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Evolution of the COVID-19 Pandemic and Evaluation of Government Measures on the Reproduction Rate in Chad as June 30, 2020

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ABSTRACT

The objective of this study was to take stock of the evolution of the COVID-19 pandemic in the world, model its evolution and assess the impacts of government measures on its instantaneous reproduction rate in Chad on the date of June 30, 2020. The exploratory analysis revealed that the evolution of this global health crisis has remained exponential and variable by country and by subcontinent with an average growth in infection cases of 7.0% per day. In addition, exposure to the COVID-19 risk which implicitly reflects the level of development of the countries is not correlated with the results achieved in the management of the pandemic. The countries exposed to the COVID-19 risk, mainly in sub-Saharan Africa, are able to contain, with a few exceptions, the evolution of cases of infections and deaths, for having put in place government measures following the recommendations of the WHO or for epidemiological factors. However, a few countries end up with a high proportion of active cases. Countries believed to have low exposure to COVID-19, mainly in the Western block, have recorded contrasting developments in the pandemic. Modeling the evolution of the pandemic in Chad has revealed that an average of 12 infected people per day escape the surveillance and control of the pandemic. In addition, the evaluation of government measures showed that the sanitary measures lowered the reproduction rate (R_t) by 28.5% and a 1% increase in the rate followed causes it to decrease by about 25.4%. On the other hand, ad-hoc border opening measures aimed at passenger arrivals led to an increase in the R_t of 20.6%. It is also observed that the measures to reduce displacements and / or containment only act on the R_t with a delay of 4 to 5 days, with the start of a significant decrease of 29.6 % of reproduction rate.

Keywords: Covid-19, infection, instantaneous reproduction rate

Introduction

The COVID-19 pandemic has seen an exponential pattern of growth in the number of cases of infection or death, which varies greatly between countries and continents. Leaving China in December 2019, the disease took hold at the end of January 2020 in 111 countries around the world, which led the WHO to declare a state of public health emergency of international concern on January 30, 2020 and declare on March 11, 2020, the outbreak of the COVID-19 global pandemic. The end of June 2020 marks the beginning of a gradual lifting by certain countries of government measures used in the process of containing the transmission of the disease, in particular to limit economic and social shocks, against the backdrop of a fear of a second epidemic wave raised in mid-July 2020. The life cycle of the disease is not fully known and as of June 30, 2020, 186 countries are affected with nearly 10.5 million cases of infections and 511.3 thousand deaths. As of this date, all affected countries have recorded, to varying degrees, an average growth in infections due to the pandemic of around 7.0% per day, as well as an average death rate of 6.8 individuals per 100,000 inhabitants. To face this pandemic, countries have taken the measures and actions required to organize the response capacity in order to contain its progression and increase overall resilience. And several studies are being undertaken around the world to analyze the epidemiological, social and economic issues. And in accordance with the International Health Regulations, countries have committed to producing daily reports on COVID-19, with statistical data taken and consolidated in international databases, and which would only be used to produce exploratory analyzes by country, region or continent. These studies and statistics are part of a context of global inequality in production and access to information, aggravated by COVID-19 [UNDESA, 2020], thus weakening in countries with low statistical capacity, aid to decision-making and research to better understand complex health, economic and social issues.

This reflection takes as a starting point, two specific studies which respectively led to the construction of an inform COVID-19 risk index which aims to identify "Countries at risk of health and humanitarian impacts from COVID-19 which could overwhelm the current national response capacity, and therefore lead to a need for additional international assistance*, and the government response index developed by the University of Oxford* which provides a measure of the extent of public policies and interventions in response to COVID-19. These two studies make it possible to have a reference situation characterized by exposure to the COVID-19 risk very unequal between countries which are not correlated with the results in terms of control of the pandemic which itself remains a function of speed and the scope of government measures and actions put in place.

* Available on the site: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Epidemic
* Thomas Hale, Sam Webster, Anna Petherick, Toby Phillips, and Beatriz Kira. (2020). Oxford COVID-19 Government Response Tracker.Blavatnik School of Government. **www.bsg.ox.ac.uk/covidtracker**

An exploratory analysis of the contrasted evolution of the COVID-19 pandemic in the world refers to this preliminary observation which underlines the importance of information and its modeling, and which highlights certain difficulties in measuring the effectiveness of public policies and factors affecting the progression of the pandemic.

Thus, it is becoming necessary to rethink the epidemiological modelling needed for crisis management to identify the effects of measures according to the specific contexts of countries, and the present study focuses on a modelling trial, in incomplete information, of the reproductive rate and evolution of the COVID-19 pandemic in Chad as of 30th June, 2020.

Exploratory analysis of the contrasted evolution of the COVID-19 pandemic, as of June 30, 2020

Global COVID-19 situation as of June 30, 2020

Starting from Wuhan, China, in early December 2019, the COVID 19 pandemic reached almost every country in the world within four months. The majority of countries around the world responded by implementing non-drug interventions, including isolating proven cases, closing schools and universities, banning mass gatherings and/or public events, social distancing, and confinement. The results of the strategies put in place by the countries can be accessed on the basis of an exploratory analysis based on three main phases of the evolution of COVID-19 as of June 30, 2020. Before March 11, 2020, the date of declaration of a pandemic by the WHO, the number of declared cases was 125,704 infections and 4,610 deaths, mainly in four countries, China, Italy, South Korea and Iran. However, this disease spread from the end of January 2020 in North America, Europe, and the Middle East, which led the WHO to declare a state of public health emergency of international concern on January 30. 2020. During this first phase, this disease experienced an average daily growth of 26.9%. A first inflection of this exponential growth took place over the period from March 12 to May 20, 2020 with a rate of 10.3% of cases of infection per day, but the COVID-19 pandemic has spread in almost all countries with 4,880,057 cases of infections and 328,483 deaths, with this particularity that the world was going to register a little less than 100,000 cases of infection per day. During this second phase, 24 countries (see Table 1 below) out of a total of 186, reported 86.1% of cases of infections and 91.5% of deaths. These 24 countries, which have this second characteristic of having recorded their first case of COVID-19 infection before the date of declaration of a global pandemic, represent, over the period from May 21 to June 30, 2020, almost the same proportions of cases infections (84.1%) and death (90.4%). During this third phase, the average daily growth of the pandemic was 7.7%, with however marked differences by country and by subcontinent, as for the second phase.

The evolution of this global health crisis has remained exponential and variable by country and by subcontinent, according to the three phases identified. With an average growth in infection cases of 7.0% per day as of June 30, 2020, the pandemic doubling time is 10 to 11 days. This exponential growth is appreciated by epidemiologists by the Basic Reproduction Rate (R0) of the virus estimated on average from 2 to 4 people that a contagious person can infect. This is a strong contagiousness which implies the effective implementation of public health actions to reduce this reproduction rate to a level lower than a secondary case.

Rank	ISO code	Country	1st_Infection	1st_Death
1	USA	United States	01/21/20	02/29/20
2	BRA	Brazil	02/26/20	03/17/20
3	RUS	Russia	01/31/20	03/19/20
4	IND	India	01/30/20	03/11/20
5	GBR	United Kingdom	01/31/20	03/06/20
6	PER	Peru	03/06/20	03/20/20
7	CHL	Chile	03/03/20	03/22/20
8	ESP	Spain	02/01/20	03/03/20
9	ITA	Italy	01/31/20	02/21/20
0	IRN	Iran	02/19/20	02/19/20
11	MEX	Mexico	02/28/20	03/19/20
12	PAK	Pakistan	02/26/20	03/19/20
13	ENG	France	01/24/20	02/15/20
14	TUR	Turkey	03/11/20	03/17/20
15	DEU	Germany	01/27/20	03/09/20
16	UAA	SaudiArabia	03/02/20	03/24/20
17	ZAF	South Africa	03/05/20	03/27/20
18	BGD	Bangladesh	03/08/20	03/18/20
19	CAN	Canada	01/26/20	03/09/20
20	COLLAR	Colombia	03/06/20	03/22/20
21	SWE	Sweden	01/31/20	03/11/20
22	EGY	Egypt	02/14/20	03/08/20
23	BEL	Belgium	02/04/20	03/11/20
24	NLD	Holland	02/27/20	03/06/20

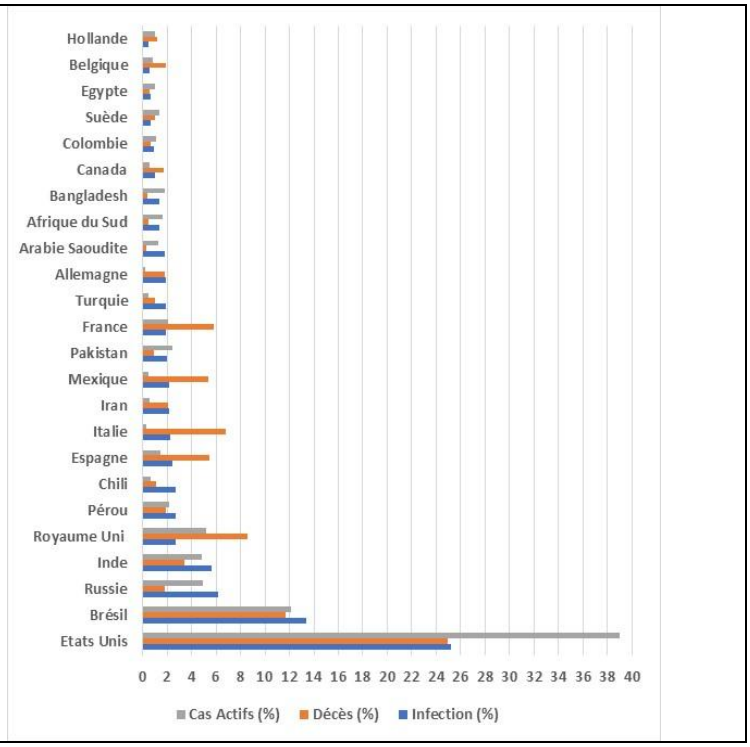
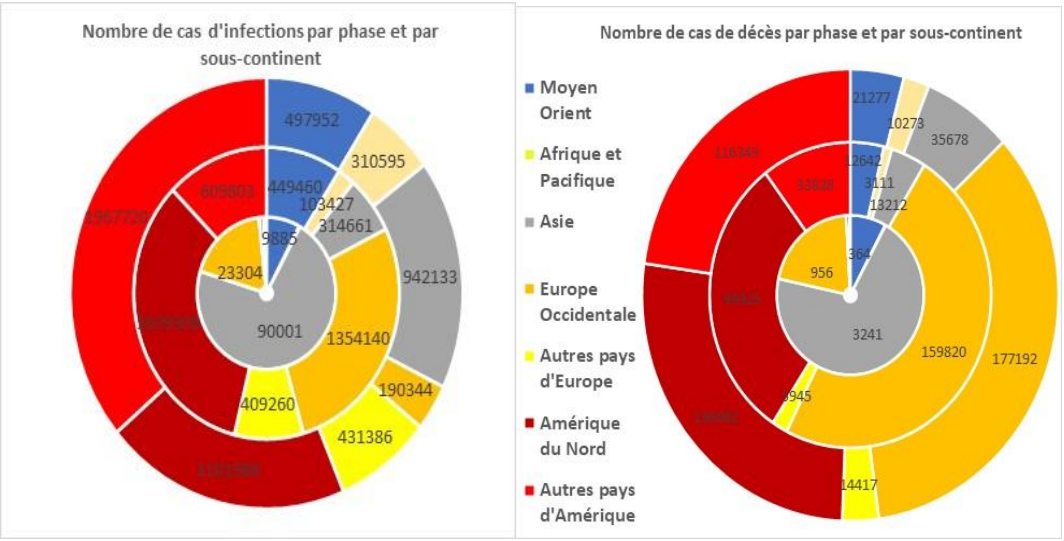


Table 1: Main countries affected by the pandemic as of June 30, 2020 (%)



Graph 1: Distribution of declared cases of infections and deaths by subcontinent according to the three phases of evolution of COVID-19 as of June 30, 2020

Literature Review

Before the declaration of a global pandemic on March 11, 2020, Asia and Western Europe accounted for more than 90% of infections and deaths. From March 12 to May 20, 2020, the pandemic moved to America with 46.0% of infections and 40.7% of deaths, while settling in Western Europe with 27.7% of infections and 48.6% % of deaths. From May 21 to June 30, 2020, this predominance of deaths was maintained in Western Europe (34.6%) with a modest proportion in terms of infections (3.5%), which lead to a differentiated picture of the overall incidence marked much more in America and Asia (73.7%) and the impact in terms of deaths in Europe and America (84.0%).

Two fundamental questions arise in the management of this global health crisis. How and to what extent have countries at different levels of development implemented effective public health measures to slow the spread of the virus? In the uncertainty of the control of this pandemic which knows no borders and in the expectation of a safe, effective and accessible vaccine, how and to what extent are the countries of different levels of development ready to face economic and social shocks in the short and medium term?

To answer the first question relating to the implementation of public health measures by the countries, it is necessary to sketch a cross-analysis of two studies relating respectively to the measurement of exposure to the COVID-19 risk and government responses, on one hand, with the results of the evolution of the pandemic as of June 30, 2020, on the other. These two studies would constitute a reference situation on the basis of the construction of a risk index* INFORM COVID-19 which aims to identify "Countries at risk of health and humanitarian impacts from COVID-19 which could overwhelm the current national response capacity, and therefore lead to a need for additional international assistance*", and an explanatory factor based on the index of government responses developed by the University of Oxford which provides "a measure of the extent of public policies and interventions in response to COVID-19". In this cross-analysis, three classes are defined on the basis of the world average for each variable considered, in order to detect the main findings below. Exposure to the COVID-19 risk, which implicitly reflects the level of development of countries, is not correlated with the results achieved in the management of the pandemic as of June 30, 2020; due to the differentiated implementation of public health measures (see Maps 1). The countries exposed to the COVID-19 risk, mainly in sub-Saharan Africa, have been able to contain, with a few exceptions, the evolution of cases of infections and deaths, for having put in place government measures following the recommendations of the WHO. However, a few countries end up with a high proportion of active cases as of June 30, 2020. In this category, only Pakistan, Bangladesh and South Africa are among the 24 main countries affected by the pandemic (Table 1). Countries classified as moderately exposed, mainly in Asia, the Middle East, North Africa and South America have experienced the pandemic with varying degrees of implementation of public policies and interventions. Eight countries in this category are among the twenty four main countries affected by the pandemic are Brazil, Peru, Mexico, Colombia, India, Iran, Turkey and Egypt.

Countries believed to have low exposure to COVID-19, mainly in the Western bloc, have recorded contrasting developments in the pandemic. In this third category thirteen countries are among the twenty four heavily impacted countries in the world, divided into three strata:

(i) Countries which have significantly implemented public policies and interventions are Russia, United Kingdom, Canada, Chile, and Saudi Arabia

(ii) Countries which have implemented public policies and interventions moderately are United States, Italy, France, Germany, Belgium, and Holland

(iii) Countries with a low level of implementation of public policies and interventions are Spain and Sweden

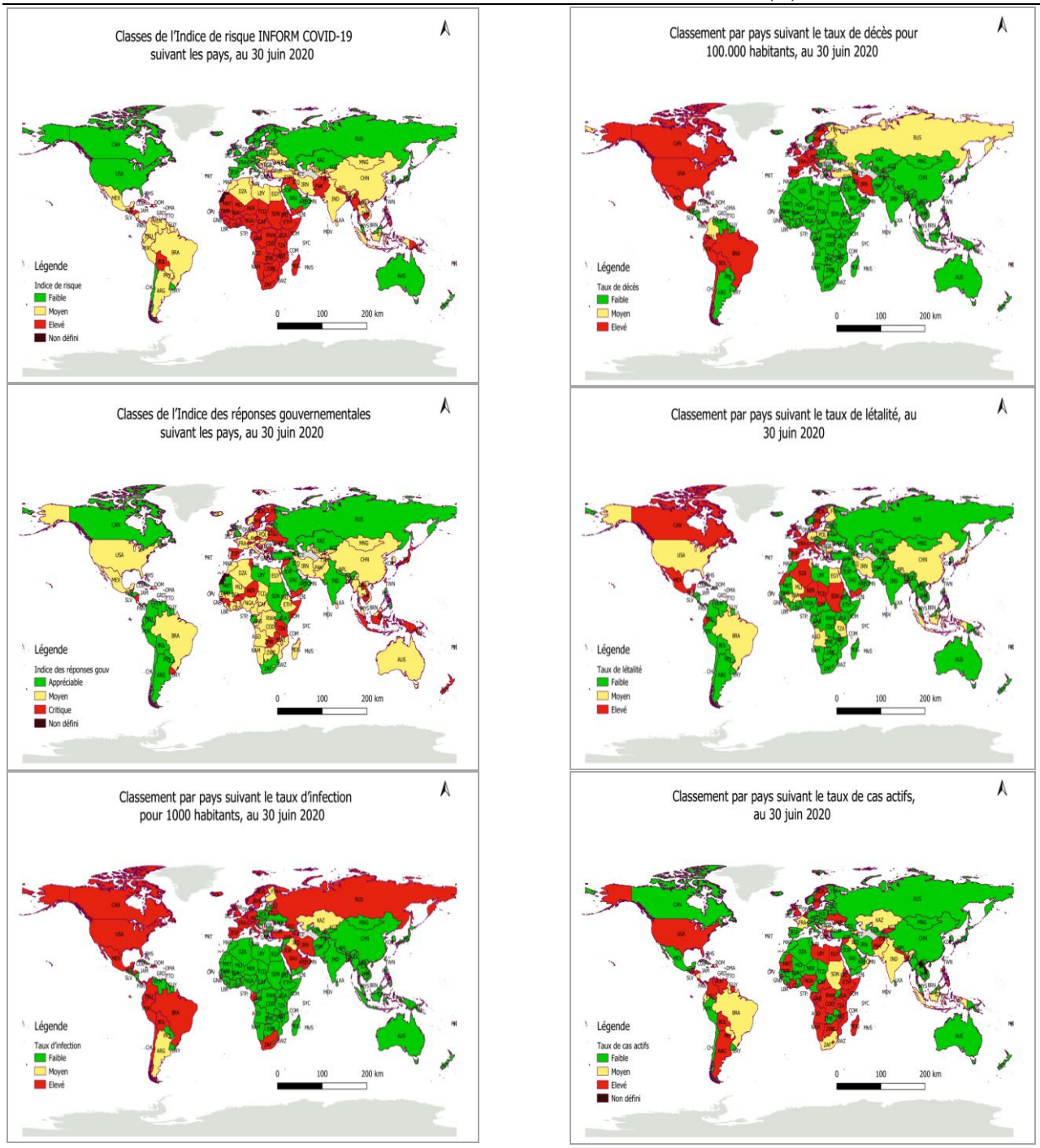
Beyond these observations on the basis of the INFORM COVID-19 risk index whose scope remains "global and regional resource allocation", countries seem to have adopted two strategies with differentiated results. The prevention strategy that make it possible to limit the progression of the COVID-19 pandemic and which combines public health measures and the limitation of shocks on the economy on the basis of anticipation on a possible vaccine.

Africa is committed to this prevention strategy with the result as of June 30, 2020 on the basis of declared cases, 404,796 infections, 10,147 deaths and 202,049 active cases, i.e. 3.9%, 2.0% and 4.4% respectively of reported cases worldwide. In relation to this result, we must keep in mind the pessimistic forecasts of the WHO* on Africa, which in addition, hopes to end COVID-19 in less than two years on the basis of the initiation of a vaccine. Chad with its 866 cases of infections, 74 deaths and 11 active cases as of June 30, 2020, is one of the countries that has recorded appreciable results in the management of the pandemic compared to neighboring countries (CEMAC, G5 Sahel and others neighboring countries) and the whole of Africa.

In this configuration as of June 30, 2020, it turns out to be impossible to predict the end of the COVID-19 pandemic, and there are serious fears of a second epidemic wave since mid-July 2020. In crisis management, countries have provided health and multisectoral responses, but major economic shocks are likely to have occurred, which should lead countries to anticipate the future and potential impact of COVID-19.

*This is an index calculated in April 2020 on the basis of structural variables, and likely to improve in the future. For more information refer to the source below.
*Available on the site: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Epidemic

* Thomas Hale, Sam Webster, Anna Petherick, Toby Phillips, and Beatriz Kira.(2020). Oxford COVID-19 Government Response



Graph 2: Oxford COVID-19, www.bsg.ox.ac.uk/covidtracker; *INFORM Global Risk Index,;* https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Epidemic; WHO, OCHA https://data.humdata.org/dataset/coronavirus-covid-19-cases-and-deaths; Calculations and author's representation

Exploratory analysis and modeling of the incidence of the COVID-19 pandemic and its instantaneous reproduction rate in Chad, as of June 30, 2020

Chad declared its first case of COVID-19 infection on March 19, 2020, and as of June 30, 2020, the pandemic situation appears to have been brought under control with 866 cases of infections, 74 deaths and 11 active cases, i.e. respectively 0.1 cases of infection per 1000 inhabitants, a case fatality rate of 8.5% and an active case rate of 1.3% resulting from a high cure rate estimated at 90.2%. It should be noted that asymptomatic cases have been notified with an accumulation of 21 cases of infections out of a total of 73 as of April 30, 2020, or 28.8%. The cases of infection are mainly men (72.3%) compared to women (27.7%) and they relate for nearly 82.0% to the working age group 15-59 years. Deaths are much higher for men (78.4%) and overall for the age group 60 years and over (56.7%). And N'Djamena, the capital, represents 87.9% of infection cases and 79.7% of deaths.

To fully understand the context of COVID-19 in Chad, it is necessary to recall the main determinants of health* characterized by the isolation and the extent of the territory, the high rate of illiteracy, socio-cultural constraints, low purchasing power and limited access to the health service, mixed access to hygiene, water and sanitation, and other factors promoting no communicable diseases such as high blood pressure or diabetes. It is also necessary to recall the adherence of Chad in 2012 to the International Health Regulations (IHR) and the joint external evaluation carried out in 2017 which concluded on the lack of documentation and written procedures, on one hand, on poor coverage due to risks with insufficient coordination of the structures concerned, on the other than [MSP, March 2020].

The chronology of the COVID-19 pandemic, inseparable from this context, makes it possible to better situate the anticipation and management of the health crisis, and to explore the factors that have contributed to limiting its progression.

An isolation and quarantine policy is defined as of March 8, 2020 and implemented gradually as soon as the first confirmed case appears, to contain the spread of the COVID-19 pandemic. Prevention protection measures such as the suspension of international flights with the exception of cargo ships, the limitation of public gatherings, the closure of all schools and universities, closure of restaurants, bars and ban on public transport. Common use by minibus and limiting the number of customers in taxis, social distancing and wearing a mask, or instituting a curfew. These measures have been partially lifted with regard to the circulation of intercity transport buses for one month, as from June 25, under strict respect of social distance and the mandatory wearing of masks.

A national contingency plan for the preparation and response to the epidemic of corona virus disease drawn up on March 16, 2020, is accompanied by the creation of a special allocation account entitled "Special fund to fight against the corona virus" by Decree No. 0374 of March 24, 2020. This plan is supported within the framework of a Rapid Credit Facility (CRF) approved by the IMF on April 14, 2020, the signing of a memorandum of understanding with creditors of the Paris Club, and partnership agreements with the main donors and technical partners. But it is estimated that this support from technical and financial partners does not meet expectations and that efforts to mobilize resources remain to do to get partners to keep their promises*. The State's efforts to implement this Plan were accentuated with the presidential announcements of April 14, 2020, which instruct the Government to implement concrete and well-targeted actions in terms of assistance to populations and support to operators.

In terms of health monitoring and coordination, a surveillance and investigation system was immediately put in place with the daily production of a response situation report, and a Crisis Committee was set up on the 21st of March 2020 with the support of a three-month operational plan. A simulation exercise is being carried out with the support of the WHO, in terms of preparation and response to COVID-19 and mass communication actions are implemented from March 21, 2020 supplemented by actions of sensitization by community relays. The coordination mechanism initiated by this intersectoral committee is supplemented at the decision-making level by a health watch and safety committee with a daily frequency of meetings for the two committees, on one hand, and through coordination meetings of technical and financial partners (TFP) with the catalytic role of WHO and the Coordination of the United Nations System (UNS).

Surveillance at air and ground ports of entry was strengthened from 27 March 2020 when five imported cases of COVID-19 infection were confirmed, all arriving by air on 15 and 17 March 2020. The surveillance system was put to test with the mass arrival of Chadian students returning from Cameroon at land border crossings at the end of March 2020, with the exception of the suspension of international flights taken on 18 March 2020, for the arrival of four flights in April and May 2020. The follow-up of contacts associated with infected cases was not exhaustive over the period from April 21 to June 24, 2020 with a rate fluctuating between 36.0% and 94.7%.In the meantime, a strong progression of the pandemic was recorded and generated the state of health emergency decreed on April 25, 2020 for 21 days, and extended after adoption by the National Assembly, from May 16 to July 16, 2020 with effect on the provinces affected by the pandemic. In this context of accentuation of the health crisis, the Crisis Committee was placed under the authority of the President of the Republic with the same frequency of daily meetings over the period May 20 to June 30, 2020.

* For more details, see [MSP, March 2020]: Ministry of Public Health, National Contingency Plan for the preparation and response to the epidemic of the coronavirus disease COVID-19, March 1 to February 28, 2021

* Livestock Research Institute for Development

In terms of the diagnosis of COVID-19, training was given to laboratory technicians at the level of the capital and the provinces, for laboratory diagnosis and bio safety. But it should be noted that until June 23, 2020, diagnostic capacities were limited to a single mobile laboratory in N'Djamena, and they were still extended only in the capital, at the general hospital and at IRED. A second laboratory was ordered and received on June 29, 2020. As a result, it was necessary to organize the collection of samples from proven or suspected cases from the whole country for analysis, which totals 5,201 samples tested out of 866 positive cases. to June 30, 2020. And it should be noted that a short phase of reagent breakage was observed from April 10 to 17, 2020.

In terms of infection prevention and control, rapid trainings were given as soon as COVID-19 appeared, followed from the beginning of April 2020 by a series of trainings for trainers and then agents on the whole. of the territory in terms of integrated management of the disease. And as part of the implementation of the presidential announcements of April 14, 2020, immediate recruitment and availability to the Ministry of Public Health were made effective on April 26, 2020, for 1,000 health workers out of the 1,638 announced, all categories combined for employment.

In terms of quarantine, arrangements were made for the establishment of sites. As of June 30, 2020, 12,143 people had been quarantined and 11,242 people were released after 14 days of observation, for a net total of 893 people still in quarantine at the end of June 2020.

As of June 30, 2020, this quarantine policy following a precautionary principle, will have generally contributed to limiting the spread of the pandemic, except in N'Djamena. Four categories emerge according to the degree of prevalence of the pandemic:

- ✓ Four provinces which accumulate 13.3% of people quarantined, are not exposed to the pandemic -Mayo Kebbi West, Ennedi West, Salamat and Barh-EI Gazel.
- ✓ Nine provinces with 25.2% of people quarantined, have a low prevalence of the pandemic, with less than ten cases of infection or death, - Mayo Kebbi Est, Lac, Ouaddaï, Wadifira, Batha, Chari-Baguirmi, Sila, Ennedi East and Mandoul.
- ✓ Five provinces with 33.0% of people quarantined, record a moderate prevalence of the pandemic.

The overall incidence (I_t^{global}) therefore includes a component based on the observed net incidence (I_t^{obs}) and another component based on untracked contacts and people quarantined and discharged without being tested (I_t^{nonobs}): $I_t^{global} = I_t^{obs} + I_t^{non\,obs}$

Where $I_t^{obs} = R_t * I_t^{net} * g, I_t^{net}$ is the cumulative number of confirmed cases at time t-1 minus the cumulative number of outgoing persons at time t-1:

$$I_t^{net} = \sum_{i=1}^{t-1} Ii - (\sum_{i=1}^{t-1} gueris + \sum_{i=1}^{t-1} decedés)$$

And I_t^{nonobs} is the incidence caused by unidentified subjects, therefore according to untracked contacts (CNS) and people quarantined and discharged without being tested (QNST):

$$I_t^{non\,obs} = Const + \alpha * CNS + \beta * QNST + \mathcal{E}$$

The coefficients $\alpha et \beta$ will be estimated by regressing the CNS and QNST variables on the difference between the effects of scenario 1 and scenario 2 (gap) which is assimilated to the unobserved incidence (I_t^{nonobs}). The effects of scenario 1 and scenario 2 are obtained by calibrating the parameters of the Gamma law (mean and standard deviation) in an optimistic and pessimistic manner, respectively. The pessimistic scenario is characterized by a high standard deviation, which indirectly reflects the lack of control of the pandemic.

We considered the Gamma law (4; 1.6) for the pessimistic scenario and Gamma (4; 0.8) for the base scenario. The difference between these two series gave us the gap on which we regressed the variables on unmonitored cases (CNS) and people released from quarantine and not subjected to tests (QNST) to obtain the coefficients $(\alpha et \beta)$ used to determine the second component of the overall incidence. VAR modeling allowed us to estimate these coefficients as follows:

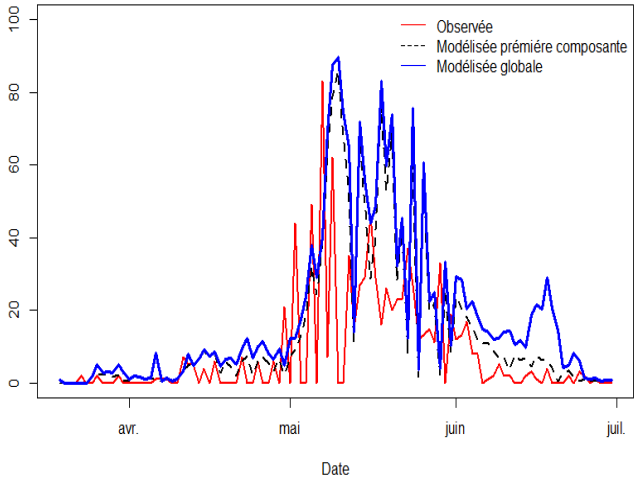
Table 2: Equation gap results

Estimate results for equation gap:				
	Estimate	Std. Error	t -value	p-value
gap	0.67648	0.06742	10.034	<2e-16 ***
CNS	0.03997	0.01574	2,539	0.0127 *
QNST	0.07704	0.04284	1,789	0.0752.
F-statistic: 72.06 on 3 and 100 DF, p-value: <2.2e-16				
Adjusted R-squared: 0.6742				

Significance degree (p-value): (***) = 0%, (*) = 5%, (.) = 10%

The model shows in terms of results that there is an average of twelve people infected per day who escape the surveillance and control of the pandemic. Indeed, out of 100 untracked contacts there are on average nearly 4 people infected per day and, out of 100 people quarantined and released without being tested there are on average nearly 8 additional people infected per day.

Graph 3: Evolution of the modeled incidence of COVID-19 in Chad, June 30, 2020



The instantaneous reproduction rate (R_t) is the average number of people that a patient can infect at time t. Its value greater than or equal to 1 means that the number of new cases can increase every day, which would cause the expansion of the pandemic. On the other hand, if it is below 1, the number of new cases gradually decreases and the virus ends up disappearing.

In this study, its estimate is based on the method of Cori et al (2013). This method estimates the based on the pandemic incidence curve and the serial interval (SI R_t)*. The serial interval is the time elapsed between the onset of the index subject's symptoms and that of the secondary case. Its series refers to the time between successive cases in a chain of transmission. In practice, this series is approximated by a law of probability, given that it is generally unobserved.

Noting I_t the total number of confirmed cases at time t (local and imported), the R_t is defined as the ratio between I_t and the total cases at time t-1, weighted by the density of the theoretical law (Ws) considered as a proxy variable of the serial interval:

$\Lambda t\ (ws) = \sum_{s=0}^{t-1} I_{t-s} w_s$.

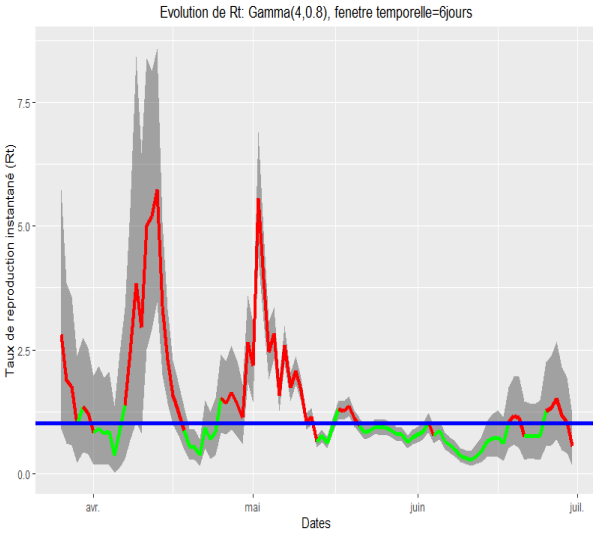
Each case confirmed at time before t contributes to infection at time t at a relative level given by w_s which represents the probability that a secondary case will occur at time s after the index case.

However, the resulting estimates of R_t can be very variable and therefore difficult to interpret when the data frequency is small (daily for example). We therefore estimate each R (t) over a chosen time interval, of length τ and ending at time t (a moving average), over which it is assumed to be less variable. Resorting to Bayesian statistical methods by postulating an a posteriori gamma law R_t leads to its simplified expression, obtained by maximizing the log likelihood of incidences (seen as a Poisoning count) as follows:

$$R_{t,\tau}(t) = argmax_{Rt} \prod_{k=t-\tau}^{t} \frac{(R_t \Lambda_k(w_s))^{I_k} (\exp(-R_t \Lambda_k(w_s))}{I_k!}$$

In this study, the serial interval is approximated by the Gamma law (4; 0.8). A time window of six (06) days was chosen according to the suggestion of Cori et al (2013) which fixes the minimum number (at three confirmed cases) from which we can start to calculate the R_t, if we consider the coefficients of variation a priori and a posteriori of incidences of 2 and 0.4 respectively. The choice of parameters (mean = 4 and standard deviation = 0.8) of the gamma law is based on observations relating to the chain of transmission of the disease at the start of its onset, taking into account the public health measures implemented. Based on the daily updated reports of confirmed cases, we have gathered the data from March 19 to June 30, 2020.We built the daily incidence curve and used it to estimate the instantaneous reproduction rate (R_t), at 95% confidence interval, with the EpiEstim version 2.2-3 package of the R software.

Graph 4: Evolution of the modeled reproduction rate, as of June 30, 2020



From this graph, we note that the modeled reproduction rate went from 2.6 to fluctuate between 0.3 and 5.7 in mid-May 2020 with two peaks respectively on April 13 and May 2, 2020, and then stabilize around a secondary case for an infected person, until June 30, 2020.

* Serial Interval in English

Assessment of government measures on the instantaneous reproduction rate

Five variables were selected to be able to measure the effects of government measures on the instantaneous reproduction rate:

- A variable relating to contact tracing. Indeed, some at-risk subjects escaped the monitoring of the pandemic management committee for one reason or another. These individuals could impact the reproduction rate;
- Three variables relating to health (MS), socio-economic (MSE), and displacement reduction and/or confinement (MRDC) measures which started respectively from 04/17, 05/20 and 04/02/2020. These measures are captured through indicator variables which take 1 from the date of their taking effect.
- The health measures concern in particular the limitation of the number of people at the funeral places, the sanitary control at the level of the borders, the isolation and quarantine, the compulsory wearing of masks and the strengthening of the health system. The socio-economic measures concern the free distribution of masks and the establishment of a legal structure for crisis management. As for the travel reduction and/or confinement measures, they refer to the control points relating to travel restriction measures, curfews, the ban on interurban transport, the closure of borders, places of worship, restaurants and the regulation of movements in credit firms.
- An exogenous variable (VE) which is also an indicator variable which captures exogenous shocks. These are precisely the arrivals of 195 passengers from Benin, Burkina Faso, Senegal, Togo and Côte d'Ivoire, 235 passengers from Egypt, Ethiopia, Dubai, Saudi Arabia and Abu Dhabi, 201 passengers from Egypt, Ethiopia, etc., and 187 passengers from France, respectively on 04/21, 04/24, 05/02, 05/06 and 05/23/2020.

A specification of the one (1) lag VAR model has been made on the above-mentioned variables as follows:

$$Yt = AYt\text{-}1 + \mathcal{E}t$$

Where Yt = [ln (Rt), ln (Tracking), MS, MSE, MRDC, VE], A is the matrix of coefficients and Ɛt is white noise.

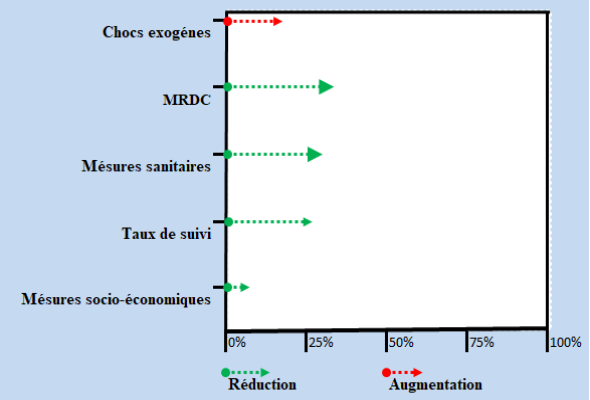
According to the results, the sanitary measures lowered the reproduction rate (R_t) by 28.5% and a 1% increase in the rate followed leads to a decrease of about 25.4% of R_t although this coefficient is not significant. On the other hand, ad-hoc border opening measures aimed at passenger arrivals resulted in an increase of R_t of 20.6%. It should be noted that the measures to reduce displacement and/or containment (MRDC) only act on the R_t with a delay of 4 to 5 days, with the start of a significant drop of 29.6% in the reproduction rate (Graph 5).

Table 3: Estimate Results

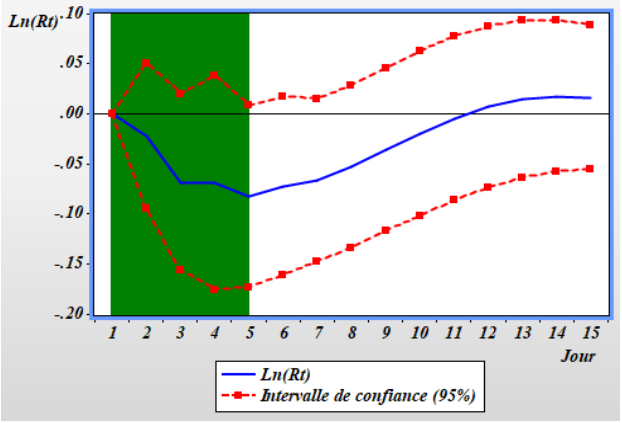
Estimate results for equation log.Rt .:				
	Estimate	Std. Error	t-value	p-value
log (Rt)	0.74170	0.06163	12.034	<2e-16 ***
log (Tracking)	-0.25394	0.18986	-1.338	0.1844
MS	-0.28459	0.12406	-2.294	0.0241 *
MRDC	0.18499	0.09248	2,000	0.0484 *
MSE	-0.07491	0.08615	-0.870	0.3869
VE	0.20588	0.08952	2,300	0.0237 *
F-statistic: 47.24 on 6 and 91 DF, p-value: <2.2e-16 R-squared: 0.749				

Significance degree (p-value): (***) = 0%, (*) = 5%, (.) = 10%

Graph 5: Influence of the impact variables of the measures on the instantaneous reproduction rate of COVID-19 in Chad



Graph 6: Variation in the reproduction rate(R_t) following a positive shock relating to the reduction of movements and / or confinement (MRDC)



Conclusion

Africa is committed to this prevention strategy with the result as of June 30, 2020 on the basis of reported cases, 404,796 infections, 10,147 deaths and 202,049 active cases, i.e. 3.9%, 2.0% and 4 respectively. , 4% of reported cases worldwide. Chad with its 866 cases of infections, 74 deaths and 11 active cases is one of the countries having recorded appreciable results in the management of the pandemic compared to neighboring countries (CEMAC, G5 Sahel and other neighboring countries) and to all of Africa. Modeling the evolution of the pandemic in Chad has revealed that an average of 12 infected people per day escape the surveillance and control of the pandemic. In addition, the evaluation of government measures showed that the sanitary measures lowered the reproduction rate (R_t) by 28.5% and a 1% increase in the rate followed causes it to decrease by about 25.4%. On the other hand, ad-hoc border opening measures aimed at passenger arrivals led to an increase in the R_t of 20.6%. It is also observed that the measures to reduce displacements and / or containment (MRDC) only act on the R_t with a delay of 4 to 5 days, with the start of a significant decrease of 29.6 % of reproduction rate.

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