Containment efficiency and covid19 economic scenarios: the case of Morocco

Abstract

In the present paper we are interested in the epidemiological evolution of Covid19 in Morocco and we try to simulate the possible trajectories of the contagion. The objective of this research is to model the economic consequences of the epidemic and also to highlight the importance of the containment policy in facilitating economic recovery in Morocco. The results obtained using a combination of Ramsey's model and the epidemiological propagation model affirm that the choice of the containment policy made it possible to reduce the negative repercussions of the pandemic on Morocco, despite the economic consequences of the latter. The comparisons made between the two situations confirm that the economic repercussions remain moderate and Morocco will be able to face this disaster with even stricter or even more intelligent containment.

JEL CLASSIFICATION: E1, I1

Keywords: COVID19, Economic conditions, Ramsey, contagion

1. Introduction

All the countries of the world today are rushing to understand the effects of Covid19 on their economy and of course to seek the most optimal solutions in favour of an adapted and rapid recovery of their economy. In this sense, the reflection today is in all fields and especially in economics to understand and explain the future for a well thought decision. COVID-19 has spread approximately all over the world. Epidemiological models in hard sciences have responded present to forecast the trend of the epidemic and of course to predict potential scenarios for the whole planet (see, Ferguson et al. (2020)). It is very important to stress that these models are of growing interest but do not take into account the economic effects of the epidemic crisis on the future of countries and economic growth. In addition and in parallel with health decisions, it is necessary to have sufficient economic support to emerge from this pandemic in the best conditions and with the least macroeconomic consequences and costs. Of course, the strategies of containment and cessation of economic activities will have an effect on macroeconomic variables, especially employment, consumption and production. In this research work, we propose an approach for measuring the economic effects of the epidemic in the context of the Moroccan economy. The idea here is to use the SIR model developed by Kermack and McKendrick (1927) and integrate key macroeconomic variables into it in order to capture the interactions between the evolution of the epidemic and economic activity. The basic hypothesis of this work is to show that containment decisions are likely to reduce consumption and employment, or even production, thus reducing the severity of the epidemic as measured by the total number of deaths. Similarly, these same decisions exacerbate the extent of the recession caused by the epidemic.

In the proposed modeling we argue that the epidemic has effects on both supply and demand. The supply effect is due to the fact that the epidemic exposes people who work to the virus. People respond to this risk by reducing their labour supply. The demand effect is because the epidemic exposes people who buy consumer goods to the virus. People respond to this risk by reducing their consumption. Supply and demand effects combine to generate a significant and persistent recession (Martin S. et al. 2020).

The only policy response by governments to consider is a general containment decision leading to a reduction in working hours and production capacity. This leads to a reduction in the economic interactions that produce wealth and allow the circulation of capital. Normally this decision exacerbates the recession, but increases the welfare of the population through a reduction in the number of deaths caused by the epidemic. Of course, our model is conceptually simple, but it will allow us to give a more rational trajectory of the outcome of the epidemic in Morocco, especially in economic terms.

Theoretically, we have opted for the model of Kermack and McKendrick (1927). In this model, the probabilities of transition between health states are exogenous parameters. We modify the model by assuming that the purchase of consumer goods and work bring people into contact with each other. These activities increase the probability of infection spreading. What we found in Morocco is that the contagion effects accelerate with the interactions between economic actors and of course this happens largely during economic decisions.

In this model, epidemics end when a sufficiently large fraction of the population acquires immunity. Unfortunately, in the absence of effective medical treatments, this process results in the death of many people who never recover from an infection. Certainly the decision to contain as a response to the current crisis, but this approach has two problems. First, permanent containment measures create a persistent economic depression. Second, the population never achieves herd immunity. Thus, infections would reappear if containment were relaxed. The best policy is to increase the fraction of the population that is immune, by reducing consumption when externalities are high, i.e. when the number of infected people is high. Such a policy consists of progressively strengthening containment measures as infections increase and slowly releasing them when new infections decrease and the population approaches the critical level of immunity.

Several studies have been carried out on this issue. The work of Philipson (2000), Adda (2016) and Manski (2016)) which analyses how private incentives for vaccination influence epidemic dynamics and optimal public health policy. Atkeson (2020) provides an overview of SIR models and explores their implications for the COVID-19 epidemic. Alvarez, Argente and Lippi (2020) study the optimal lock-in policy in a version of the classical SIR model where mortality rates increase with the number of infected persons. Toda (2020) uses a SIR model to study the impact of the epidemic on the stock market. The closest paper is Jones, Philippon and Venkateswaran (2020). These authors analyze optimal mitigation policies in a model where economic activity and epidemic dynamics interact. Jones and colleagues (2020) emphasize learning-by-doing by working from home and assume that people have a fatalistic bias about the likelihood of becoming infected in the future. Here are some other differences between our paper and theirs. First, we explicitly consider the probabilistic arrival of vaccines and treatments. Second, we consider that there is a social cost to starting containment too late or finishing it too early. Third, we look at "smart containment" policies that make allocations based on whether people are infected, susceptible, or cured. Guerrieri, Lorenzoni, Straub, and Werning (2020) develop a Keynesian supply theory in which shocks that trigger changes in aggregate demand are larger than the shocks themselves. These authors argue that the economic shocks associated with the COVID-19 epidemic may exhibit this characteristic. Guerrieri et al. (2020) analyze the effectiveness of various monetary and Öscal scale policies in dealing with these shocks. In contrast to Guerrieri et al (2020), we incorporate an extended version of SIR dynamics into our model. Berger, Herkenho§, and Mongey (2020) and Stock (2020) investigate the importance of randomized tests for estimating population health status and designing optimal mitigation policies. In contrast to these authors, we explicitly model the two-way interaction between infection rates and economic activity. A new body of work investigates the effects of the COVID-19 epidemic in models where agents are more numerous in their health status as well as in other dimensions. In ongoing work, Glover, Heathcote, Krueger and Rios-Rull (2020) investigate optimal mitigation policies in a model that takes into account the age distribution of the population. Kaplan, Moll and Violante (2020) do so in a HANK model. Faria-e-Castro (2020) studies the effect of an epidemic, modelled as a large negative shock to the utility of consuming contact-intensive services, in a model with borrowers and savers. Buera, Fattal-Jaef, Neumeyer, and Shin (2020) study the impact of an unexpected blocking shock in a heterogeneous agent model.

This document is structured in several parts. The first part presents the model to be used with the various explanations and hypotheses put forward. Then the calibration and the Moroccan data are presented. Finally, the last section deals with the results obtained for the case of Morocco and also a discussion of these results.

2.Presentation of the model

Under normal circumstances the economy operates according to the principle of utility maximisation and rational behaviour. In this sense, we consider that the economy is populated by a continuum of identical ex ante agents that maximize the objective function :

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t, n_t) \qquad \textit{Eq. 1}$$

Here, β (0; 1) indicates the discount factor and c and n indicate consumption and hours worked respectively. For simplicity, we assume that the momentary utility takes the form :

$$u(c_t, n_t) = ln(c) + \frac{\theta}{2} n^2 \quad \textit{Eq. 2}$$

The budgetary constraint of the representative agent is :

$$(1 + \mu) c_t = w_t n_t + \delta \quad \textit{Eq. 3}$$

Here, w is the real wage rate, is the consumption tax rate, and refers to lump-sum transfers from the government. As we will see below, we consider that is an approximation of containment measures to reduce social interactions. This is why we call the containment rate.

The primary condition for the representative-agent problem is:

$$(1 + \mu) \theta n_t = c^{-1} w_t \quad \textit{Eq. 4}$$

There are also agents in the economy representing firms that produce consumer goods (C) using hours worked (N) according to technology A :

$$C_t = A.N_t \quad \textit{Eq. 5}$$

Businesses optimally identify the number of working hours that maximize profit:

$$\pi = AN - wN \quad \textit{Eq. 6}$$

The government's budget constraint is given by the following relationship :

$$\mu c = \delta \quad \textit{Eq. 7}$$

To take into account the relationship between the epidemic and its effects on the country's economic context, we propose modifying the pandemic model of Kermack and McKendrick (1927). We will consider that the probabilities of transition depend on people's economic decisions. Such as the purchase of consumer goods or work that put agents in contact with each other. We also note the hypothesis that the population is decomposed into four groups of agents: susceptible individuals (those who have not yet been exposed to the disease), infected individuals (those who have contracted the disease), cured individuals (those who have survived the disease and acquired immunity), and deceased individuals (those who have died from the disease). Fractions of people in these four groups are referred to as respectively. The number of newly infected persons is indicated by "T". Susceptible persons can be infected in three ways. First, they may encounter infected people.

The first approach to infection is by conducting consumer product purchase operations. This action leads to the confrontation between the two populations S and I. Then the probability of infection is of the form the component measures the consumption of infected and potentially infected persons.

The second route of contamination is the work where the two populations may confront each other. The likelihood of being infected in the workplace depends on the amount of time that individuals undertake in the work period during the pandemic either : . With the quantity in brackets is the sum of the amount of work of the infected and potential population.

The last way we assume is to have contamination via other social mechanisms such as neighbourhood or casual encounters. So we can write the third probability as

Using the three hypotheses of existing contamination in the pandemic reality we can write the sum of the newly affected people as follows:

$$\mathrm{T} = \mathrm{p}_2(\mathrm{N^sS} * \mathrm{N^II}). + \mathrm{p}_1(\mathrm{C^sS} * \mathrm{C^II}) + \mathrm{p}_3\mathrm{SI} \quad \textit{Eq. 8}$$

Obviously in the fundamental model of the two authors only the probability p3 exists and the others of economic gateway are new that we have integrated in our model for the case of Morocco. Moreover, the number of sensitive persons at time t + 1 can be written as follows:

$$S_{t+1} = S_t - T_{\mathrm{t}} \quad \textit{Eq. 9}$$

And by analogy the persons infected at the time t + 1 can be written as follows:

$$I_{t+1} = I_t + T_t - (p_{\mathrm{r}} + p_{\mathrm{d}})\, I_t \quad \textit{Eq. 10}$$

The two probabilities are the probability of recovery or reinstatement and the probability of death, respectively. From this definition, the recovered persons and the persons who die in the period t+1 are of the following form :

$$R_{t+1} = R_t + p_{\mathrm{r}}\, I_t \quad \textit{Eq. 11}$$

$$D_{t+1} = D_t + \mathrm{p_d}\, I_t \quad \textit{Eq. 12}$$

Then the total population can be described as follows:

$$\mathrm{Pop}_{t+1} = \mathrm{Pop_t} - p_{\mathrm{d}}\, I_t{}^{1} \quad \textit{Eq. 13}$$

The initialization of infection and population susceptibility variables are :

[1] On note que le niveau de la population à l'instant 0 est égal à 1.

We will now see how the behaviour of economic agents would be taking into account the new distribution of economic agents according to their degree of infection and their pandemic position. The optimization program is therefore to be considered for each population form. We first consider the budgetary constraint which can be rewritten as follows:

$$(1 + \mu)c_t = w_t \varphi n_t + \delta \qquad \textit{Eq. 14}$$

The parameter added in the budget constraint describes labour productivity by population type, it is equal to one for susceptible and recovered persons and less than one for infected persons.

So, for those potentially affected, the utility function is of the form :

$$\mathrm{Ust} = \mathrm{u(cst;\ nst)} + \beta(1-\mathrm{p})\,\mathrm{Ust}+1 + \mathrm{pUit}+1 \qquad \textit{Eq. 15}$$

The probability p is relative to the probability of being infected and can be written according to what we have argued as :

$$p = p_1 c_s(IC) + p_2 n_s(IN) + p_3 I \qquad \textit{Eq. 16}$$

Second, for infected persons the utility function is of the following form:

$$Ust = u(cit;\ nit) + \beta(1-p_r-p_d)\,Ui_{\,t+1} + p_r Ur_{t+1} \qquad \textit{Eq. 2}$$

For people who have healed, the following utility function is noted:

$$Ust = u(crt;\ nrt) + \beta Ur_{t+1} \qquad \textit{Eq. 3}$$

The government's budgetary constraint can be rewritten in the following form as well :

$$\mu(Sc_s + Ic_i + Rc_r) = \delta\,(S + I + R) \qquad \textit{Eq. 4}$$

To simulate the economic conditions, we use the RAMSEY model. Of course, public authorities have several instruments at their disposal to respond to the epidemic crisis, including containment by reducing interactions between economic agents and hampering social relations in society. According to the work of Farhi and Werningís (2012) which deals with capital controls, we model these measures as a consumption tax whose product is refunded in one go to all agents. We call this tax the containment rate.

The goal is to maximize social welfare by government authorities adopting this type of behaviour. Then the total utility of the population is the sum of the utilities of the two infected and potentially infected components:

$$U = SU_s + IU_i \qquad \textit{Eq. 5}$$

Given the sequence of containment rates, we resolve the competitive equilibrium and assess the welfare function. We repeat this sequence until we find the optimum. The basic intuition is as follows. Containment measures internalize the externality caused by the behaviour of infected people. Thus, as the number of infected persons increases, it is optimal to intensify the containment measures. For example, at time zero, very few people are infected, so the externality is relatively small. A high rate of containment at time zero would have a high social cost relative to the benefit. As infection increases, the externality becomes more important and the optimal containment rate increases.

3.model calibration and stylized facts

The periodicity used is weekly for faster communication is adapted to the urgency of the authorities' response. To choose the mortality rate, data from the Moroccan Ministry of Health are used. For an approximation we will take the average weighted by the totality of people affected. According to the work of Atkeson (2020), we assume that it takes on average 18 days to recover or die from covid infection 19. Then with a weekly model then the sum of the probabilities of dying and recovering is the following sum :

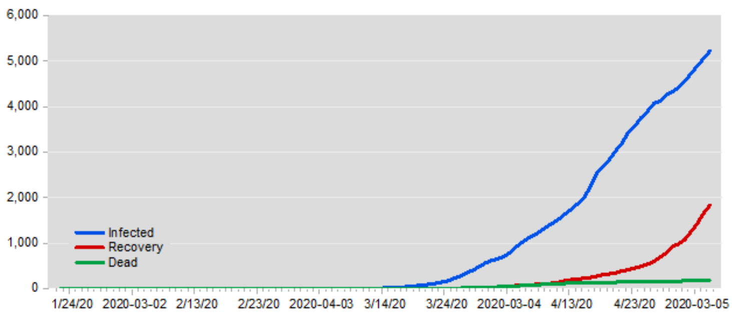
$$p_r + p_d = \frac{7}{18}$$

For the calibration of p1, p2 and p3 (probability of the three states S, I, R), we adopt the approach of Ferguson et al. (2006) who argue that 30% of transmissions occur in the household, 33% in society and 37% occur in schools and workplaces.

The initial population is normalized to one. The number of people initially infected is 0.0001. We assume that the representative person works 40 hours per week and earns a weekly income of 635 MAD. We have retained a level of weekly discount factor with a value of 0.9999 based on 52-week treasury bill rates. We introduce the notion of the value of life and approximate it by the statistical value of life according to OECD estimates. In the absence of an indication for Morocco as a developing country, we consider the schematic value of the OECD estimates, i.e. 1.5 million dollars. Concerning the infected individuals, we will consider that the productivity of these individuals is around 0.8 due to the inactivity of the covid-infected agents19.

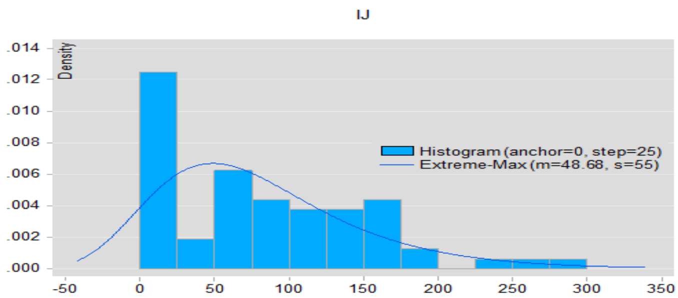
The epidemiological situation in Morocco seems to be under control as the infected cases do not exceed the bar of 6000 cases since the first case on March 2, 2020. With an attenuation of cases and deaths due to the Protocol used in Morocco. We have also noted that the number of cases of cure is increasing for the same reason (see figure 1).

Figure 1: Evolution of the epidemic in Morocco



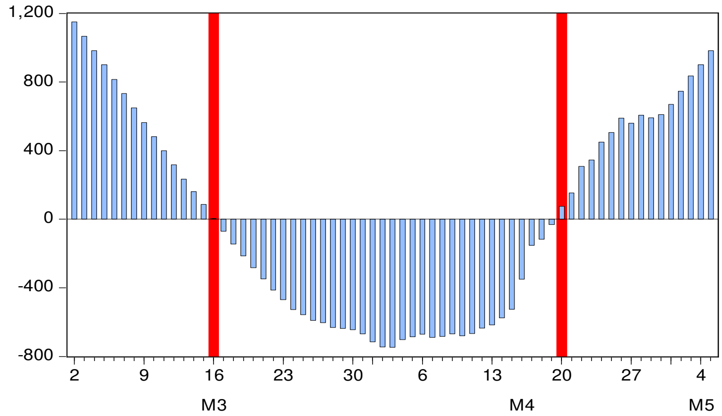
Furthermore, we have noted that the number of infected persons is increasing in daily frequency. On average this number is around 48 people per day with a rightward asymmetry which implies a very important standard deviation of 55, i.e. the idea that we can have daily cases of up to 160 cases per day (see figure 2).

Figure 2.Empirical and theoretical distribution of infected cases per day



Since 16 March 2020, Morocco has declared the situation of containment to counter the contagion of covid19. 19 This decision certainly has repercussions on the future of the Moroccan economy, but seems necessary to guarantee the well-being of its citizens. After the implementation of this decision, Morocco was able to contain the infected cases and respond positively to the epidemic. This can be easily proven by analysing the cycle of contamination. It is important to point out, however, that the implementation of the containment on 16 March allowed to reduce the cycle of contamination throughout the containment period, however, from 20 April 2020 we have noticed that the cycle starts again on the increase and this is explained by the change of decision of the authorities who decided to extend the containment even more without taking into account the reaction of the citizens (see figure 3).

Figure 1. Cycle de contamination covid19 et prise de décision



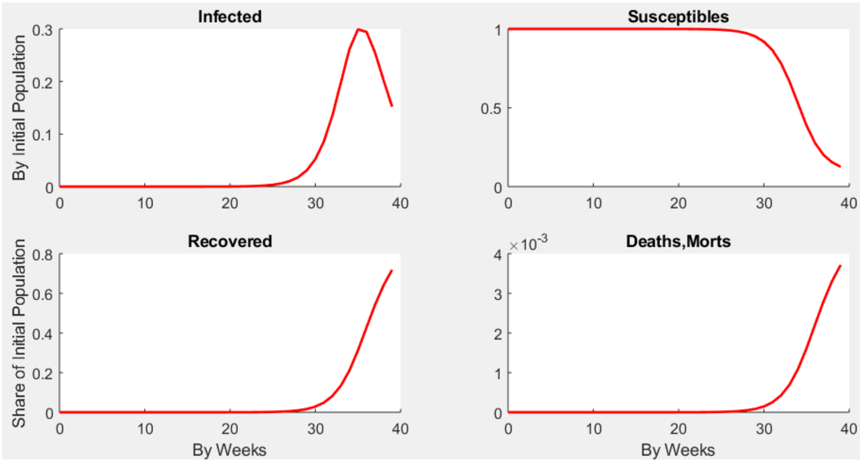
4. Outcome and discussion

From the data used and mentioned in the calibration we simulated our model for the case of Morocco. It should be noted here that the mortality rate used is weekly, i.e. a value of 0.2% depending on the infected cases. Similarly, in order to initialize the model we considered that the percentage of infections starting from the first day is 0.01%, the figure declared by the Ministry of Health of the country.

First we will present and analyze the evolution of the epidemic without intervention and then we will activate the containment policy and the restriction on movement and social contacts.

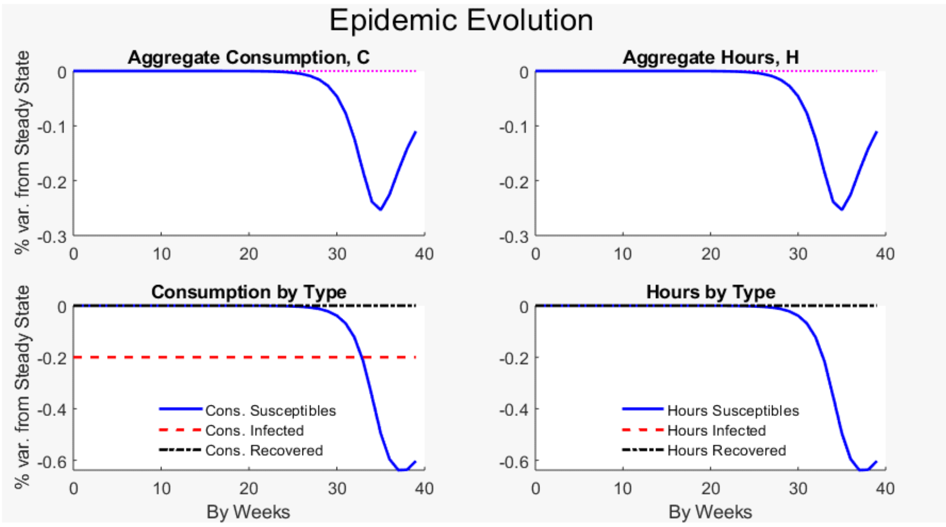
In the first case, where no containment policy is envisaged, the scenario would have been catastrophic in that we would have expected significant levels of contamination. Indeed, the number of people infected by covid19 would be around 30% of the population within 40 weeks from 16 March. Similarly, the number of deaths would be very high, with more than 14,000 deaths. Of course, the number of potentially infected cases would be very high, reaching more than 50% of the population within 40 weeks (see figure 4).

Figure 4: Simulation without containment



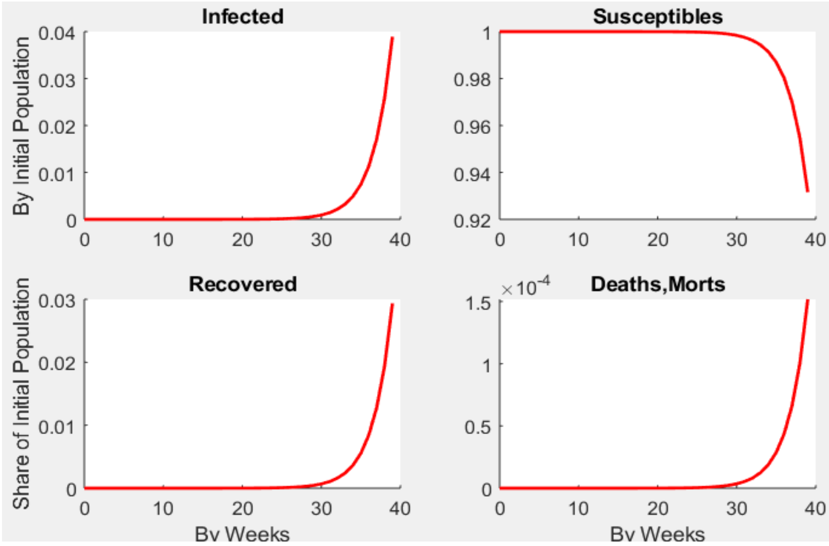
Economically, no containment measures and no government policy will have negative externalities on consumption, productivity and GDP growth. Under these conditions, consumption will have fallen by 20% with the infection of the population as well, and working hours will be slowed down by 20% over the simulation horizon. The breakdown by type of household reveals a reaction from households at greater risk than citizens who are already infected. This is a reaction behaviour out of fear of contamination.

Figure 5. Simulation of unconfined economic conditions



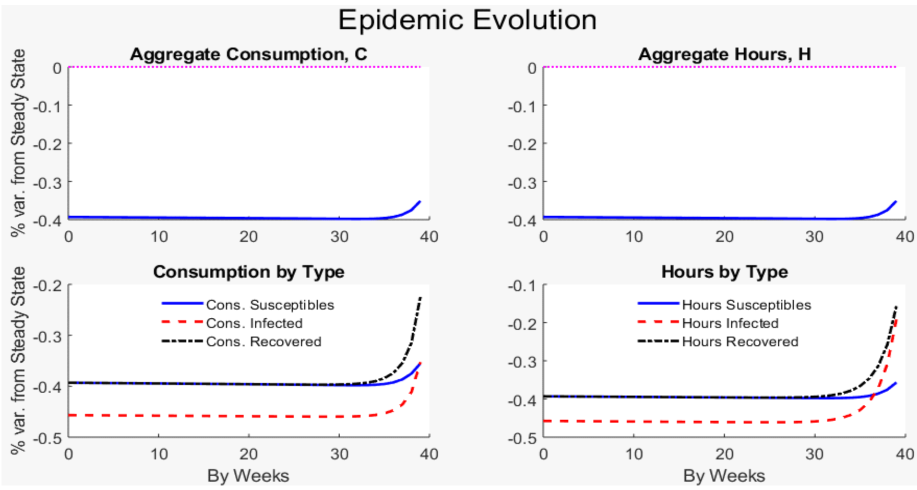
The second effective scenario for the case of Morocco is the activation of containment which will make it possible to reduce contacts between economic agents. According to our estimates, this will have a very positive effect in reducing the evolution of the pandemic. According to figure 6 a very strict respect of the co-financing will have to reside the infection rate to stabilize at 4% of the population if the outbreak confidently lasts up to 40 weeks. Then a containment policy would be able to reduce contamination. In the same way, the coverage rate would be able to cover all infected cases with a mortality rate of 0.00015, i.e. 4 times lower than without containment.

Figure 6. Simulation with containment



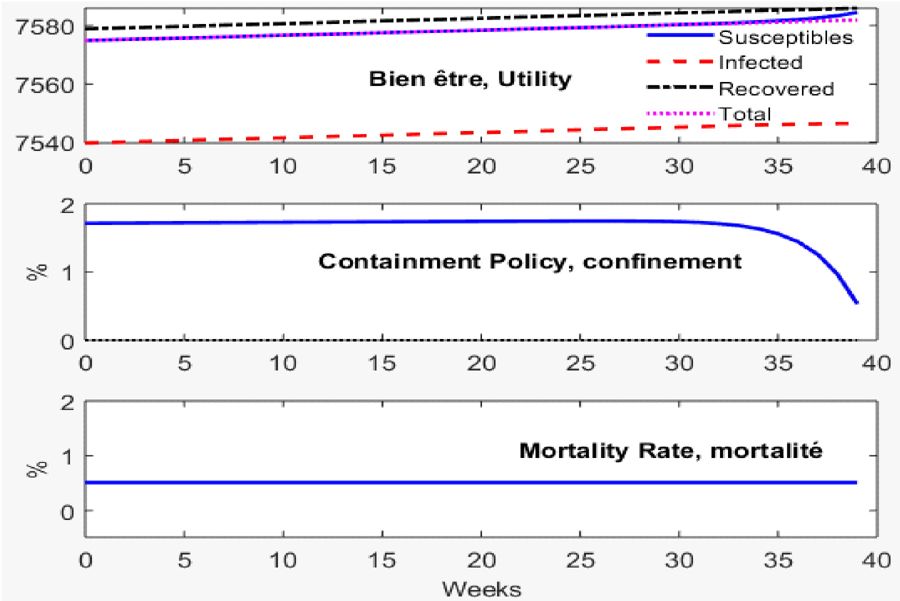
From an economic point of view, the choice of containment is very optimal in the sense that it makes it possible to control and stabilise the fall in household consumption and at the same time to forecast a recovery from the 30th week of the epidemic. The consumption of cured persons tends to be more dynamic in the recovery than other types of households, the same observation is in the working hours in the Moroccan economy.

Figure 7. Simulation of economic conditions with containment



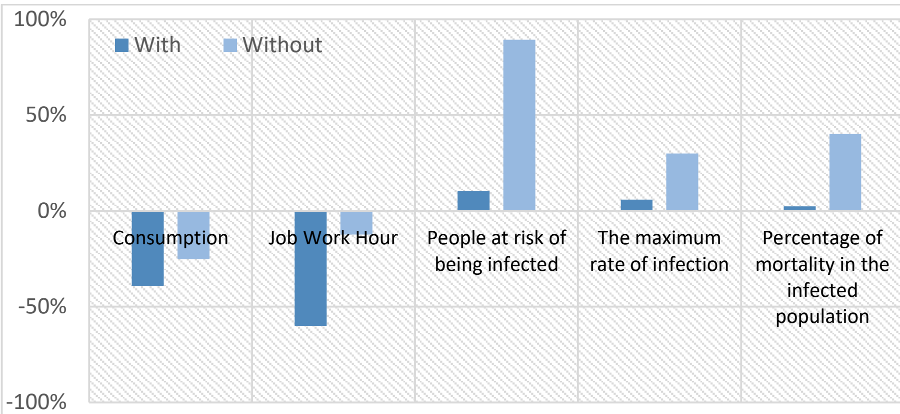
The introduction of containment as a response will increase well-being by maximizing the utility of infected and uninfected people. Using the relationship defining wellbeing we were able to simulate the wellbeing of the population over the 40-week horizon.

Figure 8. Well-being and value of life with containment



A comparison of the two situations between the two, i.e., the excess of containment and non-execution, shows that this policy will have very favorable effects on the conditions of contagion and also on the macroeconomic aggregates. Certainly, this policy will enable economic activities to resume more quickly and under the best conditions. Figure 8 confirms this observation and confirms the relevance of containment in Morocco. What is even more important is that the success of this policy is conditioned by a respected of at least 80% of the population from the conditions of containment in order to avoid being in a delicate situation of contagion and deterioration of economic conditions.

Figure 9. Comparison and trade-off between containment and non-containment



Analyses of the situation with or without confinement reveal a very delicate trade-off to be made between the economy and the health well-being of the people. Indeed, the introduction of confinement will have to slow down the country's economic activity drastically, but at the same time it will reduce the risk of contagion and mortality in theMoroccan society. On the other hand, the non-confinement is likely to keep the activity going with extreme impacts on the Moroccan health framework.

5. Conclusion

The covid 19 could affect all the world economies and the first reaction was to strengthen on either for each country in the planet, even to varying degrees. Today, in the midst of a health crisis, countries are thinking of reducing containment constraints in order to seek the optimal circulation of resources and limit the obstacles to the circulation of money. As a result, all countries are seeking to optimise the balance between health and economic well-being, which is quite difficult under the current conditions.

In this paper we have tried to measure the effects of the containment policy on the health and economic conditions in Morocco. The idea here is to put the well-being of individuals in advance through the containment decision. Certainly the results that we have found allow us to highlight important effects on the economic conditions if confinement is used but on the other hand this policy is very beneficial for the health framework and for the reduction of mortality by covid19.

The model we have used is very simple in theory and its calibration is based on Moroccan data available until early May 2020. The overall results show that economic conditions tend to deteriorate, especially as socio-economic relations become closer.

Morocco is now faced with the decision whether or not to lift the confinement and its decision will have obvious repercussions on health welfare, the objective is obviously to relaunch the economy, but this will certainly have a price, so the situation requires an intelligent lifting of the confinement and a way to manage the period of containment with optimal health welfare.

References

- Alvarez, Fernando, David Argente, Francesco Lippi ìA Simple Planning Problem for COVID-19 Lockdown,î manuscript, University of Chicago, March 2020.
- Atkeson, Andrew ìWhatWill Be The Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios,î National Bureau of Economic Research,Working Paper No. 26867, March 2020.
- Berger, David Kyle Herkenho§, and Simon Mongey ìAn SEIR Infectious Disease Model with Testing and Conditional Quarantine,î manuscript, Duke University, March 2020.
- Bootsma, Martin CJ, and Neil M. Ferguson. "The E§ect of Public Health Measures on the 1918 Ináuenza Pandemic in US Cities," Proceedings of the National Academy of Sciences 104, no. 18 (2007): 7588-7593.
- Buera, Francisco, Roberto Fattal-Jaef, Pablo Andres Neumeyer, and Yongseok Shin The Economic Ripple E§ects of COVID-10,î manuscript, World Bank, 2020.
- Damien de Walque, Jed Friedman and Aaditya Mattoo ìTwo Tests for a COVID-19 World,î manuscript, The World Bank, April 2020.
- Farhi, Emmanuel and Ivan Werning ìDealing with the Trilemma: Optimal Capital Controls with Fixed Exchange Rates,î National Bureau of Economic Research Working Paper No. 18199, June 2012.
- Faria-e-Castro, Miguel ìFiscal Policy During a Pandemic,î manuscript, Federal Reserve Bank of St. Louis, March 2020.
- Ferguson, N., Cummings, D., Fraser, C. et al. ìStrategies for Mitigating an Ináuenza Pandemic,î Nature 442, 448ñ452, 2006.
- Ferguson, Neil M., Daniel Laydon, Gemma Nedjati-Gilani, Natsuko Imai, Kylie Ainslie, Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Zulma Cucunub-, Gina Cuomo-
- Dannenburg, Amy Dighe, Ilaria Dorigatti, Han Fu, Katy Gaythorpe, Will Green, Arran Hamlet, Wes Hinsley, Lucy C Okell, Sabine van Elsland, Hayley Thompson, Robert

Verity, Erik Volz, Haowei Wang, Yuanrong Wang, Patrick GTWalker, Caroline Walters, PeterWinskill, CharlesWhittaker, Christl A Donnelly, Steven Riley, and Azra C Ghani, Impact of Non-pharmaceutical Interventions (NPIs) to Reduce COVID- 19 Mortality and Healthcare Demand,î manuscript, Imperial College, March 2020.

- Ginsberg, Jeremy, Matthew H. Mohebbi, Rajan S. Patel, Lynnette Brammer, Mark S. Smolinski, and Larry Brilliant ìDetecting Ináuenza Epidemics Using Search Engine Query Data,î manuscript, Centers for Disease Control and Prevention, 2008.
- Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Ivan Werning ìMacroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages? î manuscript, Northwestern University, April 2020.
- Gourinchas, Pierre-Olivier. ìFlattening the Pandemic and Recession Curves,î manuscript, University of California, Berkeley 2020.
- Glover, Andrew, Jonathan Heathcote, Dirk Krueger, and JosÈ-Victor RÌos-Rull ìHealth versus Wealth: On the Distribution E§ects of Controlling a Pandemic,î manuscript, University of Pennsylvania, 2020.
- Kaplan, Greg, Ben Moll, and Gianluca Violante ìPandemics According to HANK, manuscript, University of Chicago, 2020.
- Kermack, William Ogilvy, and Anderson G. McKendrick ìA Contribution to the MathematicalTheory of Epidemics,î Proceedings of the Royal Society of London, series A 115, no. 772: 700-721, 1927.
- Perrings, C., Castillo-Chavez, C., Chowell, G., Daszak, P., Fenichel, E.P., Finno§, D., Horan, R.D., Kilpatrick, A.M., Kinzig, A.P., Kumino§, N.V. and Levin, S., ìMerging Economics and Epidemiology to Improve the Prediction and Management of Infectious Disease,î EcoHealth, 11(4), pp.464-475, 2014.
- Philipson, Tomas ìEconomic Epidemiology and Infections Diseases,î in Culyer, A. and J. Newhouse, Handbook of Health Economics, vol. 1 1761-1799, Elsevier, 2000.
- Stock, James ìCoronavirus Data Gaps and the Policy Response to the Novel Coronavirus, manuscript, Harvard University, 2020.
- Toda, Alexis Akira ìSusceptible-Infected-Recovered (SIR) Dynamics of COVID-19 and Economic Impact,î manuscript, University of California San Diego, 2020.