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A global landscape of patenting activity in COVID-19 vaccines

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ABSTRACT

This paper analyses global patent filings for COVID-19 vaccines to identify where vaccine candidates were developed and where patent protection was being sought, as well as to investigate the patterns of collaboration among applicants. The paper builds on a 2023 report from the World Intellectual Property Organization (WIPO), selecting 1178 relevant patent families across eight categories of vaccine platforms, and using WIPO's data on applicants' countries and three types of applicants: corporate applicants, individual inventors, and universities and research organisations (UROs). We searched for applications in 126 jurisdictions, combined into three groups: the G7, G20 nations not in the G7, and non-G20 nations. G20 nations not in the G7 were the most common destination of filings, and applications originating in these countries constitute the greatest number of families, including those covering novel vaccine platforms. Corporate applicants dominated the G7 and the non-G20 but were as relevant as UROs for the non-G7 in G20. Applications from UROs were relatively more focused on conventional platforms, while corporate applicants were more focused on novel platforms. We repeated the analysis for pharmaceutical and biotechnological patent families more broadly in order to provide a reference point for interpreting the results for COVID-19 vaccine patents. Comparison of the two samples reveals unique patterns of patenting activity for COVID-19 vaccines, including more frequent collaboration, especially between corporate applicants and UROs.

1. Introduction

The World Health Organization (WHO) reports 183 COVID-19 vaccine candidates in different stages of development as of March 2023 [1]. By the end of 2022, the WHO had granted Emergency Use Listing (EUL) to 12 vaccine products, some developed by countries in the G7 and others from countries in the G20 but not the G7 [2]. The large number of vaccines being developed in a broad range of countries less than three years after the declaration of the pandemic by the WHO is a testament to the power of concerted efforts and the emergence of new players with strong vaccine manufacturing capacity. In that sense, this study builds on the literature on the importance of collaboration in the different innovation models applied to the development of COVID-19 vaccines [3–6], by analysing the patenting activity.

Multiple projects have mapped patent landscapes related to COVID-19 vaccines globally [7–15]. This study contributes to these inquiries by investigating the most recent trends in patent filing strategies and by analysing and comparing the related patterns of collaboration. To build our dataset we started with a 2023 report by the World Intellectual Property Organization (WIPO) that lists patent applications related to all WHO-recognised vaccine candidates, indicating the types of applicants, applicant countries, and vaccine platforms. [13] We expanded the WIPO dataset by including substantially more patent offices and updating the search for applications in those families to investigate where applicants come from and in which jurisdictions they have filed applications. We compared patterns of collaboration in terms of co-applicants per vaccine

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platform, aggregating the countries into three groups: G7, non-G7 in G20, and non-G20. To contextualise our results, we also compared the results for COVID-19 vaccines with general trends for pharmaceutical and biotechnological families.

The paper is structured in four sections. The Methodology summarises the challenges of landscaping patent families that informed our data and empirical strategy choices. The Results section compares families across the three groups of countries. In the Discussion, we situate our findings within the broader debate on global collaboration in vaccine development. In the Conclusion, we summarise the key findings, proposing future studies.

2. Methodology

This section presents our data and empirical strategy for landscaping COVID-19 vaccine patents, expanding on the landmark study by WIPO. To accomplish this task, we first define key concepts and acknowledge the challenges that this exercise entails.

2.1. Landscaping pharmaceutical patents

Identifying which patent applications cover which products, also referred to as patent landscaping, is a complex task. Multiple patents might cover one product, and one patent may cover multiple products. Moreover, while pharmaceutical companies know which of their patent applications cover their products (and candidates), they are ordinarily not required to disclose this information publicly. To compensate for this information not being public, different matching strategies have been advanced, including examples in the growing literature on COVID-19 vaccine patent data. Some search for keywords related to COVID-19 vaccines in applications [7,9,11,13,14]. Others search for references to specific COVID-19 vaccine platforms. [8,15] Alternatively, some turn to online databases like the Medicines Patent Pool's Medicines, Patents and Licences (MedsPaL) database [16], which includes data from selected vaccine candidates [10,12].

Another challenge in landscaping analyses is the territorial nature of patents, meaning applicants must typically file individual applications in each jurisdiction where they want the patent to be valid and in force. These applications are called 'twins', and the collective of all global twins constitutes a patent 'family'. Using patent families as the unit of analysis avoids double-counting, which is otherwise a risk given that patent applications are filed across multiple jurisdictions and, even at specific patent offices, often take advantage of mechanisms that allow for multiple filings at various stages, such as provisionals, divisionals, continuations or continuations-in-part. [17–21]

Depending on how applications are grouped, two types of patent families exist: simple families group twins covering the same invention, and extended families group twins by technology, even if the exact inventive concept differs [18,19,21]. While simple families are typically used for analysing where an invention is under patent protection, as in freedom-to-operate analyses, extended families are more suitable for general investigations of filing strategies [18,19,21]. Therefore, we considered extended families.

Finally, landscaping analyses must account for applications remaining in secrecy for 18 months, unless publication is anticipated by initiatives like fast-tracking. Since applicants have up to 12 months from the date of first global filing ('priority') to file twins in other countries via the Paris Convention, and 30 months via the Patent Cooperation Treaty (PCT), the twins may be published even later. For example, an applicant may file a first application in July 2022 and but not file twins globally until January 2025, with publications happening months after that. Thus, landscaping analyses of recent inventions must recognise that the families may still grow.

2.2. Data and empirical strategy

WIPO's 2023 report on patent applications related to all COVID-19 vaccine candidates included 1349 families, based on data from the American Chemical Society's Chemical Abstracts Service (CAS) for 97 patent offices from January 2020 to September 2022 [13]. The report also categorises types of applicants and vaccine platforms covered by the applications and discusses general trends in patenting activity, linking them to challenges in vaccine development.

Rather than undertaking an independent patent landscaping study, we built the dataset for our study using WIPO's report as a starting point, respecting this as a reliable source of COVID-19 patent data on vaccine candidates. We then expanded WIPO's data in four ways: increasing the coverage of patent offices, updating the search for twins, introducing more dimensions of analysis, and comparing the results with a similar analysis of pharmaceutical and biotechnological patent families.

We began by searching for all 1349 WIPO-listed families in the Orbis Intellectual Property database in May 2024, grouping them into 1178 extended families [22]. Our sample excludes one filing in Georgia not listed on Orbis. For each family, we identified three types of twins: (1) national applications filed directly at a country's patent office; (2) regional applications filed at a regional office, affecting the member states and other countries with agreements to extend or validate patents issued by the office; and (3) international applications filed at WIPO as part of the PCT system. Thus, we covered all patent filing strategies.

WIPO's report listed 28 national and two regional patent offices, while our sample has 70 and five, respectively. Considering all types of applications, WIPO's data covered 75 jurisdictions, and our sample covers 136, as shown in Fig. 1. Almost every country in the Global North was included in WIPO's report, which would be enough for an analysis restricted to the G7. However, we set out to compare the nations in three groups: G7, non-G7 in G20, and non-G20. Thus, we included data on most African and Latin American countries and some from Oceania and the Middle East. Considering all applications without double-counting the regional ones, WIPO listed 2916 twins, and our sample includes 5834.

We also extracted from WIPO's report the type and country of residence of each applicant, as well as the vaccine platforms related to the invention. The types of applicants were corporate, independent inventors, and university and research organisations (UROs). The vaccine platforms were divided into eight categories: inactivated virus, live attenuated virus, protein subunit, virus-like particle (VLP), DNA, RNA, viral vector, and others. Following WIPO's report, we considered DNA, RNA and viral vector novel platforms, or what Pizza et al. call 'digital vaccines' [23], while all other categories are conventional platforms.

We assigned the applicant data from each WIPO-listed application to all twins in the family. The same logic was applied to assigning applicant types, vaccine platforms and patterns of collaboration. This strategy was necessary because the data were grouped by extended families, which may lead to marginal changes in twins' bibliographic data.

We also expanded on WIPO's report by exploring more dimensions of analysis. Besides identifying the most frequent filing jurisdictions and applicant countries, we compared per vaccine platform: (1) how many were filed in the three country groups, (2) how many had applicants from each of the groups, (3) how many had applicants from each different type, and (4) the patterns of collaboration in terms of co-applicants across applicant types and countries.

Lastly, we went beyond WIPO's report by establishing a benchmark to compare our findings of COVID-19 vaccine patenting activity against. In September 2025, we identified 533,758 pharmaceutical or biotechnological extended patent families on Orbis Intellectual Property with a priority application filed from 2017 to 2022, based on the International Patent Classification (IPC) scheme developed by WIPO. We selected these two categories since, together, these represent 97 % of the families listed in WIPO's report.

Using the same methods applied to COVID-19 vaccine families, we

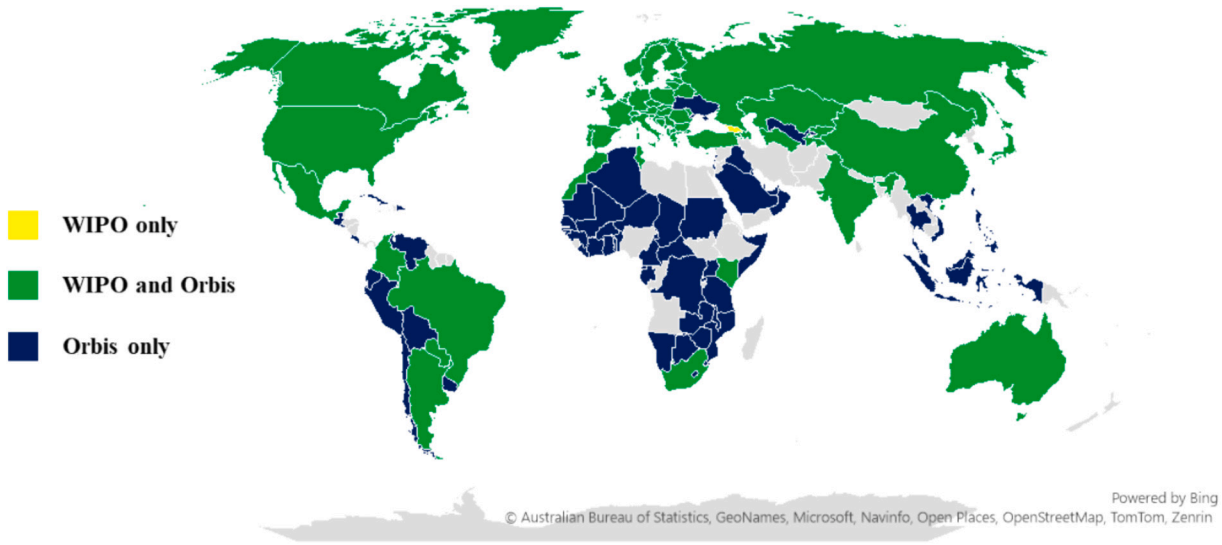

Fig. 1. World map of jurisdictions covered by any of the twins.
Source: Our elaboration, based on data from WIPO and Orbis [13,22].

searched Orbis for all jurisdictions where twins were filed per extended family [24]. In addition, we searched for each family's priority in the Spring 2025 edition of the European Patent Office (EPO) PATSTAT database to identify applicant countries and types [25]. In this process, some families were discarded because the applicant data was missing. Also, we considered only PATSTAT's applicant type categories that were clearly related to either corporate applicants, independent inventors or UROs.[1] As a result, we were able to analyse 74,907 pharmaceutical and 59,600 biotechnological families.

To test the comparability between the original analysis of COVID-19 vaccine families and the new analysis of pharmaceutical and biotechnological families, we compared the results of 344 families in both samples. The results were 99 % similar for filing jurisdictions, 98 % for applicant countries, and 90 % for applicant types. Also, the share of families discarded due to missing or unclear applicant data was roughly the same across vaccine platforms. Therefore, we considered that the methods applied in the two analyses were sufficiently similar to allow the sample of pharmaceutical and biotechnological families to serve as a reference for investigating the uniqueness of the results we found for the COVID-19 vaccine families.

3. Trends in patenting activity

In Fig. 2, we present rankings of the offices where most families were filed (panel A) and the countries whose applicants filed the most families (panel B). China stands out as the office with the most filings and the country whose applicants filed the greatest number of patent families. WIPO was the second office with the most patent filings, due to international applications via PCT, but it does not feature in panel B since WIPO is not a country of origin.

In terms of filing offices, the United States of America (USA) and the EPO have similar numbers, with slightly more than one third of the families, followed by Japan and Canada, with roughly one fifth each. The top 10 filing countries are completed by four non-G7 nations in the G20: the Republic of Korea, Australia, India, and Brazil. The remaining G7 countries are not included in the list, as most applicants chose the regional route, through the EPO, for filing in these countries: France, Germany, Italy, and the United Kingdom (UK).

Turning to applicant countries, China is followed by the USA as the office with the most filings and the country whose applicants filed the greatest number of patent families. All other countries in the top 10 have much lower shares: Korea, Germany, Russia, the UK, Japan, India, Canada and France. Italy is the only G7 country not ranked in the top 10, highlighting the significance of this group in the development of COVID-19 vaccines. Another interesting fact is that Russians filed the fifth greatest share of families despite not being among the top 10 filing offices. All other countries in ranking (B) but not in ranking (A) are part of the EPO.

Since China led both rankings, we also investigated the ranking of applicant countries based on applications filed by nationals abroad, either directly at a national office or through a regional office. In that case, the full ranking is: the US (296 or 25 %), China (153 or 13 %), Germany (37 or 3 %), Korea (35 or 3 %), the UK (29 or 2 %), Japan (25 or 2 %), Canada (18 or 2 %), France (17 or 1 %), Israel (12 or 1 %) and Switzerland (11 or 1 %).

To compare the three country groups in our analysis, we present in Fig. 3 two Venn diagrams of patent families. In diagram (C), we represent where families were filed, considering both national and regional applications. In diagram (D), we show the distribution of applicant countries, considering all types of applications.

Diagram (C) shows that applicants were actively seeking protection worldwide, with 422 families being filed in all three groups. Applicants should perceive families with twins in more jurisdictions and groups as more valuable since they sought wider protection. On the other hand, the 13 families which were only filed in non-G20 nations might be inventions considered not of interest for protection in any G20 country.[2] The total number of families per group was 575 (49 %) for G7, 972 (83 %) for non-G7 in G20, and 450 (38 %) for non-G20.

Focusing on diagram (B), only a few families had applicants from two groups, and none had applicants from all groups. In total, 462 (39 %) families had at least one applicant from the G7, 634 (54 %) from the non-G7 in G20, and 100 (8 %) from the non-G20. Therefore, almost two thirds of families come from applicants not in the G7. Interestingly, 62 %

[1] For example, we considered that an applicant classified as both a company and a university has an unclear classification, so the respective family was discarded to allow for more precise results.

[2] Most cases involve nationals filing only domestically in Bulgaria, Kazakhstan, Peru, Romania, or Taiwan. Two involve applicants filing a single twin abroad: one from the USA filing in Ukraine, and another from Slovenia filing in Luxembourg. Only one family was filed in multiple national offices: Armenia, Kazakhstan and Morocco.

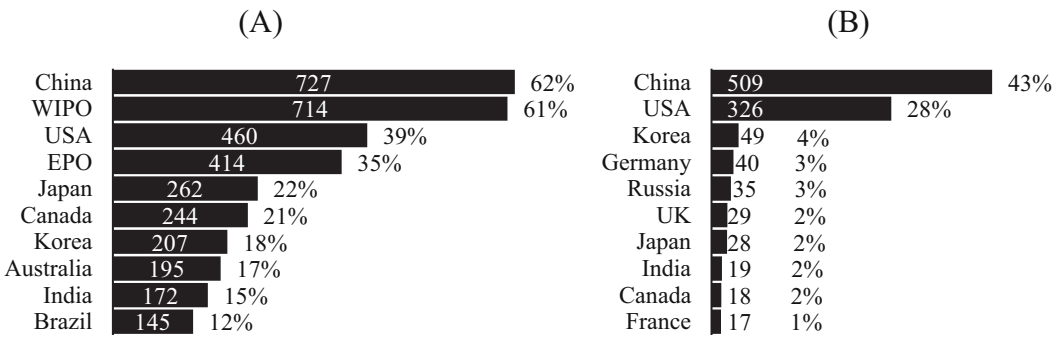

Fig. 2. Top 10 filing offices and applicant countries.
Note: For ranking (A), we considered only national applications. For example, we only counted applications filed directly at the national office for the UK, ignoring those filed at the EPO. For ranking (B), we analysed the applicant country of any type of application: national, regional or international.
Source: Our elaboration, based on data from WIPO and Orbis [13,22].

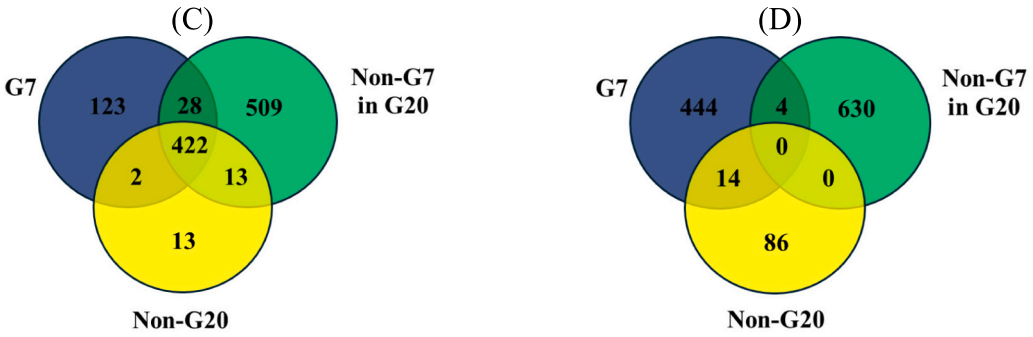

Fig. 3. Distribution of families by groups of filing offices and applicant countries.
Note: For diagram (C), we included national and regional applications, considering all jurisdictions affected by a regional office to determine to which groups the office belongs. For example, filings at the EPO are counted for all groups because, if the patents are granted, they may be designated, extended or validated in countries from the three groups. International applications are not listed in any group, as WIPO is neither a national nor a regional office. For diagram (D), we analysed the applicant country of national, regional and international applications.
Source: Our elaboration, based on data from WIPO and Orbis [13,22].

of families filed by applicants from the non-G20 were only filed abroad, not domestically. This share is much higher than for applicants from the G7 (26 %) and the non-G7 in G20 (4 %). Thus, the non-G7 in G20 is the group for which domestic filings were the most relevant.

Separating the families by vaccine platform, Fig. 4 shows the number of families and how many were filed in each country group. Considering inactivated, live-attenuated, protein subunit and VLP vaccines, 728 (62 %) families covered conventional platforms. One might have expected most families to cover newer platforms, which are more likely to be new and inventive. However, creating a vaccine for a new disease using an existing platform may still meet the patentability criteria and might be a more attractive investment for inventors who have not engaged with the knowledge and capabilities required for newer platforms.

The non-G7 in G20 group was the most frequent destination of each platform, with a variation of only four percentage points. The G7 was the second most frequent destination, followed by the non-G20. Both had a

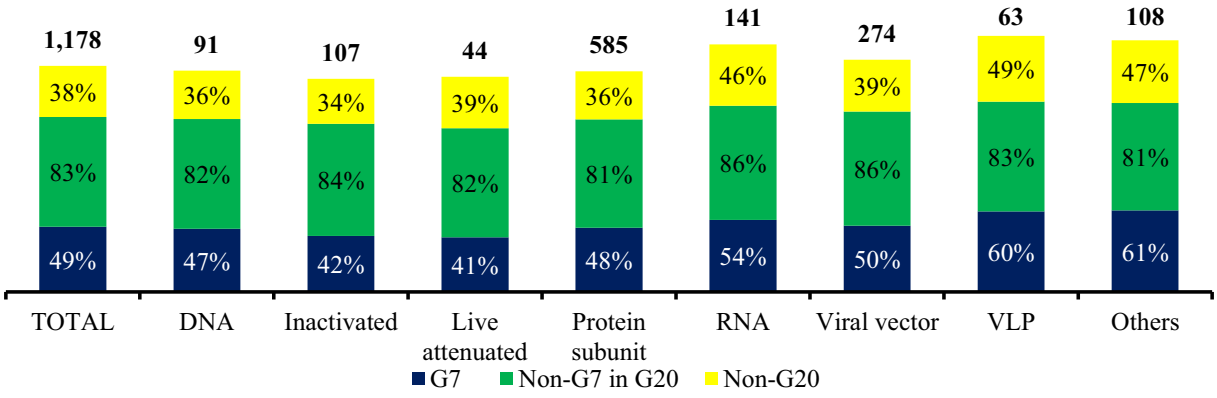

Fig. 4. Number and percentage of families per group of filing country and vaccine platform.
Note: The values above the columns indicate the number of families related to the vaccine platform. The percentages indicate how many families had at least one twin in each group of jurisdictions. The sum of percentages may be more than 100 % because families can have twins in more than one group.
Source: Our elaboration, based on data from WIPO and Orbis [13,22].

higher variation in filing rate: 20 percentage points for the G7 and 15 for the non-G20. In absolute terms, conventional platforms were the most filed in all groups, representing 60 % of filings in the G7, 61 % in the non-G7 in G20, and 59 % in the non-G20.

In Fig. 5, we repeated the analysis for applicant countries. The G7 group was the most relevant only for VLP and others. The non-G7 in G20 group accounted for the greatest number and percentage of filings in all other platforms. This might be surprising because, despite G7 countries developing most novel vaccines that were widely distributed, the non-G7 in G20 was the group that filed most of the patent families covering novel families. The non-G20 had the lowest share in all platforms. In absolute terms, the most common platforms for all groups were protein subunit and viral vector.

We also compared the platforms based on the types of applicants identified by WIPO, as shown in Fig. 6. While corporate applicants were the most frequent, their predominance over UROs is greater for novel platforms (59 % versus 43 %) than for conventional platforms (54 % versus 50 %). Thus, one might say that UROs were relatively more interested in conventional platforms, while corporate applicants were more interested in novel platforms.

In the last two figures, the size of columns varied due to the sum of percentages, which is often greater than 100 % because some families had applicants from different countries and types. There were 937 single-applicant families, so only 20 % of families had any collaboration in patent filings, which was more common in the non-G20 group (29 %) than the G7 (23 %) and non-G7 in G20 (19 %). Collaboration was also significantly more frequent for individual inventors (48 %) than UROs (27 %) and corporate applicants (25 %). Conventional platforms had a higher share of collaboration (23 %) than novel platforms (19 %). Collaboration tended to happen within the same country. When collaboration happened across country groups, this was most often between applicants from the G7 and the non-G20. Collaboration was also more frequent between applicants of the same type, with almost all collaboration in patent filings in applicant types happening between corporate applicants and UROs.

Lastly, we repeated the same analysis for pharmaceutical and biotechnological families to evaluate the uniqueness of the results for COVID-19 vaccines. Table 1 shows that the shares of applications filed in the non-G7 in G20 group and the shares of applications from these countries were greater for COVID-19 vaccine families than for pharmaceutical or biotechnological families. By contrast, the shares on both measures for the other two groups were smaller in the case of COVID-19 vaccines. This indicates that non-G7 G20 applicants had a significantly greater participation in the patent filing activity related to COVID-19 vaccines, but were less likely to file twins in other country groups.

Corporate applicants filed significantly more COVID-19 vaccine families than UROs for the non-G20 and the G7, while both had the same share for the non-G7 in G20. Comparing the samples, the shares of filings by corporate applicants and UROs were almost identical for G7 applicants. For the non-G7 in G20 and the non-G20, the share of corporate applicants is greater for COVID-19 vaccines, while that of UROs is lower. Therefore, corporate applicants from all non-G7 countries engaged more significantly with COVID-19 vaccines.

Applicants from all groups collaborated significantly more often for families related to COVID-19 vaccines, especially those from the non-G20. In addition, when collaboration happened, it was almost twice as likely to involve at least one corporate applicant and one URO for COVID-19 vaccines (42 %) than for pharmaceutical or biotechnological families (24 %). Conversely, collaboration across country groups was almost twice as frequent for the latter (12 %) than for the former (7 %). The G7 had the largest increase in corporate-URO collaboration, while the non-G7 in G20 experienced the largest drop in the rate of collaboration across country groups.

The patterns we observe of more engagement from the non-G7 in G20 and more frequent collaboration in general and between corporate applicants and UROs in the case of COVID-19 vaccines hold in comparison to pharmaceutical and biotechnological families both before (2017–2019) and during (2020−2022) the pandemic.

4. Discussion

The literature on COVID-19 vaccines has explored different aspects of patenting activity. In the early stages of the pandemic, Alshrari et al. showed that most developers of vaccine candidates had filed patent applications [7]. Bacigalupo et al. found that inventors who, before the pandemic, were already developing technologies which became interesting vaccine candidates also increased the patenting activity for these inventions [12]. Investigating the outcome of patent applications, Madhusoodanan et al. found that 84 % of COVID-19 patent families were pending, 13 % had been granted, and 3 % had already lapsed, expired or been revoked. [14] The last group probably indicates candidates that failed to produce viable products.

Analysing the key patent families listed on MedsPaL in June 2021, Chiang and Wu found more families related to novel platforms, such as mRNA and viral vector vaccines, than conventional platforms. [10] Based on WIPO's report [13], we found the opposite to be true. The difference might lie in the methodological differences of the sources. WIPO tried to capture all patent families related to any vaccine candidate, while MedsPaL focused on key families related to vaccines that had been approved for EUL by the WHO. Therefore, while there might be more important patent families related to WHO-approved vaccines that use novel platforms, our analysis suggests that, in the wider scope of all vaccine candidates, patent filing activity was more intense for conventional platforms.

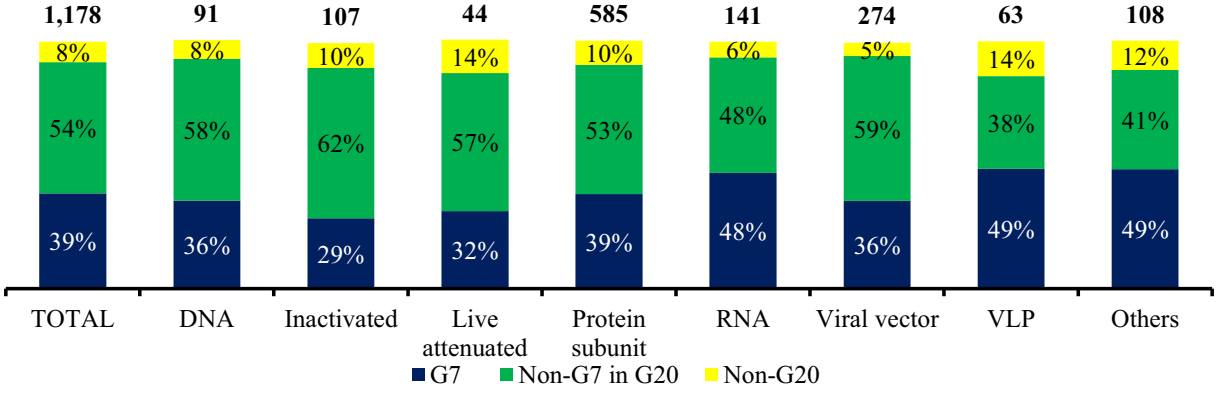

Fig. 5. Number and percentage of families per applicant country group and vaccine platform.
Note: The values above the columns indicate the number of families related to the vaccine platform. The percentages indicate how many families had at least one twin in each group of applicant countries. The sum of percentages may be more than 100 % because families can have applicants from more than one group.

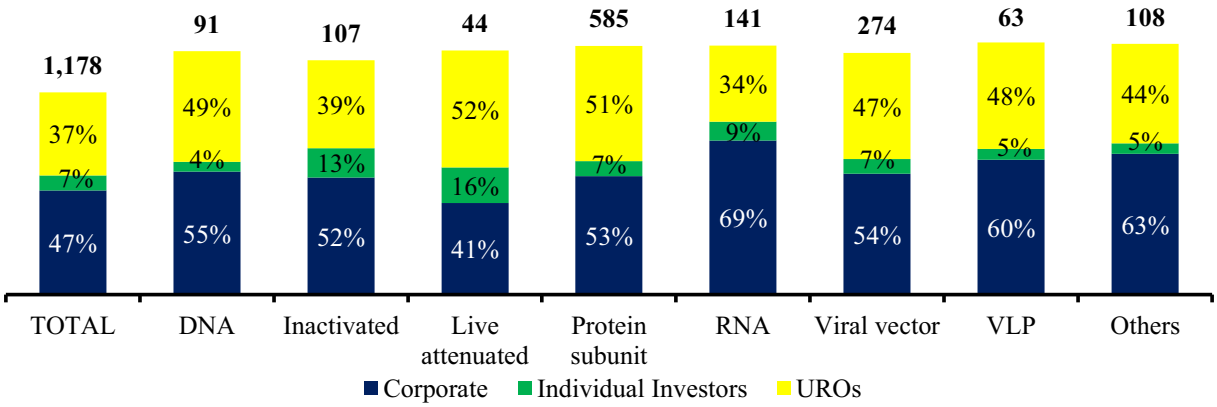

Fig. 6. Number and percentage of families filed by each applicant type per vaccine platform.
Note: The values above the columns indicate the number of families related to the vaccine platform. The percentages indicate how many families had at least one applicant from each type. The sum of percentages may be more than 100 % because families can have more than one type of applicant.

Table 1
Comparison of pharmaceutical or biotechnological families with COVID-19 vaccine families.

Parameters of comparison		Pharmaceuticals or biotechnology (134,507 families)				COVID-19 vaccines (1178 families)			
		Total	G7	Non-G7 in G20	Non-G20	**Total**	G7	Non-G7 in G20	Non-G20
Filing jurisdiction		–	69 %	71 %	53 %	–	49 %	83 %	38 %
Applicant countries		–	55 %	30 %	17 %	–	39 %	54 %	8 %
Type of applicant	Corporate	**53 %**	59 %	38 %	61 %	**56 %**	59 %	52 %	72 %
	URO	**46 %**	41 %	59 %	37 %	**46 %**	42 %	52 %	29 %
	Total	**15 %**	17 %	15 %	18 %	**20 %**	23 %	19 %	29 %
Collaboration	Across country groups	**2 %**	3 %	2 %	8 %	**1 %**	3 %	1 %	12 %
	Corporate & URO	**4 %**	4 %	4 %	4 %	**9 %**	10 %	8 %	7 %

Note: We compared the types of applicants and patterns of collaboration by applicant country, estimating the percentages based on the number of families filed by the applicants from each country group. For example, 4 % of pharmaceutical or biotechnological families filed by G7 applicants included at least one corporate applicant and one URO, while this happened for 10 % of COVID-19 vaccine families.
Source: Our elaboration, based on data from WIPO, Orbis and PATSTAT [22,24,25].

Focusing on mRNA vaccines, Gaviria and Kilic showed how different vaccines are connected in a complex network of patented inventions that are licensed. [8] Therefore, some crucial collaborations may involve patented inventions even if not evident in the patent document. In addition, there is significant litigation over patent rights for these vaccines [15]. Furthermore, Montobbio et al. show how UROs have played a vital role in the development of mRNA vaccines [15]. We found that only one third of RNA-related patent families had at least one URO applicant, but we did not analyse the comparative relevance of the inventions for the development of the vaccines. Therefore, one should not read from our descriptive analysis that the most frequent applicant type is necessarily the one who made all relevant contributions.

Since many empirical studies of COVID-19 vaccine patents tend to focus on novel platforms or WHO-approved vaccines, one should be careful when drawing wider conclusions about patent filing activity. Studies that focus on novel or WHO-approved vaccines tend to find that applicants from high-income countries, especially those in the G7, are more prominent [8,10]. However, analyses of all COVID-19 vaccines tend to find much greater activity in G20 countries not in the G7 [7,11,13]. In our paper, we confirmed both findings. Also, the significance of China has been analysed in the context of this being the country where the pandemic started and of Chinese inventors already investigating human coronaviruses [9,11].

5. Conclusion

This paper investigated the patent filing activity related to COVID-19 vaccines to understand where applications were filed, the country and type of applicants, and patterns of applicant collaboration. Our analysis focused on three groups of countries: G7, non-G7 in G20, and non-G20. Despite the apparent prominence of G7 countries in the race to develop COVID-19 vaccines based on products from Oxford/AstraZeneca, Pfizer/BioNTech and Moderna, among others, most patent filing activity came from the non-G7 in G20 group, particularly from China. This was the group that received the most applications and whose residents were the most prolific in filings. While corporate applicants dominated the other groups, they were as relevant as UROs for the non-G7 in G20. Considering the different vaccine platforms, most patent families covered conventional platforms, perhaps because these are relatively less risky and costly investments than newer platforms. Based on patent filings, corporate applicants appear to have been more interested in novel platforms, while UROs were more interested in conventional platforms.

Besides this characterisation, a significant contribution of our paper is that we have demonstrated how patenting activity in COVID-19 vaccines differs from that observed for pharmaceutical and biotechnological families more generally. This comparison confirmed the greater engagement of non-G7 in G20 applicants for COVID-19 vaccines compared with pharmaceutical and biotechnological families more generally, also reflected in higher filings. Collaboration was also more frequent, with a much higher rate of collaboration between corporate applicants and UROs, despite less frequent collaboration across country groups.

Based on our findings, we recommend that future studies should investigate the specific inventions covered by the patent families and their legal status to evaluate where patent protection was granted and what level of exclusivity it produced. Moreover, future research should examine patents alongside other intellectual property rights and related rights such as know-how, trade secrets, confidential information and

regulatory test data, and other factors that influenced the development, production and distribution of COVID-19 vaccines. This would facilitate a more general assessment of how much intellectual property rights influenced which COVID-19 vaccines were developed, imported and administered in different territories.

CRediT authorship contribution statement

Eduardo Mercadante: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Timo Minssen:** Writing – review & editing, Conceptualization. **Kenneth C. Shadlen:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Esther van Zimmeren:** Writing – review & editing, Conceptualization. **Żaneta Zemła-Pacud:** Writing – review & editing, Conceptualization. **Duncan Matthews:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

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Data availability

Data will be made available on request.

References

[1] WHO – World Health Organisation. *COVID-19 Vaccine Tracker and Landscape*. Accessed August 8, 2024, https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines; 2023.
[2] WHO - World Health Organisation. 12 vaccines granted emergency use listing (EUL) by WHO. Published online 2022. Accessed June 12, 2025, https://covid19.trackvaccines.org/agency/who/.
[3] Druedahl LC, Minssen T, Price WN. Collaboration in times of crisis: a study on COVID-19 vaccine R&D partnerships. Vaccine 2021;39(42):6291–5. https://doi.org/10.1016/j.vaccine.2021.08.101.
[4] Kalinke U, Barouch DH, Rizzi R, et al. Clinical development and approval of COVID-19 vaccines. Expert Rev Vaccines 2022;21(5):609–19. https://doi.org/10.1080/14760584.2022.2042257.
[5] Excler JL, Saville M, Privor-Dumm L, et al. Factors, enablers and challenges for COVID-19 vaccine development. BMJ Glob Health 2023;8(6):e011879. https://doi.org/10.1136/bmjgh-2023-011879.
[6] Alonso Ruiz A, Bezruki A, Shinabargar E, et al. Which roads lead to access? A global landscape of six COVID-19 vaccine innovation models. Glob Health 2024;20(1):25. https://doi.org/10.1186/s12992-024-01017-z.
[7] Alshrari AS, Hudu SA, Imran M, Asdaq SMB, Ali AM, Rabbani SI. Innovations and development of Covid-19 vaccines: a patent review. J Infect Public Health 2022;15(1):123–31. https://doi.org/10.1016/j.jiph.2021.10.021.
[8] Gaviria M, Kilic B. A network analysis of COVID-19 mRNA vaccine patents. Nat Biotechnol 2021;39(5):546–8. https://doi.org/10.1038/s41587-021-00912-9.
[9] Liu K, Gu Z, Islam MS, et al. Global landscape of patents related to human coronaviruses. Int J Biol Sci 2021;17(6):1588–99. https://doi.org/10.7150/ijbs.58807.
[10] Chiang TW, Wu X. Innovation and Patenting Activities of COVID-19 Vaccines in WTO Members: Analytical Review of Medicines Patent Pool (MPP) COVID-19 Vaccines Patent Landscape (VaxPaL). 2022. https://doi.org/10.30875/25189808-2022-1.
[11] Liu K, Zhang X, Hu Y, et al. What, where, when and how of COVID-19 patents landscape: a Bibliometrics review. Front Med 2022;9:925369. https://doi.org/10.3389/fmed.2022.925369.
[12] Bacigalupo ML, Pignataro MF, Scopel CT, Kondratyuk S, Mellouk O, Chaves GC. Unveiling patenting strategies of therapeutics and vaccines: evergreening in the context of COVID-19 pandemic. Front Med 2023;10:1287542. https://doi.org/10.3389/fmed.2023.1287542.
[13] WIPO – World Intellectual Property Organization. *COVID-19 Vaccines and Therapeutics: Insights into Related Patenting Activity throughout the Pandemic*.; 2023. Accessed August 8, 2024. https://www.wipo.int/publications/en/details.jsp?id=4658.
[14] Madhusoodanan L, Soni P, Sharma R, Dubey A. Patent scenario of COVID-19 vaccines: a promising analysis and review of innovation and development. World Intellectual Property 2024;27(1):3–26. https://doi.org/10.1111/jwip.12282.
[15] Montobbio F, Pellegrino G, Sterzi V. Patent landscape analysis of mRNA Covid-19 vaccine technology: examining the role of biotech companies, public research and universities. In: Park WG, editor. Handbook of innovation and intellectual property rights. Edward Elgar Publishing; 2024. p. 417–39. https://doi.org/10.4337/9781800880627.00034.
[16] MPP – Medicines Patent Pool.. The Medicines, patents and licenses database - MedsPaL. Published online 2024. Accessed August 8, 2024, https://medicinespatentpool.org/what-we-do/medspal.
[17] Hegde D, Mowery D, Graham S. *Pioneers,* Submariners, or thicket-builders: which firms use continuations in patenting? National Bureau of Economic Research; 2007:w13153. doi:https://doi.org/10.3386/w13153.
[18] Martínez C. Insight into Different Types of Patent Families 2010;2010/02. https://doi.org/10.1787/5kml97dr6ptl-en.
[19] Martínez C. Patent families: when do different definitions really matter? Scientometrics 2011;86(1):39–63. https://doi.org/10.1007/s11192-010-0251-3.
[20] Minn M. Strategic patenting decisions in the European pharmaceutical industry: the use of divisional applications and follow-on patenting practices. Journal of Intellectual Property Law & Practice 2016;11(8):619–27. https://doi.org/10.1093/jiplp/jpw099.
[21] Dechezleprêtre A, Ménière Y, Mohnen M. International patent families: from application strategies to statistical indicators. Scientometrics 2017;111(2):793–828. https://doi.org/10.1007/s11192-017-2311-4.
[22] Moody's. Orbis Intellectual Property. Accessed May 25, 2024. https://login.bvdinfo.com/R1/OrbisIntellectualProperty.
[23] Pizza M, Pecetta S, Rappuoli R. Vaccines 2020: the era of the digital vaccine is here. Sci Transl Med 2021;13(624):eabm3249. https://doi.org/10.1126/scitranslmed.abm3249.
[24] Moody's. Orbis Intellectual Property. Accessed September 30, 2025. https://login.bvdinfo.com/R1/OrbisIntellectualProperty; 2025.
[25] European Patent Office. PATSTAT - Spring. Accessed September 30, 2025, https://www.epo.org/en/searching-for-patents/business/patstat; 2025.