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Confinement efficiency and economic scenarios of Covid-19: The case of Morocco

A b s t r a c t

In the present paper we are interested in the epidemiological evolution of Covid-19 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.

1   Introduction

All the countries of the world today are rushing to understand the effects of Covid-19 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

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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 magnitude of the pandemic which should be measured by the number of deaths. In addition, these decisions will lead to a significant economic downturn.

• 4 •

In the proposed modelling 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 for 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 of total pandemic-related deaths. 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, the model of Kermack and McKendrick (1927) has been revisited. Via this model, the probabilities of transitions between health states are considered as exogenous parameters. A reorganization of the model is carried out by assuming that the purchase of consumer goods and services, as well as work facilitate the interactions between economic

agents and citizens. This increases the probability of the pandemic spreading. What we have observed in Morocco is that the effects of contagion accelerate with the interactions between economic actors and of course this occurs largely during economic decisions.

The model adopted in this paper makes it possible to consider that the pandemic stops when total immunization is acquired by the entire population. Certainly, in the absence of medical treatment, contagion will have the effect of accelerating the mortality process. Admittedly, the decision to set up containment in response to the current crisis would be effective, but this approach is vitiated by two problems. On the one hand, containment measures will have negative effects on the macroeconomic context. Second, the population is still in a situation of immune impossibility. Thus, infections would reappear if the containment was released. The best policy is to increase the fraction of the immune population by reducing consumption when the externalities are high, that is, when the number of people infected is high. One such policy is to gradually strengthen containment measures as infections increase and to release them slowly 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 paper by Jones, Philippon and Venkateswaran (2020) is close to our proposed approach. The authors analyze optimal mitigation policies in a model where economic activity and epidemic dynamics interact. The two authors analyze learning by doing while working from home and assume that people have a fatalistic bias about the probability of being infected in the future. Guerrieri, Lorenzoni, Straub and Werning (2020) use the Keynesian theory in which the shocks that trigger changes in aggregate demand are more important than the shocks themselves. These authors argue that the economic shocks associated with the Covid-19 epidemic may exhibit this characteristic. They also analyze the effectiveness of various monetary and fiscal policies in coping with these shocks. In this paper we propose to extend the dynamics

of the SIR model in the Keynesian framework1. In addition, Berger, Herkenho§ and Mongey (2020) and Stock (2020) study the importance of random tests to estimate the health status of the population and design optimal mitigation policies. Inspired by this work, the fundamental idea of our work is to model the link that may exist between the rate of infection and economic activity. Other authors analyze the effects of the Covid-19 epidemic using multi-agent models. Glover, Heathcote, Krueger and Rios-Rull (2020) study optimal mitigation policies in a model that takes into account the age distribution of the population. Kaplan, Moll and Violante (2020) do this in a HANK model. Faria-e-Castro (2020) studies the effect of an epidemic, modeled as a significant negative shock on the usefulness 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. Certainly one of the aspects that must be highlighted today is the possibility of this pandemic influencing the financial stability of the Moroccan banking and financial system. The pandemic is a systemic risk and it is urgent to conduct analyzes to deduce its effects on the dynamics of financial stability (Firano Zakaria, 2012, 2015, 2018).

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 maximization and rational behavior. In this sense, we consider that the economy is populated by a continuum of identical ex ante agents that maximize the objective function:

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t, n_t) \tag{1}$$

Here, β (0; 1) is the discount factor and c and n are consumption and hours worked respectively. For simplicity, we assume the utility function as :

$$u(c_t, n_t) = ln(c) + \frac{\theta}{2} n^2 \tag{2}$$

The budgetary constraint of the representative agent is:

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[1] *In a developed version of the model on which we will work, we will be inspired by works on the macroeconomic framework using the DSGE models in order to define all the behaviors of the actors and also the financial system and the effects of the pandemic on development. financier du Maroc (Firano, Z. (2016). Financial stability: An old concept and A new challenge, Firano, Z., Benbachir, S., & Abouch, M. (2012). Macroeconomic framework for financial stability for Morocco.)*

$$(1 + \mu)c_t = w_t n_t + \delta \qquad (3)$$

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

The primary condition for the representative-agent problem is:

$$(1 + \mu)\theta n_t = c^{-1}w_t \qquad (4)$$

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

$$C_t = A.N_t \qquad (5)$$

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

$$\pi = AN - wN \qquad (6)$$

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

$$\mu c = \delta \qquad (7)$$

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). It is to be supposed that the transition probabilities depend on the economic decisions of the populations. As an example, these are purchases of consumer goods and services. To this end, we consider that individuals are broken down into four types of agents: sensitive or potential individuals who have not yet been infected, infected individuals, healed individuals and deceased persons. The number of newly infected people is indicated by "T". Sensitive people can be infected in three ways. First, they can meet 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 $p_1(C^S S * C^I I)$ the component $(C^S S * C^I I)$ 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 $p_2(N^S S * N^I I)$.. With the quantity in brackets is the sum of the amount of work of the infected and potential population.

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The last way we assume is to have contamination via other social mechanisms such as neighborhood or casual encounters. So we can write the third probability as $p_3 SI$.

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

$$T = p_2(N^s S * N^I I). + p_1(C^s S * C^I I) + p_3 SI \qquad (8)$$

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:

$$S_{t+1} = S_t - T_t \qquad (9)$$

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

$$I_{t+1} = I_t + T_t - (p_r + p_d) I_t \qquad (10)$$

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 :

$$R_{t+1} = R_t + p_r I_t \qquad (11)$$

$$D_{t+1} = D_t + p_d I_t \qquad (12)$$

Then the total population can be described as follows:

$$Pop_{t+1} = Pop_t - p_d I_t^2 \qquad (13)$$

The initialization of infection and population susceptibility variables are :
$I_0 = \varepsilon \ et \ S_0 = 1 - \varepsilon.$

We will now see how the behavior 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:

$$(1 + \mu) c_t = w_t \varphi n_t + \delta \qquad (14)$$

The parameter added in the budget constraint describes labor 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 :

$$Ust = u(cst; nst) + \beta(1 - p)Ust + 1 + pUit + 1 \qquad (15)$$

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[2] *We note that the level of the population at time 0 is equal to 1..*

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

$$p = p_1 c_s(IC) + p_2 n_s(IN) + p_3 I \qquad (16)$$

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

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

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

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

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

$$\mu(Sc_s + Ic_i + Rc_r) = \delta (S + I + R) \qquad (4)$$

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:

$$U = SU_s + IU_i \qquad (5)$$

The objective is to model the competitive balance taking into account the containment rate. An iteration is adopted until the model reaches its optimality. The basic idea of our research is simply explained as follows: Containment measures internalize the externality caused by the behavior of infected people. Thus, containment is modeled according to the degree of infection of the population. For example, at time zero, very few people are infected and the negative externality is moderate. To this end, considering a high containment rate at zero time would have an unbearable socioeconomic cost on the economic level. As the 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

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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 p_1, p_2 and p_3 (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.

• 10 •

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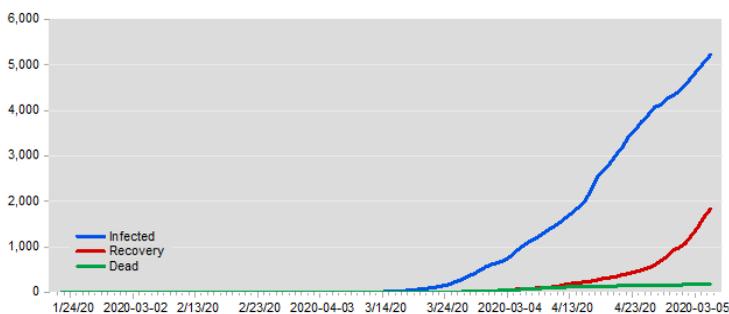
Furthermore, we have noted that the number of infected persons is increasing in daily frequency. On average this number is around 48 people per day with a rightward asymmetry which implies a very important standard deviation of 55, i.e. the idea that we can have daily cases of up to 160 cases per day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

Since 16 March 2020, Morocco has declared the situation of containment to counter the contagion of Covid-19 . 19 This decision certainly has

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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).

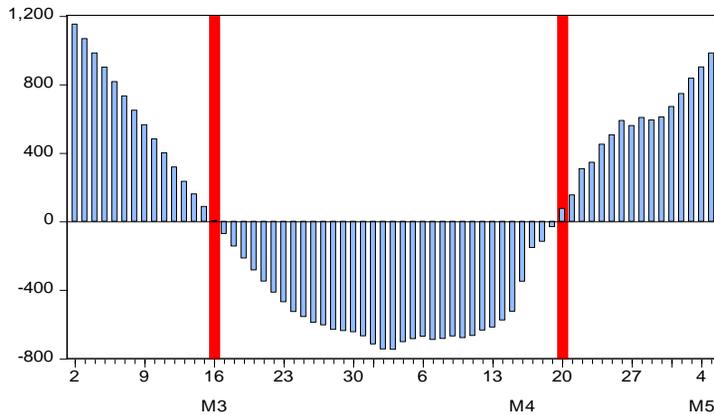**Figure 2.** Empirical and theoretical distribution of infected cases per day
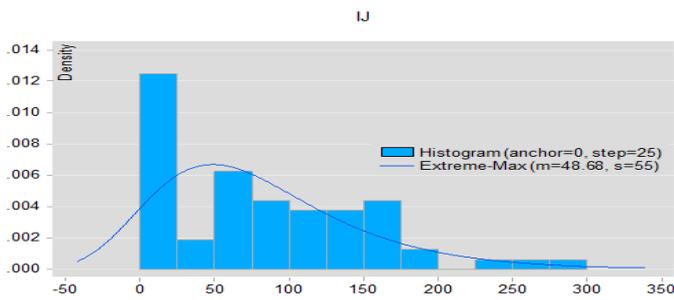
Figure 1. Cycle de contamination Covid-19 et prise de décision


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.

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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 Covid-19 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
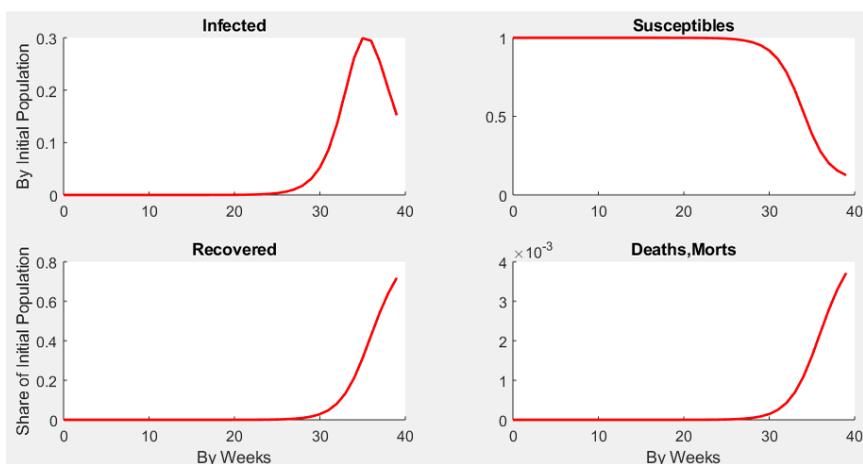
Economically, no containment measures and no government policy will have negative externalities on consumption, productivity and GDP growth. Under these conditions, consumption will have fallen by 20% with the infection of the population as well, and working hours will be slowed down by 20% over the 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.

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.

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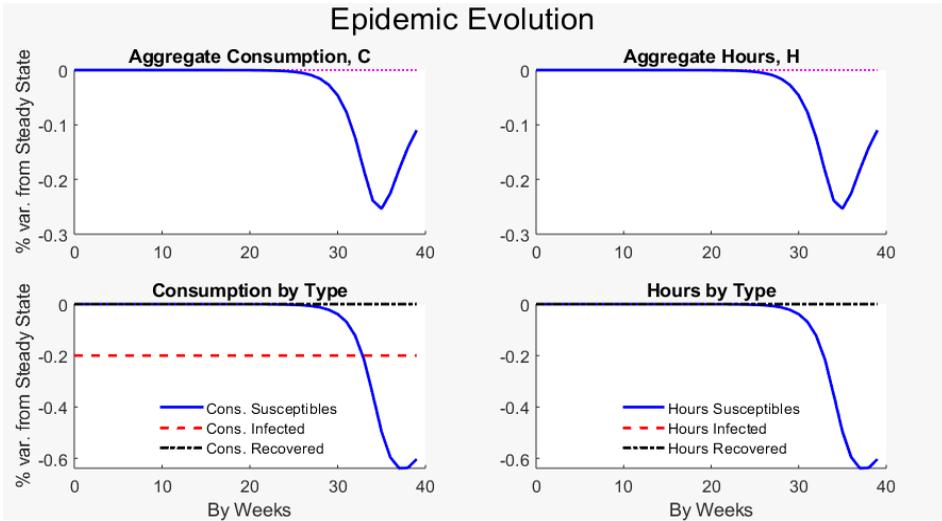**Figure 5.** Simulation of unconfined economic conditions

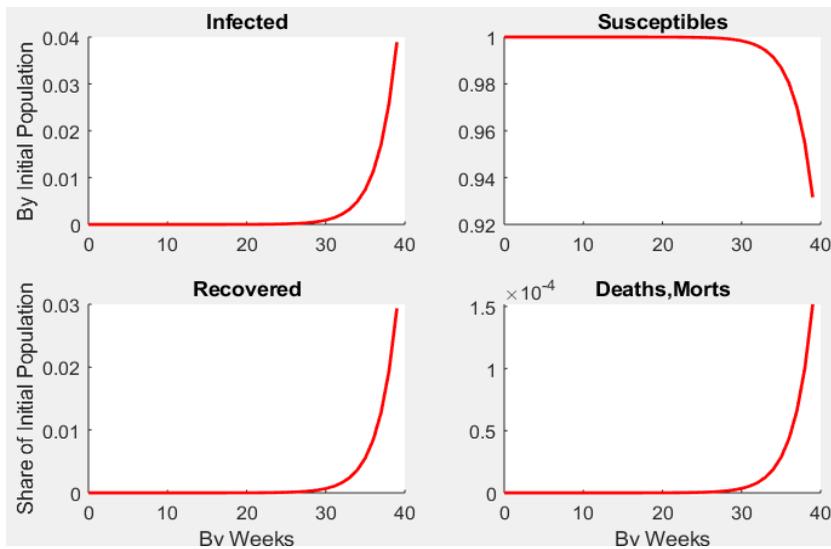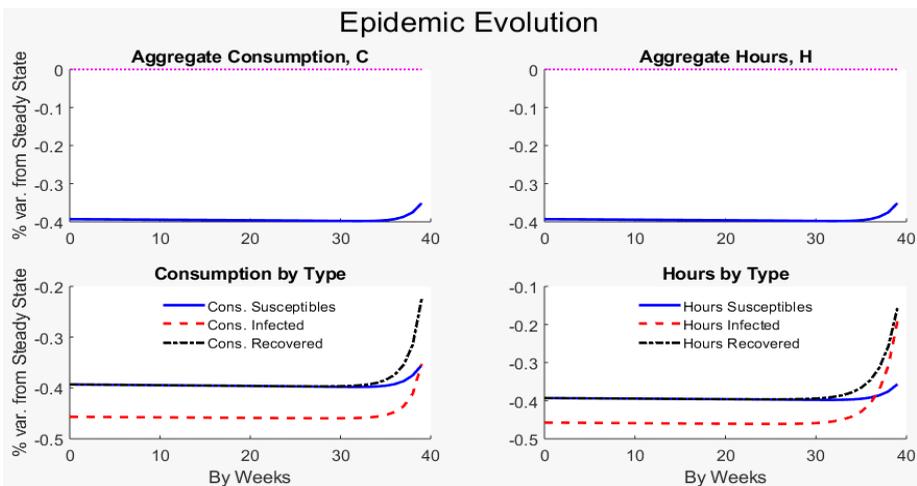

**Figure 6.** Simulation with containment

Figure 7. Simulation of economic conditions with containment

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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.

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
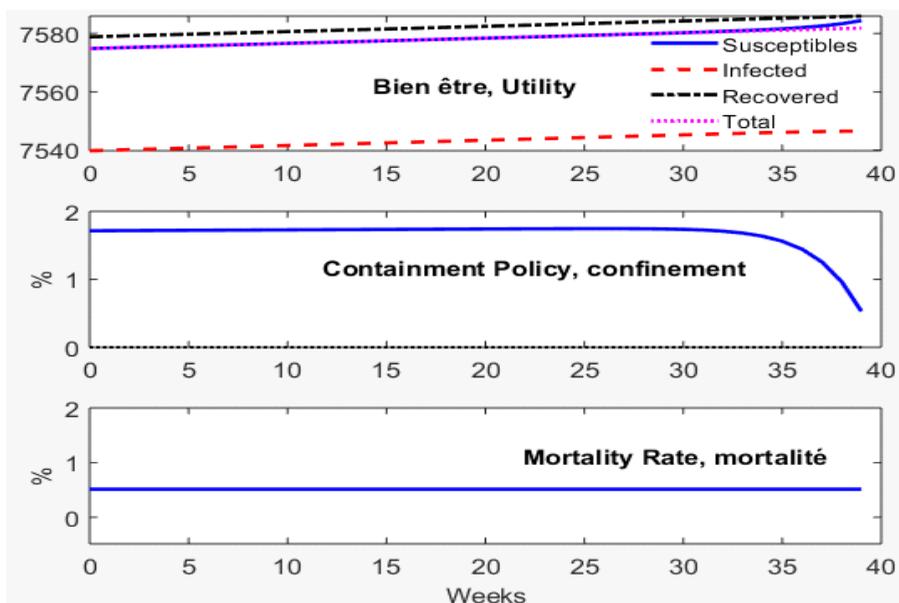
A comparison of the two situations between the two, i.e., the excess of containment and non-execution, shows that this policy will have very favorable effects on the conditions of contagion and also on the macroeconomic aggregates. Certainly, this policy will enable economic activities to resume more 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.

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 the Moroccan society. On the other hand, the non-confinement is likely to keep the activity going with extreme impacts on the Moroccan health framework.

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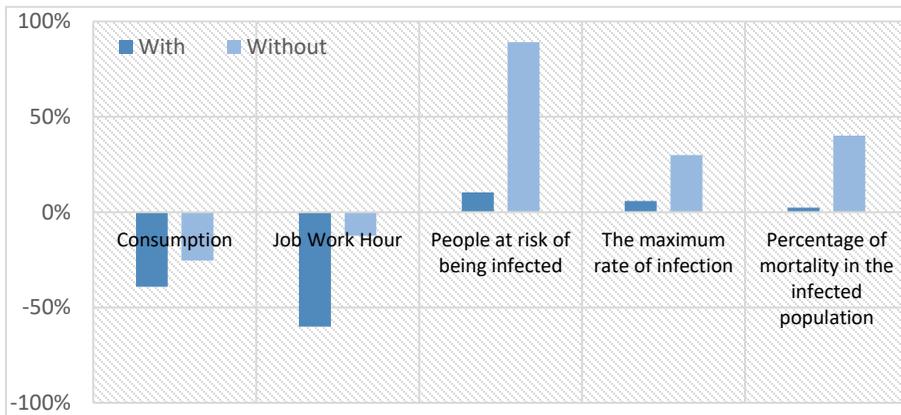
5 Conclusion

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 Covid-19. 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.

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