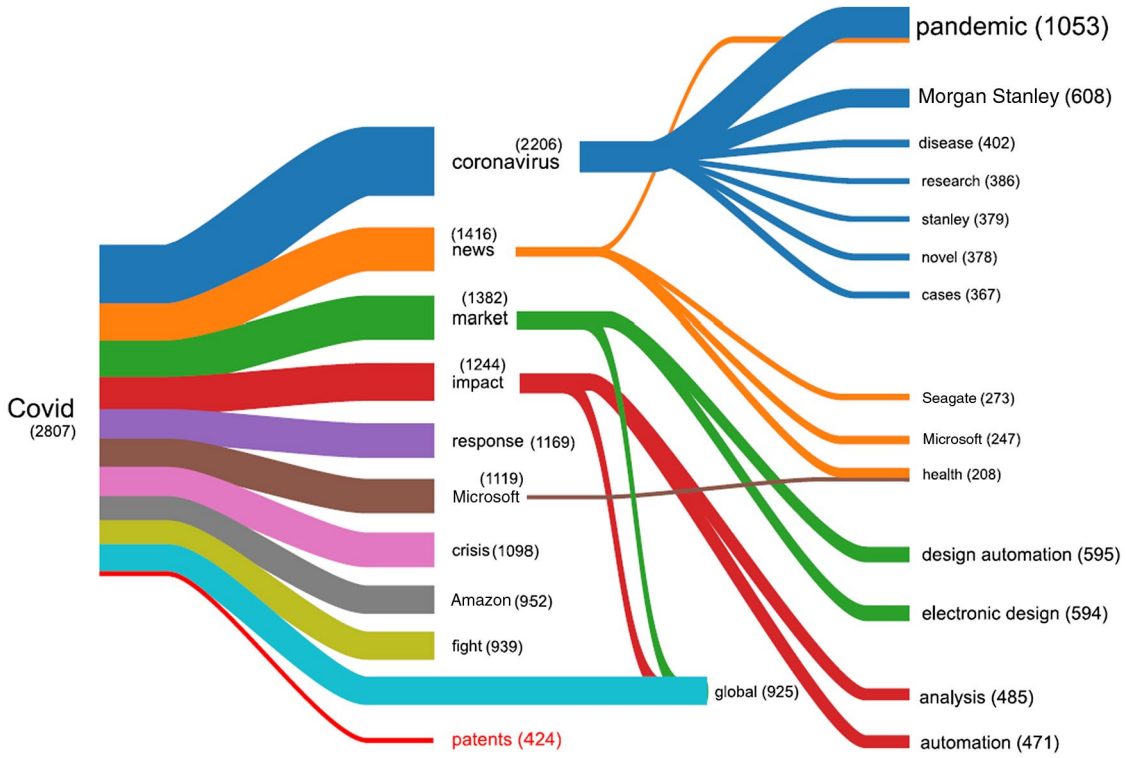

Figure 3. Open COVID Pledge Manifesto overview. Notes: The graph starts with the most relevant word in terms of inbound links from other words, and it shows the relation with the top linked words/couples of words in terms of outbound links. The number in brackets indicates the number of inbound links. Exceptionally, the graph includes the relation with the word 'patents' (which ranked very low with only 424 links) only because it is considered relevant for our interpretation. *Source:* Authors' Elaboration (2021).

happened to be very weak, with only 424 links, albeit the same word is ranked 9th in the list of the top 20 main words, (as detailed in Appendix C). As a final remark, the visualization also reveals the names of many pledgors involved, such as Microsoft, Amazon, Seagate, Morgan Stanley, which therefore seem to act as driving forces of the initiative great resonance.

5.2. Open COVID Pledge pledgors overview

In the second study, we investigated how pledgors companies communicated their participation in the OCP initiative, through the semantic analysis of the contents of their official web pages and related press releases. This analysis is meant to complement the descriptive overview that we presented in paragraph 3. The findings are depicted in Figure 4.

As for Figure 3, the main word is again 'covid' (with 2,947 inbound links) and its top linked words are 'open', 'pandemic', 'open covid', 'free', 'help', 'access' and 'fight' and 'property' and 'intellectual', which resemble the broader 'types of commitment' of the pledgor organizations. This is also visible in the remaining displayed relations, which emphasize the same word/couple of words. The semantic analysis, therefore, suggests that, besides some exceptions not semantically relevant, the main message communicated by the companies conforms pretty much with the OCP's general Manifesto.

5.3. Open COVID Pledge patents overview

In the third study, we pursued the semantic analysis of all the available documents regarding pledged patents. We argue that this further step can enhance the overall understanding of the pledgors' commitment, which is only synthesized in their official communication channels. Therefore, we applied the semantic method to the available OCP patent cards, displayed on the website in the 'Featured IP' section.[38] The results are shown in Figure 5.

In sum, the flow chart suggests that the showcased patent documents semantically relate to the words 'demand' and 'information' with the words 'management', 'real time', 'system', 'supply', 'providers', 'services' and 'request' and 'contextual', 'post', 'healthcare', 'access', 'systems' and 'network', respectively. Moreover, the relevance of these words is also evident in the remaining set of portrayed relations, with some specifications, such as 'data', 'authentication', 'essential', 'social', 'resources' and 'devices'. Overall, these findings enrich the descriptive analysis of featured patents exhibiting the prevalence of the classes H04 and G06 and seem to suggest that available technologies mainly refer to the real-time search and analysis of contextual information.

As the previous analysis was only based on a limited number of patent cards, we tried to enlarge our potential pool of patent knowledge, and we retrieved additional documents related to the OCP's patents through the AI-based search tool (IP Screener),[39] available upon registration. Through the 'AutoMatch Technology', this tool returns the top 25 patents semantically associated with either the research ideas proposed (first criterion) or the patents of interest (second criterion). We applied the latter criterion, by using the titles and abstracts of the featured patents, and we extracted all the available information on the related patents.[40] By applying the semantic method to this new set of patent documents and cross-referencing the previous findings, we were able to depict Figure 6.

Compared with Figure 5, we found, as expected, that the range of domains and application is substantially wider. Together with general words such as 'systems', 'data', 'information', which recall the previous findings, the semantic analysis enucleates a full range of new relations with the most relevant words like 'device', 'detection' and 'method', which correspond to a higher intensity of blue cells (about 88.9%, which means eight out of nine pledgors' showcased patents display this word in the documents). Right after, we found words like 'medical' (66.7%), 'network' (66.7%), 'input' (66.7%), 'detect' (55.6%), 'method' (55.6%), 'identify' (55.6%) and 'display' (55.6%), which all suggest technologies related to devices for the detection, display and monitoring of the virus diffusion. In addition, the figure shows the percentage of overlap between the OCP featured patents – belonging to the nine pledgors displayed in the figure – and all the top-25 related patents. It is interesting to note that the range varies substantially among pledgors, with upper (71.1% of Mitsubishi Electric Research Lab) and lower bound (7.9% of NJIT).

6. Conclusion

We provide a semantic analysis of the available information on the OCP, encompassing the general overview of its Manifesto, the analysis of the pledgor companies and the investigation of their featured and related pledged patents. We proved the great resonance of the initiative, which has started an international movement of complementary efforts

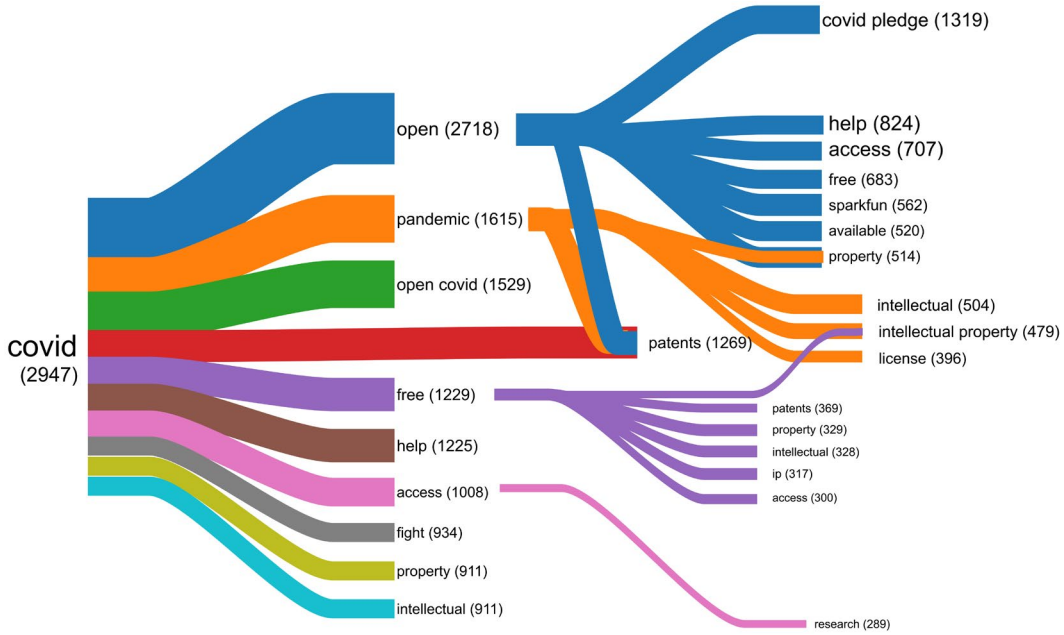

Figure 4. Open COVID Pledge pledgors overview. Notes: The graph starts with the most relevant word in terms of inbound links from other words, and it shows the relation with the top linked words/couples of words in terms of outbound links, which emerged from the semantic analysis. The number in brackets indicates the number of inbound links. *Source:* Authors' Elaboration (2021).

all around the globe; we also emphasized the nature of participation of the founding adopters and additional pledgors, all very well-known companies with international reach and mostly with highly intense patenting activity. We enriched this analysis by deep diving into the content nature of the showcased patents and integrating these findings with the additional evidence on the related patents resulted from the employment of the AI-based search tool (IP Screener) available online. Overall, the findings suggest that the covered technologies refer to the real-time demand and search of contextual information and to the devices for virus detection. We, therefore, provide an enhanced understanding of the nature of the OCP in the direction marked by previous studies towards the need to provide contextual information, 'ongoing stewardship and active assessment of the rights being made available' (Contreras et al., 2020, p. 1,148).

Despite this contribution, the inherent research design of the paper poses some relevant questions about the representative nature of our results. While the first two studies do not suffer from potential selection bias as we have collected all the available information related to the initiative at the broader level and the company level; the third study is driven, also in the case of the integration of the top 25 related patents, by the availability of information on the limited pool of pledged patents, whose cards were showcased in the official webpage of the OCP. As the available patent portfolios, sometimes encompass even thousands of patents,[41] we are fully aware of the under-estimation that we might have made. Nevertheless, it is interesting to note that our evidence is perfectly in line with the declared 'access rule' limited solely to 'the purpose of diagnosing, preventing, containing and treating COVID-19'. Hence, it seems that the featured IPs represent exemplary cases for potential users to learn what kind of IPs were mostly available. Another issue, which might undermine the representativeness of this study, is due to the great novelty of this OCP initiative – which is still undergoing and therefore attracting new partners and new IPs. Indeed, our results must be considered partial because they refer to the period ranging from April to August 2020. The evidence is also limited because it only refers to patents, while featured IP also encompasses other types of rights, such as copyright, that we did not include in the analysis. Besides potential bias and partiality of our findings, we should also consider that while patents are official documents, widely available and accessible (Choi et al., 2013), press releases and websites are drafted by the company press office for different purposes and are freely accessible to a wide audience (e.g. suppliers, customer and even competitors); hence, it is less likely that they contain competition-sensitive information. The edulcorated material available may represent a potential limitation of the analysis, in terms of the level of in-depth investigation that we

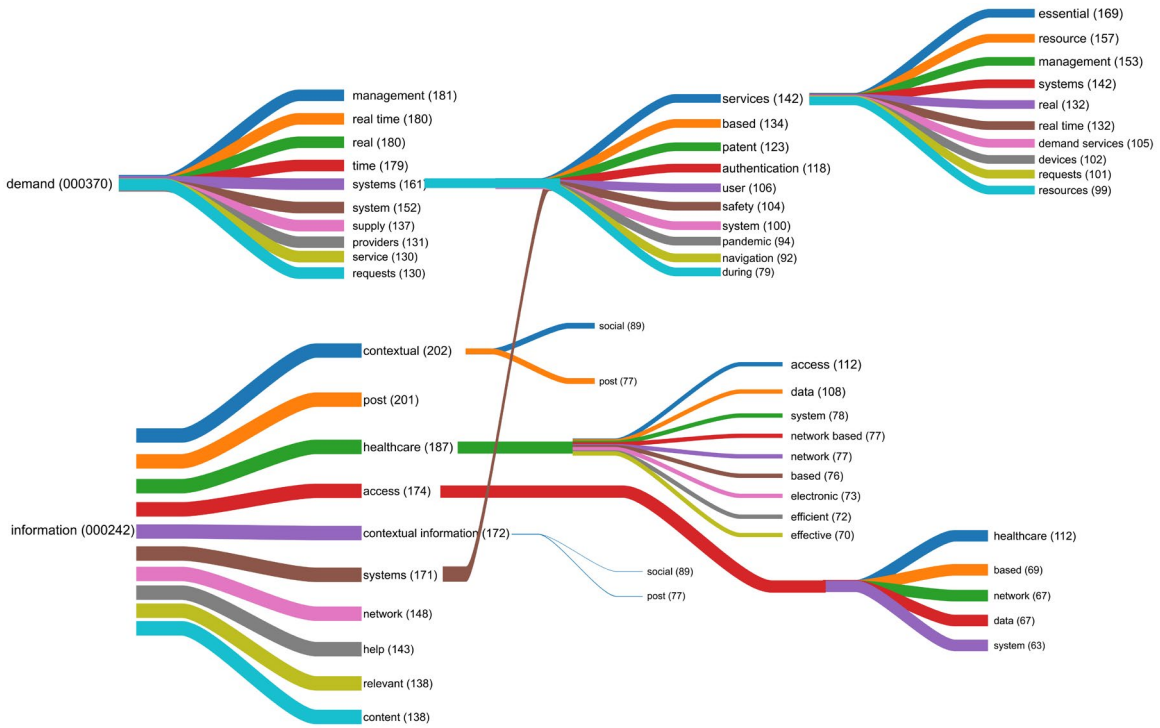

Figure 5. Open COVID Pledge featured patents. Notes: The graph starts with the most relevant word in terms of inbound links from other words, and it shows the relation with the top linked words/couples of words in terms of outbound links, which emerged from the semantic analysis. The number in brackets indicates the number of inbound links. *Source:* Authors' Elaboration (2021).

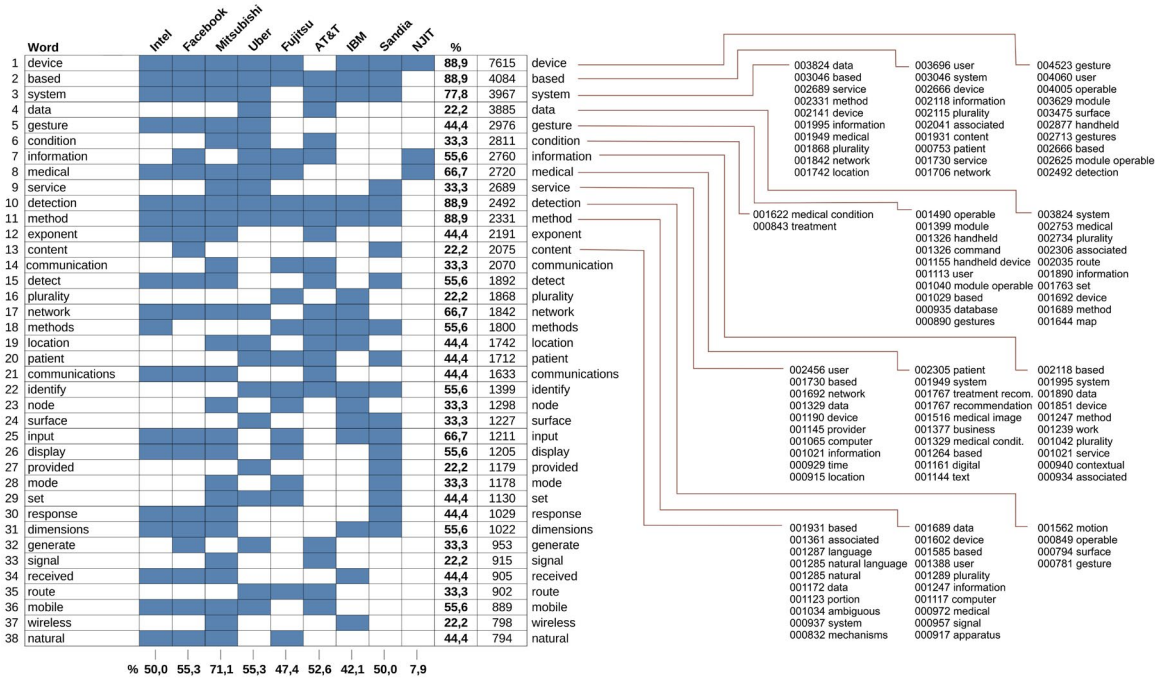

Figure 6. Open COVID Pledge showcased and related patents. Notes: Similarly, to Figures 3–5, the graph lists the most relevant word in terms of inbound links, and it shows the relation with the top linked words/couples of words in terms of outbound links, which emerged from the semantic analysis. Among the most relevant words, we listed only the top 38 that can be also found in the available document of OCP showcased patents. Hence, the intersection between the main words and the name of the company is colored in blue anytime the same word is also present in the available document of OCP showcased patents of that specific company, otherwise is left white. *Source:* Authors' Elaboration (2021).

could have eventually achieved. In fact, the second study based on press release and official websites of the pledgors companies was not so informative as it showed a high degree of isomorphism across organizations. Nevertheless, albeit limited in depth, the data available can be considered truthful, given the fact that companies with a high reputation, such as the OCP pledgors, are increasingly encouraged to ensure veracity and accountability in web-reported information. In addition, social scientists have recently proved the methodological relevance of web scraping and its robustness (Youtie et al., 2012; Arora et al., 2013; Gök et al., 2015). For instance, Gök et al. (2015) find that website data offer advantages in 'coverage, currency, accessibility, quantity and flexibility' (Gök et al., 2015, p. 668). Thus, we are confident that the combination of the data, the three levels of the study and the semantic method used overall allowed us to offer a comprehensive and real picture of the portrayed phenomenon.

For future research, we identified some potential trajectories that are worth pursuing given their impact at the single and collective level. From a company perspective, it might be interesting to understand the exact perimeter of the pledged IP portfolio, and eventually, the drivers for the selection of the IP included in the pledge. Do companies select the most or the less valuable IP to pledge? Do companies pledge the entire portfolio or do they select the IP most relevant for the achievement of the pledge aim? If the pledge encompasses only related patents, the decision burden is shifted to the participating company and, therefore, the search cost of the potential user is downsized, and this could eventually stimulate the use of the featured IP. However, this circumstance may limit the range of potential solutions that can be developed as the knowledge base available is much narrower. Same considerations apply if we consider the potential value of IP, which may not necessarily lead to valuable solutions depending on the type of users and scenario. From a collective perspective, all these questions address the relevant need to assess whether the pledge has an impact on follow-on innovations, especially in the case of 'mission-oriented' pledges, which are set to achieve social and philanthropic goals, such as in the pandemic. Moreover, answering these questions is also important to seize the impact of regular pledges, in comparison with other IP practices, such as patent pools and compulsory licensing.

Acknowledgements

This research has benefitted from the technical support of the innovative startup InstantTechnologies (https://instantechnologies.com/), which has provided resources and tools to tackle the methodological challenges of this paper. We specifically thank Alessandro Paolini, Chairman and co-CEO of the company, and Marco de Biagi for copious and useful insights on data handling and analysis.

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Notes

[1] Navigating opportunities for innovation and entrepreneurship under COVID-19, available at https://cmr.berkeley.edu/2020/06/innovation-entrepreneurship/, last accessed on July 2020.

[2] The COVID-19 Open Research Dataset, aimed at publishing all of the known medical literatures on the coronavirus in a machine-readable format, has been generated through the collaboration of different partners, such as Semantic Scholar, the Allen Institute for AI and leading research groups. It is a free resource made available for the global research community, containing more than 280,000 scholarly articles on coronavirus. The dataset is available at https://www.semanticscholar.org/cord19, last accessed on July 2020.

[3] For a more comprehensive review, see Tiezte et al. (2020a, pp. 4–5).

[4] Medtronic Shares Ventilation Design Specifications to Accelerate Efforts to Increase Global Ventilator Production, available at http://newsroom.medtronic.com/news-releases/news-release-details/medtronic-shares-ventilation-design-specifications-accelerate/, last accessed on July 2020.

[5] Emergency mask for hospital ventilators, available at https://www.isinnova.it/easy-covid19/, last accessed on August 2020.

[6] Open COVID Pledge, available at https://opencovidpledge.org/, last accessed on July 2020.

[7] The full list of Complementary efforts is also available at https://opencovidpledge.org/complementary-efforts/, last accessed March 2021.

[8] The World Health Organization launched a voluntary COVID-19 product pool. What happens next? Available at https://www.statnews.com/pharmalot/2020/05/29/who-covid19-coronavirus-patents/, last accessed on August 2020.

[9] Open COVID-19 Declaration, available at https://www.gckyoto.com/covid-2, last accessed on August 2020.

[10] Putting pledged IP to work – identifying IP available under the Open COVID Pledge, available at https://opencovidpledge.org/2020/06/12/putting-pledged-ip-to-work-identifying-ip-available-under-the-open-covid-pledge/, last accessed in March 2021.

[11] 'This special issue aims to capture the evolving practice of such COVID-19 stimulated innovative efforts, to crystallize some of the lessons about the innovation approaches taken in the effort to prevent, mitigate and ultimately overcome the crisis. Through bringing together the reflections of the innovation community, firstly we strive to disseminate this emerging best practice actions to aid current and future efforts in the fight against COVID-19 and secondly, to understand how practice of these innovations may reshape the theories and approaches that our field has relied on over the last 50 years'. (R&D Management Special Issue call on 'Providing solutions in emergencies: R&D and innovation management during COVID-19'), available at https://onlinelibrary.wiley.com/pb-assets/assets/14679310/RADM%20Covid-19%20Special%20Issue%20CFP-1586946806503.pdf, last accessed in March 2021.

[12] 'The Open COVID movement goes global', available at https://opencovidpledge.org/2020/05/21/the-open-covid-movement-goes-global/, last accessed in March 2021; 'Internationalizing the Open COVID Pledge: Translations and Outreach', available at https://opencovidpledge.org/2020/10/15/internationalizing-the-open-covid-pledge-translations-and-outreach/, last accessed in March 2021.

[13] The literature on the topic of pledges involves different types of pledges, besides patents' one, such as share and stock pledges, especially in relation to organizations' innovative capabilities (Pang and Wang, 2020; Wang et al., 2020) and firm value (Li et al., 2019).

[14] The initiative started in 2008 and failed in 2016 because of governance and organizational issues. However, it

involved 13 participant companies that pledged 238 'green technology' patents (Contreras, 2018).

[15] Bowman (2009) 'The Eco-Patent Commons: caring through sharing', available at https://www.wipo.int/wipo_magazine/en/2009/03/article_0004.html, last accessed on March 2021.

[16] In this sense, we can interpret the resistance opposed by pharmaceutical leaders, and by some governments, such as the United States, to the voluntary patent pool on COVID-19 products, promoted by the World Health Organization. Likewise, we can read the competition that emerged between different countries in the race for the new vaccine, leading to a real antagonism amongst governments for the acquisition and development of solutions crucial in the fight against COVID-19.

[17] For a comprehensive review of patent pledges, see http://www.pijip.org/non-sdo-patent-commitments/, last accessed in March 2021.

[18] See footnote 11.

[19] OCP Manifesto, available at https://opencovidpledge.org/about/, latest accessed in March 2021.

[20] 'Patent holders urged to take "Open COVID Pledge" for quicker end to pandemic', available at https://opencovidpledge.org/2020/04/07/patent-holders-urged-to-take-open-covid-pledge-for-quicker-end-to-pandemic-2/, last accessed on March 2021; 'Top patent holders make Open COVID Pledge', available at https://opencovidpledge.org/2020/05/25/top-patent-holders-make-open-covid-pledge/, last accessed in March 2021.

[21] OCL-P v1., available at https://opencovidpledge.org/licenses__trashed/v1-1-ocl-p/, last accessed on August 2020.

[22] The three options are namely Open COVID Standard Licenses (standard), Open COVID Compatible Licenses; and Open COVID Alternative Licenses. More information available at https://opencovidpledge.org/licenses/.

[23] OCL-P v1., available at https://opencovidpledge.org/licenses__trashed/v1-1-ocl-p/, last accessed on August 2020.

[24] Collected data referred either to year 2019 or to year 2020, which is the latest available record on ORBIS or Nexis Uni dataset. For Unified Patents, Sandia National Laboratories, Nasa JPL, OVSI and Semantic Scholar, no information on revenues was found (n.a.).

[25] Orbis (comparable data resource on private companies), available at https://neworbis.bvdinfo.com/; Nexis Uni (dynamic research tool connecting you to comprehensive content for accurate, targeted searches), available at http://www.nexisuni.com. In particular, most data have been extracted from Nexis Uni relying mainly on Zoom Company Information.

[26] Founding adopters are pledgors that have joined the cause in April 2020; the additional pledgors have married the cause in a later stage. As of the 20th of August 2020 – our cut-off point – there were 29 listed on OCP Official website.

[27] Showcased patents, also called Featured IP, are available at https://opencovidpledge.org/partner-ip/, last accessed on August 2020. For our research, the showcased patent cards taken into account were those displayed until the 20th of August with a specific link to a well-defined patent (generic referrals to pledged technologies were excluded).

[28] According to patent literature (e.g. Reitzig, 2004), patents' claims allow us to understand which are the specific elements of a patent that are legally protected (providing a measure of the scope of protection); through backward citations, we can comprehend how much these patents rely on prior art (offering a measure of radicalness); and with forward citations, it is evident how much that protected technology has been impactful in terms of stimulating the production of subsequent related knowledge. Indeed, they suggest a measure of value and importance of the patent (Amore et al., 2013). To conclude, technological classes allow us to understand the application area of the protected knowledge.

[29] International Patent Classification (IPC), available at https://www.wipo.int/classifications/ipc/en/, last accessed on September 2020. We reported the IPC of 19 out of 22 showcased patents. Indeed, three IPC concerning two open-source Sandia's projects and one NJIT's patent, focused on 3D printing, which is still pending, were not available.

[30] Google Patents, available at https://patents.google.com/, last accessed on September 2020.

[31] Espacenet, available at https://worldwide.espacenet.com/, last accessed on September 2020.

[32] These numbers are referred to the available information until the 20th of August.

[33] An explanatory case of the most represented classes (G06) is the 'Gesture-based signature authentication systems' held by Intel that allows reducing contacts during the daily activities that require personal validation, reducing the spread of the virus. Another remarkable case is the 'method of estimating location of nodes in wireless networks', classified in H04 and held by Mitsubishi Electric, that allows implementing an effective contact tracing system to avoid virus diffusion.

[34] The TAG runs based on an AI-engine trained by patent/covid/tech and innovation-related readings/documents. The AI-generated database encompasses items, topics and corresponding correlation weight (+9/−9) between items and topics.

[35] The relevance of the topics is assessed by summing up all the corresponding weights.

[36] The TAG also measures the distance between all the items in the text, by counting the words separating the two items and attributing a 'distance value' anytime the sentence is interrupted by a full stop.

[37] For the sake of clarity, we select only the top linked words, but the overall knowledge base analyzed is available upon requests. Moreover, we provide the list of the top 20 main words with their top linked words, to allow a

more comprehensive view of the findings of the semantic analysis. These tables, available for Figures C1–C3, included in Appendix C, should be read as companion documents for a complete understanding.

[38] Those cards are created ad hoc for the initiative and translate the content of the patent documents into more friendly-to-use information, allowing for a more effective search of interested IP from outsiders. Full information is accessible at https://opencovidpledge.org/partner-ip/. For our research, the patent cards taken into account were those displayed until the 20th of August with a specific link to a well-defined patent (generic referrals to pledged technologies were excluded).

[39] Search Open COVID Pledged IP, available at https://opencovidpledge.org/ip/, last accessed on September 2020.

[40] Our analysis dates back to the 20th of August 2020, in line with other data extraction activities.

[41] 'Amazon, Facebook, Hewlett Packard Enterprise, IBM, Microsoft and Sandia National Laboratories join "Open COVID Pledge" to make patents freely available in the fight against COVID-19', available at https://opencovidpledge.org/2020/04/20/amazon-facebook-hewlett-packard-enterprise-ibm-microsoft-and-sandia-national-laboratories-join-open-covid-pledge-to-make-patents-freely-available-in-the-fight-against-covid-19-2/, last accessed in March 2021.

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APPENDIX A
Showcased OCP patents statistics

Assignee	Patent ID Number	Granted Year	Tech Class IPC	Claims	Patent Bkw cites	Non-patent Bkw cites	All Bkw cites	Fwd cites
AT&T	US7298836B2	2007	G06	19	133	-	133	28
AT&T	US20190197438A1	Pending	G06	20	n.a.	n.a.	n.a.	n.a.
Facebook	US20190163794A1	Pending	G06	20	n.a.	n.a.	n.a.	n.a.
Fujitsu	US20200118682A1	Pending	G06	15	3	-	3	-
Fujitsu	US20190179999A1	Pending	G06	8	n.a.	n.a.	n.a.	n.a.
IBM	US9682100B2	2017	A61	22	11	11	22	1
IBM	US9772714B2	2017	A61	7	15	11	26	7
Intel	US20200128006A1	Pending	G06	20	31	0	31	54
Mitsubishi Electric	US20180103116A1	2019	H04	20	12	0	12	1
Mitsubishi Electric	US10514437B2	2019	G01	20	19	5	24	3
Mitsubishi Electric	US10425910B1	2019	H04	20	10	2	12	2
Mitsubishi Electric	US9282531B1	2016	H04	12	18	0	18	5
Mitsubishi Electric	US8054226B2	2011	H04	8	7	0	7	24
Mitsubishi Electric	US7729659B2	2010	H04	9	1	3	4	3
NJIT	-	Pending	-	n.a.	n.a.	n.a.	n.a.	n.a.
Sandia	Open Source	-	-	n.a.	n.a.	n.a.	0	n.a.
Sandia	Open Source	-	-	n.a.	n.a.	n.a.	0	n.a.
Sandia	US9546887B1	2017	B01	18	8	3	11	2
Sandia	US8163154B1	2012	B01	23	8	22	30	5
Sandia	US7527977B1	2009	B01	25	10	5	15	15
Uber	US10563994B2	2020	G01	20	9	1	10	5
Uber	US10460411B2	2019	G06	20	98	9	107	4

Source: Authors' Elaboration (2021)

APPENDIX B
Data source details

Level of Information	Data sources	Volume	Urls (latest accessed 30th of August 2020)
World wide web	Websites	▪ 1974 web pages	Accessed pages are available upon request, they include pledgor companies' official websites: https://www.unifiedpatents.com/; https://www.intel.com/content/www/us/en/homepage.html; https://fabricatorz.org/ https://www.apheris.com/; https://www.hpe.com/us/en/home.html; https://www.facebook.com/ https://www.ibm.com/us-en/?lnk=m; https://www.microsoft.com/en-gb/; https://www.amazon.com/ https://www.sandia.gov/; https://www.hmjmed.com/; https://www.skoposlabs.com/; https://meedan.com/ https://www.bowmarketsomerville.com/; https://www.njit.edu/; https://ovsi.org/; https://www.uber.com/it/en/ https://www.sifive.com/; https://www.att.com/; https://www.jpl.nasa.gov/; https://www.agnisys.com/ https://www.fujitsu.com/global/; https://www.sparkfun.com/; https://www.seagate.com/ https://www.merl.com/; https://www.sap.com/corporate/en.html; https://www.leonardocompany.com/en/global https://www.morganstanley.com/; https://www.semanticscholar.org/
Pledgors Companies	Companies' press releases	▪ 27 press releases ▪ 1 web page	https://www.unifiedpatents.com/open-covid-pledge; https://blogs.intel.com/csr/2020/04/open-covid-pledge/#gs.4u3814 https://fabricatorz.org/news/opencovidpledge/; https://www.apheris.com/covid-pledge https://www.hpe.com/us/en/newsroom/blog-post/2020/04/hpe-opens-its-patents-to-fight-covid-19.html https://about.fb.com/news/2020/06/coronavirus/ https://www.ibm.com/blogs/research/2020/04/IBM-patent-portfolio-access-combat-covid-19/ https://blogs.microsoft.com/on-the-issues/2020/04/20/open-covid-19-pledge-patents/ https://share-ng,sandia,gov/news/resources/news_releases/rapid_deployment/ https://www,hmjmed,com/; https://coronavirus,skoposlabs,com/#opencovid https://meedan,com/blog/meedan-supports-the-open-covid-pledge/; https://www,safesupplyfieldguide,org/open-covid-pledge https://research,njit,edu/open-covid-public-statement; https://ovsi,org/ovsi-makes-the-open-covid-pledge https://www,uber,com/en-AU/newsroom/open-covid-pledge/; https://www,sifive,com/press/sifive-joins-open-covid-pledge-to-fight-global-pandemic https://about,att,com/story/2020/open_covid_pledge,html https://opencovidpledge.org/2020/05/06/nasa-jpl-supports-the-open-covid-pledge-makes-respirator-designs-freely-available/ https://www.agnisys.com/news-release/agnisys-takes-the-open-covid-pledge-to-fight-pandemic/ https://www.fujitsu.com/global/about/resources/news/press-releases/2020/0512-01.html https://www.sparkfun.com/news/3296 https://www.seagate.com/it/it/news/news-archive/seagate-technology-to-open-up-patents-in-fight-against-covid-19-pr/ https://www.merl.com/news/news-20200528-1314 https://news.sap.com/2020/06/sap-joins-open-covid-pledge-and-provides-access-to-patents-to-fight-covid-19/ https://techtransfer.leonardocompany.com/en/news/covid19; https://medium,com/ai2-blog/why-were-joining-the-open-covid-pledge-7a071ed2c60a https://opencovidpledge.org/partners/
Pledged Patents	OCP Featured IP cards IP Screener	▪ 22 Patent Cards grouped in 18 pledgors' featured IP pages ▪ 1 web page ▪ 1 search engine	https://opencovidpledge.org/2020/08/11/intel-touchless-password-for-authentication-of-people/ https://opencovidpledge.org/2020/08/11/facebook-combating-the-spread-of-covid-19-related-misinformation/ https://opencovidpledge.org/2020/08/07/mitsubishi-electric-optimizing-resources-available-for-essential-services/ https://opencovidpledge.org/2020/08/07/mitsubishi-electric-wireless-localization-for-contact-tracing/ https://opencovidpledge.org/2020/08/07/sandia-face-covering-and-face-shield-designs/ https://opencovidpledge.org/2020/06/03/uber-safe-routing-for-navigation-systems/ https://opencovidpledge.org/2020/06/03/uber-real-time-resource-management-for-on-demand-services/ https://opencovidpledge.org/2020/06/03/fujitsu-faster-disease-diagnosis-using-computer-software/ https://opencovidpledge.org/2020/06/03/fujitsu-techniques-to-aid-in-drug-discovery/ https://opencovidpledge.org/2020/06/03/att-effective-and-efficient-access-to-healthcare-data/ https://opencovidpledge.org/2020/06/03/att-reducing-emergency-transport-time-to-hospitals/ https://opencovidpledge.org/2020/05/20/drive-up-booth-for-safer-covid-19-testing/ https://opencovidpledge.org/2020/05/20/njit-forcep-swab-for-covid-19-testing/ https://opencovidpledge.org/2020/05/20/reducing-false-positives-in-detection-techniques/ https://opencovidpledge.org/2020/05/20/separation-of-proteins-by-applying-an-electric-field/ https://opencovidpledge.org/2020/05/20/protein-detection-system/ https://opencovidpledge.org/2020/05/20/potential-treatment-for-viruses/ https://opencovidpledge.org/2020/05/20/touchscreen-that-uses-uv-light-for-preventing-pathogen-transmission/ https://opencovidpledge.org/ip/ https://my.ipscreener.com/login/opencovidpledge

Source: Authors' Elaboration (2021)

APPENDIX C
Top 20 main words
Figure C1

inbound links	Main word (#1)
2807	covid

# of links	Top 10 linked words
2206	coronavirus
1416	news
1382	market
1379	coronavirus
1299	news
1244	impact
1169	response
1119	microsoft
1098	crisis
1060	impact

inbound links	Main word (#6)
1121	open covid

# of links	Top 10 linked words
241	covid
211	covid
209	free
203	fight
200	free access

inbound links	Main word (#11)
952	amazon

# of links	Top 10 linked words
852	covid
470	amazon
264	coronavirus
233	coronavirus

inbound links	Main word (#16)
766	technology

# of links	Top 10 linked words
581	covid
499	seagate
358	open
332	open patents
282	patents fight
257	coronavirus
226	patents
222	fight
220	njit
217	fight covid

inbound links	Main word (#2)
2206	coronavirus

# of links	Top 10 linked words
1379	covid
1053	pandemic
684	news
608	morgan stanley
586	morgan stanley
548	news
402	disease
392	during
386	research
379	stanley

inbound links	Main word (#7)
1119	microsoft

# of links	Top 10 linked words
735	covid
386	microsoft
247	news
227	health

inbound links	Main word (#12)
939	fight

# of links	Top 10 linked words
495	covid
353	open
340	patents
332	open patents
282	technology open
267	coronavirus
258	pledge
256	seagate technology
222	technology
211	hand washing

inbound links	Main word (#17)
762	health

# of links	Top 10 linked words
637	covid
306	coronavirus
228	care
227	microsoft
208	news
205	public

inbound links	Main word (#3)
1416	news

# of links	Top 10 linked words
1299	covid
684	coronavirus
548	coronavirus
407	news
289	pandemic
273	seagate
247	microsoft
242	covid pandemic
208	health
201	market

inbound links	Main word (#8)
1060	impact

# of links	Top 10 linked words
766	market
440	market
394	analysis
360	global
314	coronavirus
276	electronic design
242	global
206	analysis
203	covid global

inbound links	Main word (#13)
841	intel

# of links	Top 10 linked words
290	intel

inbound links	Main word (#18)
760	electronic

# of links	Top 10 linked words
711	design
480	automation
479	automation market
386	market
225	covid

inbound links	Main word (#4)
1382	market

# of links	Top 10 linked words
821	global
766	impact
760	covid
595	design automation
594	electronic design
570	market
528	impact covid
512	covid impact
485	analysis
476	global

inbound links	Main word (#9)
1039	patent

# of links	Top 10 linked words
455	patent
422	unified patent
396	unitary
352	patent court
335	patent court
318	unified
307	unified patent
260	european
253	unitary patent
233	court

inbound links	Main word (#14)
821	global

# of links	Top 10 linked words
723	covid
476	market
360	impact
281	coronavirus
249	impact covid
242	impact
220	coronavirus

inbound links	Main word (#19)
752	electronic design

# of links	Top 10 linked words
660	automation market
594	market
319	covid
276	impact
211	agnisys

inbound links	Main word (#5)
1229	unified patent

# of links	Top 10 linked words
422	patent
307	patent
264	patent court
245	unitary patent
240	unified patent
208	court

inbound links	Main word (#10)
965	response

# of links	Top 10 linked words
322	coronavirus
315	covid pandemic
277	coronavirus
264	pandemic

inbound links	Main word (#15)
773	nasa

# of links	Top 10 linked words
692	ventilator
604	propulsion
451	laboratory
405	covid
340	coronavirus
333	nasa
277	ventilator
259	covid ventilator
249	coronavirus
224	engineers

inbound links	Main word (#20)
738	mitsubishi

# of links	Top 10 linked words
475	research labs
467	research laboratories
311	labs
301	mitsubishi electric
282	mitsubishi electric
275	laboratories
274	research
244	electric
207	mitsubishi

Source: Authors' Elaboration (2021)

Figure C2

inbound links	Main word (#1)
2947	covid

# of links	Top 10 linked words
2718	open
1615	pandemic
1529	open covid
1269	patents
1229	free
1225	help
1008	access
934	fight
911	property
911	intellectual

inbound links	Main word (#2)
2028	open

# of links	Top 10 linked words
1319	covid pledge
849	pandemic
826	patents
824	help
707	access
683	free
562	sparkfun
529	open covid
520	available
514	property

inbound links	Main word (#3)
1529	open covid

# of links	Top 10 linked words
1529	covid
668	pandemic
625	patents
572	help
547	free
529	open
520	covid pledge
479	access
435	available
433	open

inbound links	Main word (#4)
1319	covid pledge

# of links	Top 10 linked words
836	pledge
756	covid
574	pandemic
555	patents
543	covid
520	open covid
496	help
479	free
429	access
392	available

inbound links	Main word (#5)
1036	pandemic

# of links	Top 10 linked words
849	open
668	open covid
574	covid pledge
508	property
504	intellectual
479	intellectual property
449	free
396	license
391	help
362	patents

inbound links	Main word (#6)
1008	access

# of links	Top 10 linked words
707	open
697	pledge
479	open covid
429	covid pledge
333	pandemic
300	free
297	patents
289	research
288	help
208	property

inbound links	Main word (#7)
894	patents

# of links	Top 10 linked words
826	open
625	open covid
555	covid pledge
509	help
492	ibm
369	free
362	pandemic
315	patent
309	available
297	access

inbound links	Main word (#8)
883	available

# of links	Top 10 linked words
715	pledge
520	open
435	open covid
392	covid pledge
339	pandemic
309	patents
297	intellectual property
297	intellectual
295	property
262	free

inbound links	Main word (#9)
834	help

# of links	Top 10 linked words
824	open
572	open covid
509	patents
496	covid pledge
391	pandemic
324	fight
288	access
273	solutions
257	patent
248	technology

inbound links	Main word (#10)
775	free

# of links	Top 10 linked words
683	open
547	open covid
479	covid pledge
449	pandemic
369	patents
329	property
328	intellectual
317	ip
315	intellectual property
300	access

inbound links	Main word (#11)
744	ibm

# of links	Top 10 linked words
492	patents
426	assert
405	covid
349	pledge
237	disease
197	subsidiaries
194	shall
193	matter
191	pledged patent
191	pledged

inbound links	Main word (#12)
732	pledge

# of links	Top 10 linked words
729	intellectual
729	intellectual property
715	available
697	access
604	patent
603	covid pandemic
573	fight
502	solutions
467	technologies
455	research

inbound links	Main word (#13)
729	intellectual

# of links	Top 10 linked words
648	property
511	open
504	pandemic
395	open covid
354	covid pledge
328	free
297	available
250	patents
233	covid pandemic
227	world

inbound links	Main word (#14)
729	intellectual property

# of links	Top 10 linked words
511	open
479	pandemic
395	open covid
354	covid pledge
317	property
315	free
297	available
242	patents
218	world
208	covid pandemic

inbound links	Main word (#15)
604	patent

# of links	Top 10 linked words
362	assert
326	pandemic
315	patents
287	open
274	patents
260	technologies
257	help
253	open covid
248	disease
248	covid pledge

inbound links	Main word (#16)
603	covid pandemic

# of links	Top 10 linked words
494	open
407	covid
402	open covid
374	covid
289	free
252	license
239	covid pledge
233	intellectual
232	property
231	patents

inbound links	Main word (#17)
588	charge

# of links	Top 10 linked words
386	pledge
302	open
261	free
254	open covid
220	covid pledge
207	pandemic

inbound links	Main word (#18)
573	fight

# of links	Top 10 linked words
495	open
361	open covid
328	covid pledge
324	help
318	pandemic
256	patents
248	seagate
232	solutions
223	free
198	impact

inbound links	Main word (#19)
462	license

# of links	Top 10 linked words
406	pledge
396	pandemic
284	open covid
252	covid pandemic
219	covid pledge
215	ip
210	technology
209	entity
207	pledgor
204	patent

inbound links	Main word (#20)
447	disease

# of links	Top 10 linked words
344	open
307	pandemic
263	open covid
248	patent
237	ibm
230	covid pledge
226	free
225	covid pandemic
221	patents
184	fight

Source: Authors' Elaboration (2021)

Figure C3

inbound links	Main word (#1)
370	demand

# of links	Top 10 linked words
181	management
180	real time
180	real
179	time
161	systems
152	system
137	supply
131	providers
130	service
130	requests

inbound links	Main word (#6)
183	services

# of links	Top 10 linked words
169	essential
157	resource
153	management
142	systems
132	real
132	real time
105	demand services
102	devices
101	requests
99	resources

inbound links	Main word (#11)
162	evaluated

# of links	Top 10 linked words
83	design

inbound links	Main word (#16)
154	authentication

# of links	Top 10 linked words
118	systems
80	system
78	signature
76	based
72	applications
71	password

inbound links	Main word (#2)
242	information

# of links	Top 10 linked words
202	contextual
201	post
187	healthcare
174	access
172	contextual information
171	systems
148	network
143	help
138	relevant
138	content

inbound links	Main word (#7)
174	access

# of links	Top 10 linked words
112	healthcare
69	based
67	network
67	data
63	system

inbound links	Main word (#12)
159	surfaces

# of links	Top 10 linked words
75	even
69	screen
63	light
62	uv light
62	uv

inbound links	Main word (#17)
153	management

# of links	Top 10 linked words
82	time
69	systems
66	resource
66	demand services
65	real time
65	real

inbound links	Main word (#3)
205	electric

# of links	Top 10 linked words
107	membrane
73	fields
71	technique
69	field
67	protein
64	separation
520	covid pledge
479	access
435	available
433	open

inbound links	Main word (#8)
172	contextual information

# of links	Top 10 linked words
89	social
77	post

inbound links	Main word (#13)
157	resource

# of links	Top 10 linked words
114	essential
111	demand
97	time
88	essential services
78	complete
76	systems
74	scheduling
66	management

inbound links	Main word (#18)
152	localization

# of links	Top 10 linked words
111	networks
107	tracing
104	method
103	wireless
78	device
78	communication
77	based
74	building
72	occupants building
72	occupants

inbound links	Main word (#4)
202	contextual

# of links	Top 10 linked words
89	social
77	post
574	pandemic
555	patents
543	covid
520	open covid
496	help
479	free
429	access
392	available

inbound links	Main word (#9)
169	essential

# of links	Top 10 linked words
114	resource
112	time
110	scheduling
99	complete
84	safe
74	resources
73	tasks
71	systems
69	services organizations
69	optimizing

inbound links	Main word (#14)
155	systems

# of links	Top 10 linked words
142	services
134	based
123	patent
118	authentication
106	user
104	safety
100	system
94	pandemic
92	navigation
79	during

inbound links	Main word (#19)
143	help

# of links	Top 10 linked words
77	medical
75	time
75	services
65	demand
64	systems
60	essential

inbound links	Main word (#5)
187	healthcare

# of links	Top 10 linked words
112	access
108	data
78	system
77	network based
77	network
76	based
73	electronic
72	efficient
70	effective
362	patents

inbound links	Main word (#10)
165	design

# of links	Top 10 linked words
83	evaluated
60	sandia

inbound links	Main word (#15)
155	membrane

# of links	Top 10 linked words
107	electric

inbound links	Main word (#20)
138	content

# of links	Top 10 linked words
60	social

Source: Authors' Elaboration (2021)

