Estimates of the Public Health Impact of the Global Fund's COVID-19 Response Mechanism on COVID-19

Ines Gerard-Ursin, Charles Whittaker, Timothy Hallett, Azra Ghani
MRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London
July 2023

Executive summary

In 2020, the Global Fund set up the COVID-19 Response Mechanism (C19RM) to distribute funds to mitigate the impact of the COVID-19 pandemic on health programs and systems across a portfolio of low- and middle-income countries. Here we estimate the impact that a subset of this investment (provided for the COVID-19 direct response) had on the COVID-19 pandemic.

Data on supplies procured under four categories (diagnostics, personal protective equipment (PPE), oxygen, and therapeutics) from 2020-2022 were provided by the Global Fund to Fight AIDS, Tuberculosis and Malaria. We restricted our model-based estimates of impact under each of the four categories in the following way: 1) for diagnostics, we extracted data on the number of antigen and polymerase chain reaction (PCR) tests by country and over time, ignoring other miscellaneous items; 2) for PPE, we limited our analysis to masks and respirators as a proxy for protection; 3) for oxygen, we used data on oxygen supplies (either through cannisters or fixed supply) as a proxy for oxygen availability; and 4) for therapeutics, we limited our analysis to dexamethasone as this has evidence-based, direct impact on survival. We further limited our analysis to interventions that had been delivered between May 2020 and November 2022 to 79 countries for which COVID-19 epidemic estimates were available. This represented funding of US$405 million.

We developed simple models to relate these investments to outputs (demand met). For diagnostics, we estimated the demand met of antigen- and PCR-based tests in the hospital setting to improve triage and the demand for antigen-based tests in the community. For PPE, we estimated the demand met as the number of health care worker days protected with masks or respirators among health care workers in the hospital (doctors and nurses). For oxygen and therapeutics (dexamethasone) we estimated the demand met in terms of the number of patients receiving the intervention. Given the wide uncertainties in parameters, we present results as a central scenario with lower and upper ranges generated through univariate sensitivity analysis.

We found that a high proportion of the demand for testing in the hospital setting could have been met through the C19RM supplies procured and delivered, with 3.4 million (range 1.9 million–5.4 million) or 74% (range 67%–80%) of patients potentially correctly triaged as a result. We further estimate that 17 million (range 14 million–19 million) symptomatic mild cases could potentially have obtained a rapid diagnostic test (RDT) in the community. Based on World Health Organization (WHO) estimates of numbers of health care workers (restricted to doctors and nurses), we estimate that 65 million (range 51 million–80 million) health care

worker days[1] were protected, representing 34% (28%–46%) of the demand for masks and respirators. Supplies of oxygen and dexamethasone increased significantly from 2022 onwards, with the potential to treat 17,000 (range 9,300–32,000) severely ill patients with oxygen and 15,500 (8,000–29,500) critically ill patients with dexamethasone. We note that there is considerable uncertainty in all of these estimates given the uncertainty in the evolving local epidemics, the proportion of patients seeking care and the readiness of health systems to administer the supplies.

There were many challenges in generating the estimates presented here and therefore the results are highly uncertain. Throughout we have assumed that there is perfect efficiency in the distribution of the supplies to where they are needed, that all other required equipment to administer these supplies are available (such as PCR diagnostic processing machines, oxygen administration supplies including ventilators and masks), and that there are enough trained health care workers and staff members to facilitate their use. While we assumed that 10% of supplies would have been wasted, lost, or damaged, data from these settings were not available to inform this assumption. We also did not include any intervention- or time-specific estimates of absorptive capacity. Alongside the need for broader investment in monitoring and mapping health care system variability across countries, it would be helpful to monitor distribution of commodities delivered to countries so that data on availability and usage can be captured in future modeling exercises. Our analysis was further limited by a lack of comparative data on support provided through other means – either from other international partners or through domestic funds.

[1] One "health care worker day" is equivalent to one full day of work for one health care worker.

COVID-19 Response Mechanism funding

In 2020, the Global Fund set up C19RM to distribute funds to mitigate the impact of the COVID-19 pandemic on health programs and systems within a portfolio of low- and middle-income countries. As of 23 December 2022, C19RM had awarded US$4.76 billion[2] within three categories: 1) COVID-19 response; 2) adjustment of HIV, TB and malaria programs in response to COVID-19-related disruptions; and 3) health systems strengthening.

We developed models to evaluate the impact of four interventions:

1. Diagnostic tests, either in a hospital or community setting.
2. PPE – focusing solely on masks and respirators.
3. Provision of oxygen – focusing on oxygen cylinders and concentrators.
4. Provision of dexamethasone as a therapeutic.

We limited our analysis to 79 countries for which model-estimates of the COVID-19 epidemic were available, representing a spend of US$405 million (Table 1). The breakdown of spend by intervention is shown in Table 1. These data contained detailed information on the product type and unit of each commodity distributed to countries. The data were further processed to translate these text data into single units – for example, doses of dexamethasone and liters of flow of oxygen. Each was evaluated over time, with commodities carried over if unused as appropriate to the commodity.

Table 1: Summary of the breakdown of the C19RM grants by category

Category	Total grants awarded (US$, millions) as of January 2023	Modeled interventions delivered to the 79 countries between May 2020 and November 2022 (US$, millions)	Percentage of total grants awarded
Diagnostic tests	1,017	330.6	32.5%
PPE	769*	60.9	7.9%
Oxygen	605*	12.9	2.1%
Dexamethasone	28*	0.791	2.8%

**Includes other interventions than those modeled. For PPE this includes gloves, face shields, gowns, and other items; for oxygen, this includes miscellaneous oxygen equipment and pressure swing adsorption (PSA) plants; for dexamethasone, this includes medicines labeled "other therapeutics."*

[2] C19RM Monthly Update to the Board, 2023.

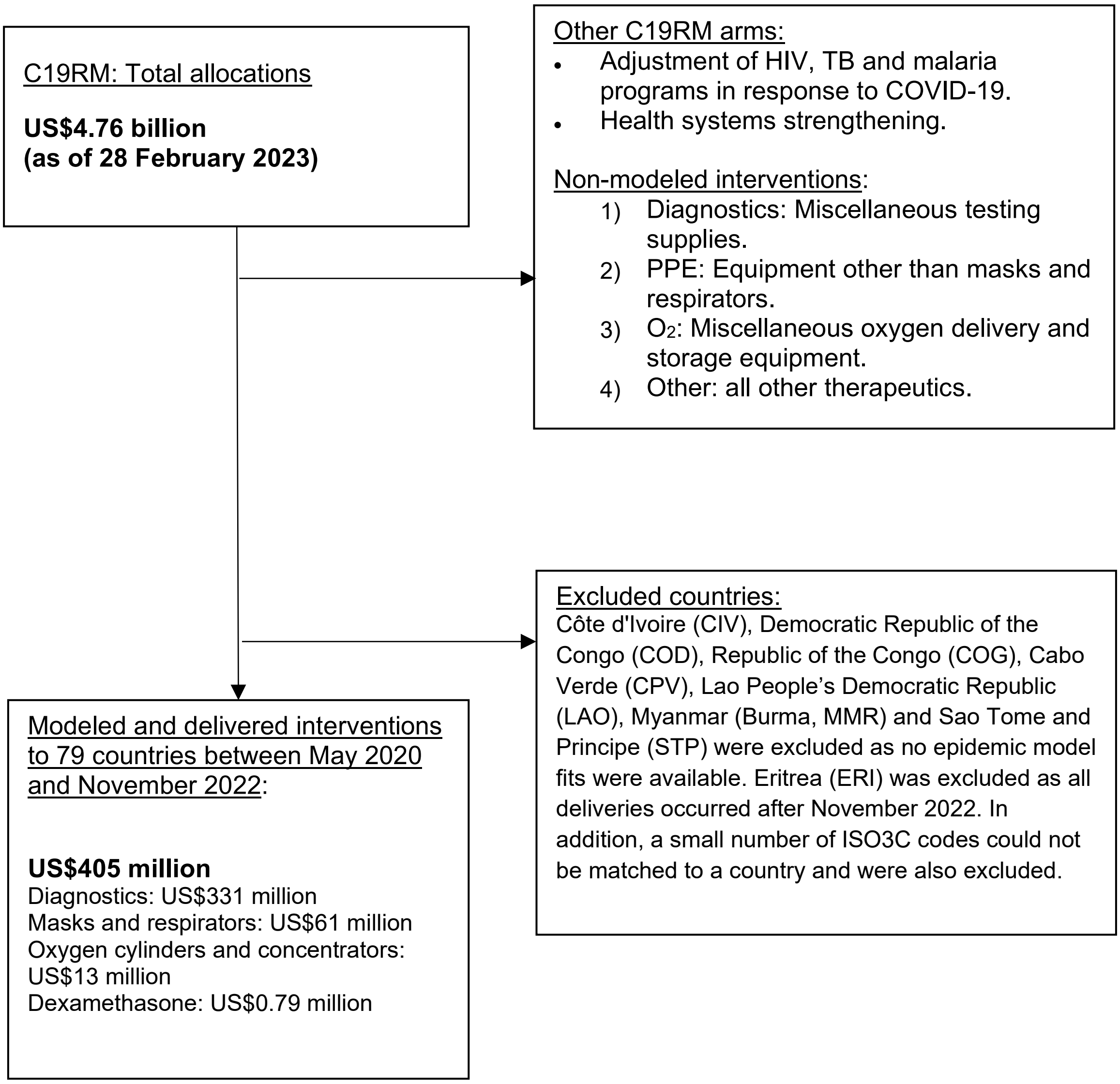

Figure 1: Summary of the breakdown of C19RM grants and spend. Modeled interventions are the subset of the interventions that are used in this analysis. Modeled and delivered refers to the subset of the interventions that were delivered at least three months prior to November 2022.

Overview of approach

To estimate the demand for the products delivered as part of C19RM, we generate epidemic scenarios for each country and for each commodity. This observed epidemic is an estimate of COVID-19 trajectories that capture implicitly the C19RM health products delivered in each country (as well as all other interventions and behavioral changes that occurred). It is based on backward inference from excess deaths as a measure of the true scale of the epidemic given the substantial levels of under-ascertainment of COVID-19 cases and deaths.[3]

For each commodity we use the observed epidemic to calculate product **demand**. We compare this demand to the **supply**, calculated from the procurement data supplied by the Global Fund, which contained data on the units of each of the commodities. **Demand met** is then defined as the lower of supply or demand.

The Global Fund was one of many actors contributing to the international COVID-19 response, and there would have been a standing capacity of PPE and oxygen supply in health care facilities. However, we do not know the baseline commodity estimates per country, nor do we know the contributions of other actors or the standing capacity. Therefore, this approach might overestimate impact.

COVID-19 Response Mechanism interventions

We modelled the impact of three groups of commodities – diagnostics, PPE and therapeutics (incorporating oxygen and dexamethasone). For each commodity, we define one or more use cases (Table 2).

Outputs are defined as the commodities delivered to the 79 countries considered (Table 1). These were calculated for each use case from the procurement data. For all commodities we assume a three-month lag between the recorded delivery date and usage. Thus, items had delivery dates between May 2020 and August 2022 and were assumed to be available for use between August 2020 and November 2022. We additionally incorporated a 10% wastage estimate, using the same value that the COVID-19 Vaccines Global Access (COVAX) working group used when modeling vaccine distribution.[4]

We define the **outcomes** as the demand that was met – by comparing the modeled demand to the supplies available. These are summarized for each commodity and use case in Table 3.

[3] Watson et al., 2022.
[4] Griffiths et al., 2021.

Table 2: Summary approach and key assumptions relating commodities and use cases to estimated outputs and outcomes

Commodity provided by C19RM	Use case	Approach and key assumption	
		Estimates of outputs	**Estimates of outcomes**
Diagnostics	Severely symptomatic patients presenting at a hospital being tested for COVID-19 and then being isolated and treated accordingly.	PCR plus RDTs delivered. Three-month lag, 10% wastage	Country-specific estimates of the number of people presenting to a hospital was used to estimate the required number of tests at admission. This was compared with the number of tests available each month. We assumed 30% of those that develop severe symptoms would seek care and hence be hospitalized for the central scenario, with (15%,60%) used for the uncertainty bounds. These values reflect access to health care estimates in the literature.[5] The demand met was multiplied by the test sensitivity to estimate the number of COVID-19 patients correctly triaged.
	Symptomatic people using an RDT in the community and if the result is positive, they take necessary precautions to prevent onward transmission.	RDTs delivered subtracting those used in the hospital setting. Three-month lag, 10% wastage We assume that RDTs were not used in the community prior to October 2021 (following revised WHO guidelines).	Country-specific estimates of the number of people with mild symptomatic infection were used to estimate the demand for testing for those that would test positive. We assumed 50% of these people would test in the central scenario with (20%, 80%) used for the uncertainty bounds. This demand was compared with the number of RDTs available each month.
PPE	Health care workers (HCWs) (doctors and nurses only) use masks and respirators while in contact with COVID-19 patients.	Total masks plus respirators delivered. Three-month lag, 10% wastage	Estimates of HCWs by country from WHO. For the central scenario we assumed 51% of these HCWs were allocated to the COVID-19 response (in line with WHO COVID-19 Essential Supplies Forecasting Tool), with (25%, 75%) used for the uncertainty bounds. HCWs were assumed to work one 8-hour shift per day, for an average of 222 days per year (country-based estimates used). Multiplying this we obtained the number of HCW shifts to estimate demand for PPE.

[5] Eyeberu, 2021; Skrip, 2020; Tran, 2020.

Commodity provided by C19RM	Use case	Approach and key assumption	
		Estimates of outputs	**Estimates of outcomes**
Therapeutics	Severe cases receiving oxygen in a hospital.	Cylinders and concentrators delivered. Three-month lag, 10% wastage Converted to oxygen supplied using oxygen cylinder user manuals for each product. Estimated flow rates from delivered products were not sufficient for critical cases and so the use case was limited to severe cases.	Country-specific estimates of the number of people presenting to a hospital with severe disease. We assumed 30% of those requiring hospitalization would seek care for the central scenario, with (15%,60%) used for the uncertainty bounds. Oxygen demand is calculated as the product of the incidence of severe patients, the mean number of days oxygen is required and the flow rate of the oxygen. Supply is determined by the liters of oxygen in the cylinders and concentrators. We assume that oxygen cylinders are non-reusable when estimating availability over time and that unused cylinders are carried over each month. Concentrators are assumed to be available continuously.
	Critically ill patients receiving dexamethasone in a hospital.	Three-month lag, 10% wastage Tablets and intravenous supplies converted into required dosage for a full treatment course using WHO treatment guidelines.	Country-specific estimates of the number of people presenting to a hospital as a critical case. We assumed 30% of those requiring hospitalization would seek care for the central scenario, with (15%,60%) used for the uncertainty bounds. Demand is the incidence of critical cases seeking hospital care.

Results

Table 3 summarizes the items delivered under the four commodity categories.

Table 3: Summary of items and cost of delivered C19RM supplies by category

Category	Number of items delivered (millions)	Unit of delivery	Cost of supplies delivered to countries and modeled (US$, millions)	Expected dates in use (delivery date + three months)
Diagnostic tests	61.8 of which 49.6 were antigen rapid diagnostic tests (Ag-RDTs)	Ag-RDT and PCR diagnostic tests	330.6	2020-08-06 - 2022-11-26[1]
PPE	553.0	Masks, respirators[2]	60.9	2020-12-18 - 2022-11-30
Oxygen	0.020	Cylinders and concentrators[3]	12.9	2021-01-10 - 2022-11-02
Dexamethasone	0.283	Ampoules or packages of tablets[4]	0.791	2021-11-30 – 2022-11-10

1. We assume that RDTs were not used in the community prior to October 2021.
2. Includes surgical masks and respirator masks (e.g., N95 or FFP2).
3. Oxygen concentrator unit is the machine and includes both single and double flow units.
4. Defined as the package, typically containing 10 ampoules or 100 tablets.

Table 4 summarizes the demand met under each use case scenario. The ranges quoted here represent the limited sensitivity analyses incorporated; however, we note that there is considerable uncertainty in these numbers. Given the assumptions made about unlimited supportive capacity and perfect distributional efficiency, they represent optimistic impact estimates.

Table 4: Summary demand met by commodity and use case

Commodity provided by C19RM	Use case	Date of use case becoming active	Demand met
Diagnostics	Severely symptomatic patients presenting at a hospital being tested for COVID-19 and then being isolated and treated accordingly.	August 2020 (Estimated date of in-country delivery plus lag of three months.)	3,400,000 (1,900,000–5,400,000) patients presenting to a hospital would be correctly triaged [74% (67%–80%) of all those who presented to a hospital in that period].
	Symptomatic persons using an RDT and isolating themselves if the result is positive.	October 2021 (Date when WHO guidance for such a "community testing" use case was issued.)	49,600,000 RDTs could have been used by individuals with symptoms, of which 17,000,000 (14,000,000–19,000,000) could have been used in those experiencing mild symptoms of COVID-19 infection (others would have had symptoms from another cause). This represents 6% (4%–10%) of all those estimated to have experienced mild symptoms of infections in the period.
PPE	Health care workers (doctors and nurses) using masks and respirators while working on COVID-19 wards.	December 2020 (Estimated date of in-country delivery plus lag of three months.)	65,419,600 (51,383,700–80,349,500) health care worker days on COVID-19 wards could have been protected [34% (28%–46%) of the total amount of health care worker days].[6]
Oxygen (cylinders and concentrators)	Severe cases receiving the oxygen they required in a hospital.	January 2021 (Estimated date of in-country delivery plus lag of three months.)	17,000 (9,300–32,000) severely ill patients could have received the recommended amount of oxygen [13% (12%–13%) of severely ill hospitalized patients].[7]
Dexamethasone	Critically ill patients receiving dexamethasone in a hospital.	November 2021 (Estimated date of in-country delivery plus lag of three months.)	15,500 (8,000–29,500) critically ill patients could have received a full course of dexamethasone [8% (7%–8%) of critically ill hospitalized patients].[8]

[6] Assuming that protection for one health care worker day requires four masks or one respirator.
[7] Assuming that all other health care needs were met.
[8] Idem.

Limitations

Across all categories of spend, given the lack of data, we made the optimistic assumption that there is near perfect efficiency in the distribution of these supplies to both the location where they are needed and at the calendar time that they are needed; that all other required equipment to administer these supplies are available (such as PCR diagnostic processing machines, oxygen administration supplies including ventilators and masks); and that there are enough health care workers and staff members to facilitate their use. In reality, there is likely to be considerable variability in all of these factors that is likely to reduce the estimated impact of the spend. While we included an assumed small proportion of wastage in supplies, this estimate was based on modeling of vaccine delivery. Our analysis would have been strengthened by evidence-based, intervention- or time-specific ranges of wastage of donated products or absorptive capacity. Furthermore, while we incorporated a delay between delivery and use by including a three-month lag period, the analysis was limited by the absence of country specific, evidence-based estimates of the delay between delivery and use. Alongside the need for broader investment in monitoring and mapping health care system variability across countries, it would be helpful to monitor distribution of commodities delivered to countries so that data on availability and usage can be captured in future evaluations.

Our analysis was further limited by a lack of comparative data on support provided through other means – either from other international partners or through domestic funds (including standing capacity). This is particularly true for those categories of spend in which we estimated a high proportion of demand to have been met through the C19RM response – namely diagnostics in hospitals and dexamethasone demand towards the end of 2022.

Within each spend category, we made several additional assumptions, all of which are likely to result in optimistic estimates of impact. Within diagnostics, we assumed that diagnostics in the hospital setting were used only on COVID-19 cases, and that for each case, only a single test was required. However, in practice, cases as well as uninfected patients with similar symptoms and health care workers may have been tested multiple times. Similarly, for community-based diagnostic testing, we assume symptomatic cases would test once, whereas both cases and non-cases may have tested multiple times.

For PPE, we assumed that no PPE provision is equivalent to zero protection, when improvised PPE could potentially be effective at prevention. Additionally, given the lack of data on other supplies, we were not able to calculate "full kits" and so instead used only masks and respirators as an indication of adequate PPE. In the absence of these data, if masks and respirators were more common, we may have over-estimated the impact of PPE.

For the therapeutics considered here – oxygen and dexamethasone – we assumed that their use is not constrained by other health care system resources. In practice, administration of oxygen requires equipment and trained professionals, while dexamethasone use is contingent upon patients also receiving oxygen and/or advanced respiratory support if required. Neither of these were constrained in our analysis by the availability of an appropriate hospital bed or intensive care unit (ICU) facilities.

There could have been positive effects on health through the use of these commodities beyond what is captured here: For instance, effective triage may have helped other health care services be maintained, and the provision of PPE for health care workers will have contributed to maximizing the number of health care workers available to provide frontline care.[9] Furthermore, some of the diagnostic tests could have been used to meet other demands (e.g., outbreak investigation, testing health care workers regularly) that are not quantified here.

[9] Wang et al, 2023.

References

C19RM Monthly Update to the Board. The Global Fund, 2023. https://www.theglobalfund.org/media/13030/covid19_2023-04-14-board_update_en.pdf.

Therapeutics and COVID-19: living guideline. World Health Organization, 2022. https://www.who.int/publications/i/item/WHO-2019-nCoV-therapeutics-2022.4

WHO COVID-19 essential supplies forecasting tool (COVID-ESFT). World Health Organization, 2021. https://www.who.int/publications/i/item/WHO-2019-nCoV-Tools-Essential-forecasting-2021-1.

Brazeau, N. F., Verity, R., Jenks, S., Fu, H., Whittaker, C., Winskill, P., Dorigatti, I., Walker, P. G. T., Riley, S., Schnekenberg, R. P., Hoeltgebaum, H., Mellan, T. A., Mishra, S., Unwin, H. J. T., Watson, O. J., Cucunubá, Z. M., Baguelin, M., Whittles, L., Bhatt, S., . . . Okell, L. C. (2022). Estimating the COVID-19 infection fatality ratio accounting for seroreversion using statistical modelling. *Communications Medicine*, *2*(1), 54. https://doi.org/10.1038/s43856-022-00106-7.

Eyeberu, A., Mengistu, D. A., Negash, B., Alemu, A., Abate, D., Raru, T. B., Wayessa, A. D., Debela, A., Bahiru, N., Heluf, H., Kure, M. A., Abdu, A., Dulo, A. O., Bekele, H., Bayu, K., Bogale, S., Atnafe, G., Assefa, T., Belete, R., . . . Dessie, Y. (2021). Community risk perception and health-seeking behavior in the era of COVID-19 among adult residents of Harari regional state, eastern Ethiopia. *SAGE Open Med*, *9*, 20503121211036132. https://doi.org/10.1177/20503121211036132.

Grassly, N. C., Pons-Salort, M., Parker, E. P. K., White, P. J., & Ferguson, N. M. (2020). Comparison of molecular testing strategies for COVID-19 control: a mathematical modelling study. *Lancet Infect Dis*, *20*(12), 1381-1389. https://doi.org/10.1016/s1473-3099(20)30630-7.

Griffiths, U., Adjagba, A., Attaran, M., Hutubessy, R., Van de Maele, N., Yeung, K., Aun, W., Cronin, A., Allan, S., Brenzel, L., Resch, S., Portnoy, A., Boonstoppel, L., Banks, C., & Alkenbrack, S. (2021). Costs of delivering COVID-19 vaccine in 92 AMC countries. World Health Organization. https://www.who.int/docs/default-source/coronaviruse/act-accelerator/covax/costs-of-covid-19-vaccine-delivery-in-92amc_08.02.21.pdf

Skrip, L., Derra, K., Kaboré, M., Noori, N., Gansané, A., Valéa, I., Tinto, H., Brice, B. W., Gordon, M. V., Hagedorn, B., Hien, H., Althouse, B. M., Wenger, E. A., & Ouédraogo, A. L. (2020). Clinical management and mortality among COVID-19 cases in sub-Saharan Africa: A retrospective study from Burkina Faso and simulated case analysis. *Int J Infect Dis*, *101*, 194-200. https://doi.org/10.1016/j.ijid.2020.09.1432.

Tran, B. X., Vu, G. T., Le, H. T., Pham, H. Q., Phan, H. T., Latkin, C. A., & Ho, R. C. (2020). Understanding health seeking behaviors to inform COVID-19 surveillance and detection in resource-scarce settings. *J Glob Health*, *10*(2), 0203106. https://doi.org/10.7189/jogh.10.0203106.

Wang, H., Zeng, W., Munge Kabubei, K., Rasanathan, J. J. J., Kazungu, J., Ginindza, S., Mtshali, S., Salinas, L. E., McClelland, A., Buissonniere, M., Lee, C. T., Chuma, J., Veillard, J., Matsebula, T., Chopra, M. (2023). Modelling the economic burden of SARS-CoV-2 infection in health care workers in four countries. Nat Comm, 14(1), 2791. https://doi.org/10.1038/s41467-023-38477-7.

Watson, O. J., Barnsley, G., Toor, J., Hogan, A. B., Winskill, P., Ghani, A. C. (2022). Global impact of the first year of COVID-19 vaccination: a mathematical modelling study. Lancet Infect Dis 22(9) 1293-1302. https://doi.org/10.1016/S1473-3099(22)00320-6.

Whittaker, C., Watson, O. J., Alvarez-Moreno, C., Angkasekwinai, N., Boonyasiri, A., Carlos Triana, L., Chanda, D., Charoenpong, L., Chayakulkeeree, M., Cooke, G. S., Croda, J., Cucunubá, Z. M., Djaafara, B. A., Estofolete, C. F., Grillet, M. E., Faria, N. R., Figueiredo Costa, S., Forero-Peña, D. A., Gibb, D. M., . . . Hallett, T. B. (2022). Understanding the Potential Impact of Different Drug Properties on Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Transmission and Disease Burden: A Modelling Analysis. *Clin Infect Dis*, *75*(1), e224-e233. https://doi.org/10.1093/cid/ciab837.