ASSESSMENT OF THE IMPACT OF COVID-19 PANDEMIC ON THE ALGERIAN ECONOMY: THE IMPORTANCE OF THE INFORMAL ECONOMY

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SUMMARY

The main objective of the article is to study the interaction between COVID-19 pandemic and the informal economy and its impact on the Algerian economy using SIR epidemiologic model. The article expands SIR model to count for economic decision made by individuals and the availability of treatment.

The results show that counting for the size of informal economy is critical when analyzing the impact of COVID-19 pandemic on the Algerian economy. It is noted that the policy of optimal containment augmented the severity of the recession from 2.15% to 7.87%. Nevertheless, it saves the lives of 8300 people.

Based on the best containment policy, the study suggests that starting reducing containment policy on 14\06\2020 is too early because in this period the optimal containment policy was not optimal, and as result of this decision the number of infected individuals started to increase again.

KEY WORDS: Informal economy; COVID-19; SIR model; economic recession; Estimation.

JEL CLASSIFICATION: E26; O1.

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تقييم أثر جائحة COVID-19 على الاقتصاد الجزائري:

أهمية الاقتصاد غير الرسمي

ملخص

الهدف الرئيسي من المقال هو دراسة التفاعل بين جائحة COVID-19 والاقتصاد غير الرسمي وأثره على الاقتصاد الجزائري باستخدام النموذج الوبائي SIR. يوسع المقال النموذج الوبائي SIR ليأخذ بعين الاعتبار القرارات الاقتصادية التي يتخذها الأفراد بالإضافة إلى توفر العلاج.

أظهرت النتائج أن حساب حجم الاقتصاد غير الرسمي أمر بالغ الأهمية عند تحليل تأثير جائحة COVID-19 على الاقتصاد الجزائري.

يلاحظ أن سياسة الاحتواء المثالية زادت من حدة الركود لاقتصادي ليرتفع من 2.15٪ إلى 7.87 ٪. ومع ذلك، فإنها انقذت حياة 8300 شخص في الجزائر.

بناءً على أفضل سياسة احتواء، تقترح الدراسة أن البدء في تقليل سياسة الاحتواء في 14 \ 06 \ 2020 مبكر جدًا لأنه في هذه الفترة سياسة الاحتواء المثلى لم تبلغ ذروتها، ونتيجة لهذا القرار بدأ عدد الأفراد المصابين في الزيادة مرة أخرى.

كلمات المفتاحية: اقتصاد غير الرسمي؛ كوفيد–**19؛** نموذج وبائي SIR؛ كساد اقتصادي؛ تقدير.

تصنيف جال:E26؛ O1**.**

ÉVALUATION DE L'IMPACT DE LA PANDEMIE DE COVID-19 SUR L'ECONOMIE ALGERIENNE: L'IMPORTANCE DE L'ECONOMIE INFORMELLE

RÉSUMÉ

L'objectif principal de l'article est d'étudier l'interaction entre l'épidémie de COVID-19 et l'économie informelle et son impact sur l'économie algérienne en utilisant le modèle épidémiologique SIR. L'article élargit le modèle SIR pour tenir compte des décisions économiques prises par les individus et de la disponibilité du traitement. Contrairement à la littérature précédente, ce dernier prend en considération la taille de l'économie informelle.

Les résultats montrent qu'il est essentiel de compter la taille de l'économie informelle lors de l'analyse de l'impact du COVID-19 épidémie sur l'économie algérienne. Il a été constaté que la politique du confinement optimal a fait passer la gravité de la récession de 2.15% à 7.87%. Néanmoins, il a laissé la vie sauve à 8300 personnes.

L'étude suggère que commencer à réduire le confinement le 14/ 06/2020 est trop tôt car pendant cette période, la politique de confinement n'était pas optimale, et à la suite de cette décision, le nombre d'individus infectés a commencé à augmenter encore.

KEY WORDS : économie informelle, covid-19, model SIR ; récession économique ; Estimation.

JEL CLASSIFICATION : E26 ; O1.

INTRODUCTION

On 11 March 2020, the World Health Organization declared COVID-19 as a pandemic (Munthali & Xuelian, 2020). This pandemic originated in Wuhan, the capital of China's Hubei province, in December 2019 (Perone, 2020). COVID-19 or Coronavirus is a novel strain of coronavirus from the Severe Acute Respiratory Syndrome (SARS) species (Ozili & Arun, 2020) caused by the SARS-CoV-2 virus, with symptoms of fever, coughing, shortness of breath (McKibbin & Fernando, 2020). As the COVID-19 pandemic started to spread around the world, the government of many countries started to take containment policies to reduce infection and mortality caused by this pandemic. This procedure toke the form of shutting down stores, restaurants, canceling in and out flights, and maintenance of good hygiene... etc. with social distancing as the sole option. However, it's not an option for workers in the informal economy with most activities are face-to-face. This raises the question about the interaction between Coronavirus and informal economy. In literature the latter is often referred to as shadow, hidden informal, irregular, unobserved, unrecorded, subterranean, parallel. These are just a handful of the terms that have been used to describe economic activity (Bennihi & Bouriche, 2019). (De colin & Schneider, 2016) counted 44 adjectives and 10 nouns to describe this phenomenon which, for whatever reason, is not directly measured by any of the usual economic and fiscal indicators. According to (Dell' Anno , 2010), the informal economy refers to all economic activities by workers and economic units that are-in-law or in practice—not covered or insufficiently covered by formal arrangements. As for (Schneider & Williams , 2013) the informal economy insofar as it contains all market-based production of legal goods/services that are intentionally hidden from public authorities for many reasons such as to avoid payment of income, value added or other taxes and to avoid payment of social security contributions.

This part of the economy is often ignored when it comes to supportive policies particularly in times of crises. Although it contains 2 billion workers (ILO, Short-term Policy Responses to COVID-19 in the World of Work Special focus on state level and informal sector, 2020a) worldwide, and with no alternative source of income, stop working is not an option for those working in the informal economy.

This paper shines the light on the interaction between COVID-19 and the informal economy in the case of Algeria. Especially that it has an important size of informal sector (Adair & Bellache, 2008; Adair P. , 2014; Adair & Souag, 2018; Schneider & Buehn, 2018) and aims to answer the following question.

Does the interaction between COVID-19 and the informal economy worsen the economic situation in Algeria?

To answer this question, the paper adopts a modified SIR model that counts for economic decision and the availability of treatment for coronavirus and unlike the previous studies, this article takes in consideration the size of informal economy.

The remainder of the paper is organized as follows section two outlines the related literature; section 3 describes the methodology; results are presented in section 4; finally, section 5 discusses results and concludes.

2. LITERATURE REVIEW

A large set of literature has emerged and is still expanding on macroeconomic issues surrounding the COVID-19 pandemic. We summaries some of the relevant studies related to our study.

(Eichenbaum, Rebelo, & Trabandt, 2020) extend the SIR epidemiologic model to study the interaction between economic decisions and pandemics. The researcher concluded that individual's decision to lower their consumption and work lowers the severity of the pandemic, as measured by total deaths. These decisions worsen the size of the recession caused by the pandemic. The researcher concluded that the best simple containment policy increases the severity of the recession but saves roughly half a million lives in the United States. Summarily (Toda, 2020) applied the SIR model to study the COVID-19 pandemic on the stock market. He found that without containment policy 28% of the population can be infected at the peak, potentially overloading the healthcare system. However, this percentage is reduced under the optimal containment policy to 6.2%. In addition, the author predicted that the pandemic will peak in early May 2020 in Europe and North America, at which point around 30 percent of the population will be infected.

In line with the previous studies (Alvarez, Argente, & Lippi, 2020) analyzed how to optimally balance the COVID-19 deaths with the output costs of containment policy using a modified SIR epidemiology model that counts for the possibility of testing and the non-availability of a cure. The results found that the optimal policy prescribes a severe containment beginning 2 weeks after the COVID-19 pandemic outbreak. They showed that the absence of testing increases the economic costs of the containment, and reduces the period of the optimal lockdown which ends more shortly. However, (Buera, Fattal-Jaef, & Hopenhayn, 2020) used an extended SEIR model to analyze the role of testing and case dependent quarantine. Advanced testing in conjunction with targeted quarantine policies can reduce peak symptomatic infections — related to hospital capacity — and reduce the economic impact of COVID-19.

(Guerrieri, Lorenzoni, Straub, & Werning, 2020) applied theory of Keynesian supply shocks: supply shocks that trigger variations in aggregate demand higher than the shocks themselves. They claim that the economic shocks associated with the COVID-19 pandemic may have this feature. In another study (Jones, Philippon, & Venkateswaran, 2020) chose to apply neoclassical model considering the dynamics of contagions to study the response of the economy in the presence of an pandemic outbreak. The authors found two main observations. First, that relative to the incentives of private agents, a planner wishes to significantly front-load mitigation strategies. Second, the prospect of mitigation together with the possibility of agents working from home gives quantitatively meaningful reductions in the spread of a disease and the economic costs.

Despite the different and sophisticated method applied by the researchers above. They overlooked the important role of the informal economy and its interaction with COVID-19 pandemic. Especially this sector contains 2 billion workers worldwide, in addition it's very vulnerable to shocks generated by pandemics (ILO, 2020b). Omitting the size of the informal economy can bias the estimation of covid-19 impact on economies. Accordingly, reducing effectiveness of policies made by policy-makers to combat COVID-19 consequences. This issue is more vital in countries with large informal economy.

As most African developing countries, Algeria has an important size of informality (Nchor & Adamec, 2015). Based on the estimation of (Boudlal, 2012) the average size of Algerian informal economy to be 24.5% of official GDP using the Currency Demand Approach (CDA) from 1970 to 2010. (Alm & Embaye, 2013) estimated the size of the IE in 111 countries using the CDA approach from 1984 to 2006. The results suggested that Algeria had an average of 48.09% of GDP as the informal economy which is the highest estimate in the existing literature.

Turning to the researchers who used the latent variable approach to estimate the Algerian informal economy in general the estimations are higher than the previous method. (Bounoua, sebbah, & Benikhlef, 2014) analyzed the determinants and evolution of the shadow economy in Algeria from 1990 to 2009. The econometric analysis was based on a multiple indicator multiple causes model, results from the study showed that the size of the informal economy varies from 41.68% in 1991 to 46.43% in 2009. Another study by (Quintano & Mazzocchi, 2014) measured the informal economy in subsamples of Mediterranean countries during the period from 1995 to 2010. Results showed that the Algerian informal economy was unstable during this period the highest percentage 46.4% of GDP was in 2008 and the lowest percentage 32.4% of GDP was in 2002 with a means of 39.47% over the study period.

According to (Medina & Schneider, 2018) the Algerian informal economy was estimated to vary between 38.88% and 23.98% as the smallest percentage with an average of 30.86% and stander deviation of 5.47%. (Kori, 2018) found that the informal part of the economy in Algeria constitutes 47.4% of the official GDP in 2016.

Unlike the previous studies (Smaili, 2019) used a direct approach at the state level to estimate the Algerian informal economy and estimated to be 46.16% of the official GDP.

Based on the above literature, the study argues that studying only the interaction between formal economy and COVID-19 pandemic without considering the size of the informal economy takes a large portion of reality. Hence, the current study shines the light on the interaction between informal economy and COVID-19 pandemic.

3- METHODOLOGY

To investigate the equilibrium interaction between economic decisions, and the spread of the COVID-19 pandemic in Algeria. SIR Epidemiologic models suggested by (Kermack & McKendrick, 1927) is used. Following the literature, the SIR model is modified assuming the availability of treatment and that buying consumption goods/services along with working brings people in contact. Thus increasing the likelihood that the infection spreads.

These economic activities can't be done only in the formal economy, but also in the informal economy. Which can add more contact that is not considered in the studies that only focused on the formal economy and the resulting contact, the paper argues that these overlooked activities can attribute to the spread of COVID-19.

For this purpose, the theoretical economy before the outbreak of infection is presented. After that, the basic SIR model is introduced along with the modified two SIR models named SIR-formal models which counts for the economic decisions made only in the formal sector, and SIR-all model which computes for economic decisions made by individuals in both formal and informal economy. After that, the paper discusses the optimal containment policy and the implication of it on the economy.

3.1- Model economy pre-infection

The economy is occupied by a continuum of ex-ante identical agents. Previous to the start of the pandemic, all agents are identical and seek to maximize their lifetime utility:

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

Where, β (0; 1) denotes the reduction factor and c_t and n_t signify consumption and hours worked respectively.

For convenience, it's assumed that momentary utility form is:

$$u(c_t, n_t) = lnc_t - {}^{\emptyset}/_{2}\, n_t^2 \quad (2)$$

The budget constraint of agent is:

$$(1 + \mu_t)c_t = \ w_n n_t + \varphi_t \quad (3)$$

Where, $w_n$denotes the real wage rate,φ_t is the government transfers and μ_t It is the tax rate of consumption. It can be seen as a proxy for containment measures aimed at reducing social interactions. Therefore, it can be interpreted as the containment rate. Accordingly, the first-order condition of agents is:

$$(1 + \mu_t)\emptyset n_t = \ c_t^{-1} + w_t \quad (4)$$

There is a continuum of illustrative competitive firms of unit measure that produce consumption goods/ services (CT) using hours worked (NT) according to the technology:

$$C_t = AN_t \quad (5)$$

The firm chooses hours worked to maximize its time-t profits π_t:

$$\pi_t = AN_t - w_t N_t \quad (6)$$

The government's budget constraint is given by:

$$\mu_t c_t = \varphi_t \quad (7)$$

3.2- Model economy pre-infection

In SIR model, the entire population (N) is divided into four categories which are mutually exclusive to each other. The first category is called susceptible (S) contains all individuals who are capable of catching the disease and becoming infected. The second category is called Infected (I) contains the infected individuals who have the disease and can transmit it to others. The third category is named Recovered (R) consists of individuals who were infected by the disease and have recovered, and the fourth category is deceased (D). Eventually, the SIR model can be written as follows:

$$\begin{aligned} Susceptible\ (S_t) + Infected(I_t) + Recovered\ (R_t) \\ + Deceased\ (D_t)\ = population\ (N_t) \end{aligned} \quad (8)$$

The initial value problem divided by constant population (N) is:

$$\left(\frac{dS}{dt}\right) = \ -\beta SI \quad (9)$$

$$\left(\frac{dI}{dt}\right) = \beta SI - \beta_r R - \beta_d D \tag{10}$$

$$\left(\frac{dR}{dt}\right) = \beta_r R \tag{11}$$

$$\left(\frac{dD}{dt}\right) = \beta_d R \tag{12}$$

Where β is the contact rate, β_r is the recovery rate and β_d It is the mortality rate.

The previous model is modified to account for the viability of treatment and we allow for the spread of infection to be related to individual economic activities. Unlike most epidemiology models which assumes the probabilities governing the change between different states of health are not associated with individual economic decisions. Accordingly, the spread of the disease is correlated with the individual's contact during purchasing goods/ services and working in both formal and informal economy.

In the modified SIR model susceptible individuals can become infected in three ways:

1- They can come in contact with an infected individual while purchasing consumption goods/ services and this can happen either in the formal or informal economy. This interaction can be written as follows:

$$\beta_{1f}(S_t C_t^s)\left(I_t C_t^i\right) + \beta_{1if}(S_t C_t^s)\left(I_t C_t^i\right) \tag{13}$$

While β_{1f} , β_{1if} the likelihood of getting infected while shopping from the formal sector and informal sector respectively, $\left(S_t C_t^i\right)$ is consumption expenditures by susceptible and $\left(I_t C_t^i\right)$ is consumption expenditures by infected people.

2- They can get infected while working and this can happen either in the formal or informal economy. The newly infected individuals from this interaction can be written as follows:

$$\beta_{2f}\,(S_t N_t^s)\left(I_t N_t^i\right) + \beta_{2if}(S_t N_t^s)\left(I_t N_t^i\right) \tag{14}$$

While β_{2f} ,β_{2if} are the likelihood of getting infected while working in the formal and informal sector respectively, ($S_t N_t^s$) is the total hours worked by susceptible and $\left(I_t N_t^i\right)$ It is total hours worked by infected people.

3- They can get infected during making activities that are not related to consumption and working. This can be written as follows:

$$\beta_3 S_t I_t$$

While β_3 is the likelihood of getting infected, S_t and I_t are number of susceptible at time t and the number of infected individuals at time t, respectively .

Hence the newly infected individuals in SIR-all model is given by:

$$\lambda_t = [\beta_{1f}(S_t C_t^s)(I_t C_t^i) + \beta_{1if}(S_t C_t^s)(I_t C_t^i)] + [\beta_{2f}(S_t N_t^s)(I_t N_t^i) + \beta_{2f}(S_t N_t^s)(I_t N_t^i)] + \beta_3 S_t I_t \quad (15)$$

The optimization problem of different agents in the economy and their first order condition is given in the table below:

Table 1: Utility function and first order condition for the different categories

	Susceptible
Utility function	$U_t^s = u(c_t, n_t) + \beta[(1-\tau_t)U_{t+1}^s + \tau_t U_{t+1}^i]$ (16)
First order conditions	$u_1(c_t, n_t) - (1-\mu_t)L_{bt}^s + L_{\tau t}\beta_1(I_t C_t^i) = 0$ (17) $u_2(c_t, n_t) + w_t L_{bt}^s + L_{\tau t}\beta_2(I_t N_t^i) = 0$ (18)
	Infected
Utility function	$U_t^i = u(c_t, n_t) + (1-\delta_c)\beta[(1-\beta_r-\beta_d)U_{t+1}^i + \beta_r U_{t+1}^r] + \delta_c \beta U_{t+1}^r$ (19)
First order conditions	$u_1(c_t, n_t) - L_{bt}^i(1+\mu_t) = 0$ (20) $u_2(c_t, n_t) + -\vartheta^i w_t L_{bt}^i = 0$ (21)
	Recovered
Utility function	$U_t^r = u(c_t, n_t) + \beta_r U_{t+1}^r$ (22)
First order conditions	$u_1(c_t, n_t) - L_{bt}^r(1+\mu_t) = 0$ (23) $u_2(c_t, n_t) + w_t L_{bt}^r = 0$ (24)

Source: Authors own construction

With τ_t is the likelihood of a susceptible individual becomes infected:

$$\tau_t = (\beta_{1f} + \beta_{1if})c_t^s(I_t C_t^i) + (\beta_{2f} + \beta_{2if})n_t^s(I_t C_t^i) + \beta_3 I_t \quad (16)$$

ϑ^i It is the productivity rate, it's equal to one for susceptible and recovered individuals and less than one of the infected ones.

δ_c It is the probability of discovering an effective treatment.

Government budget constrains is:

$$\mu_t(S_t c_t^s + I_t c_t^i + R_t c_t^r) = \varphi_t(S_t + I_t + R_t) \quad (17)$$

In the equilibrium every individual solves their maximization problem and the government constraint is fulfilled:

$$S_t C_t^s + I_t C_t^i + R_t C_t^r = A N_t \tag{27}$$

$$S_t N_t^s + I_t N_t^i \vartheta^i + R_t C_t^r = N_t \tag{28}$$

3.3- Parameters values

The model parameters are chosen based on the COVID-19 situation in Algeria, official national statistics data and the work of (Eichenbaum, Rebelo, & Trabandt, 2020) and they are reported in the table 2.

The initial population is normalized to one. The first confirmed case caused by COVID-19 was declared by the Algerian ministry of health on 26/02/2020. Therefore, the initial confirmed cases caused by COVID-19 is set to 0.023 per million (1/43 000000= 2.3 x 10-8) given a population of 43 million. The mortality rate in Algeria had an upward trend at the beginning of the pandemic with the majority of deaths in people over 60 years (83% of total deaths) resulting in a death rate of 9% on average and this can cause a bias in the estimation also an important proportion of people over 60% are not treated with the protocol adopted by the Algerian health government due to chronic diseases which contradict with the study assumption of availability of treatment therefor people over 60 years are excluded. the average mortality rate becomes 2,5% when excluding this group, the later rate is used in the empirical study. However, we provide a robustness check with a mortality rate of 5% and 7%.

For the calibration of the infection parameters, the paper fallows (Ferguson, et al., 2006) who found that 30% of transmissions occur in the household, 33% in society and 37% occur in schools and workplaces; the paper assumes that these values are the same in the two sectors. Time spent on general community activities related to consumption activities is 48%. Based on the later it is calculated that transmissions related to consumption is 16% $(48 \times 33 = 16\%)$. The transmissions related to work estimation procedure is explained below:

According to ONS the total number of workers in 2019 is 11.3 million and the number of students is 11.2 million in all educational stages. The latter are weighted by the average daily contact at school and workplace calculated by (Lee, Brown, & Cooley, 2010). The number students are weighted by 10 and the number of workers by 4. Accordingly, the transmission percentage in the formal work is 10.51%.

$$([11.2 \times 4/11.2 \times 4 + 11.3 \times 10] \times 0.37) * 100 = 10.51 \qquad (29)$$

Turning to the transmission percentage while working in the informal economy using equation (29) and based on the statistics of ONS informal labor in 2019 is estimated to be 45.37% of the official workforce using OLS regression. Therefore, the transmission percentage while working in the informal is equal to 17.25%.

It is assumed that transmission percentage that are not related to consumption or work in either formal/ informal economy is exogenous and the β_1, β_2 and β_3 in SIR-all model are chosen to satisfy:

$$\frac{\beta_1 C^2}{\beta_1 C^2 + \beta_2 N^2 + \beta_3} = 0.16 \qquad (30)$$

$$\frac{\beta_1 N^2}{\beta_1 C^2 + \beta_2 N^2 + \beta_3} = 0.1725 \qquad (31)$$

Where C and N are consumption and hours worked in the pre-infection steady state.

Accordingly, the resulting values for β_1, β_2 and β_3 are $1.5596e^{-}05$, $2.1793e^{-}04$ and 0.3479 respectively. The average weekly income is calculated by devising the average annual income (4115$) in Algeria in 52.

Table 2: Model parameters

Parameters	value
Simulation iterations	150 week
Average mortality rate β_d	2.5%
Time to recover or die	18 days
likelihood of getting infected β_1 in SIR-all	$1.5596e^{-}05$
likelihood of getting infected β_2 in SIR-all	$2.1793e^{-}04$
likelihood of getting infected β_3 in SIR-all	0.3479
probability of discovering an effective treatment δ_c	1/52
Long-run probability to either recovers or dies from the COVID-19	64%
productivity rate ϑ^i	80%
population	43 million
Initial infected cases	0.023 per million
Average weekly income	79.13 $
Average working hours*	27.5 h

Source : Authors own construction

*Weekly worked hours were adjusted due to the factors of quarantine and the working hours during Ramadan.

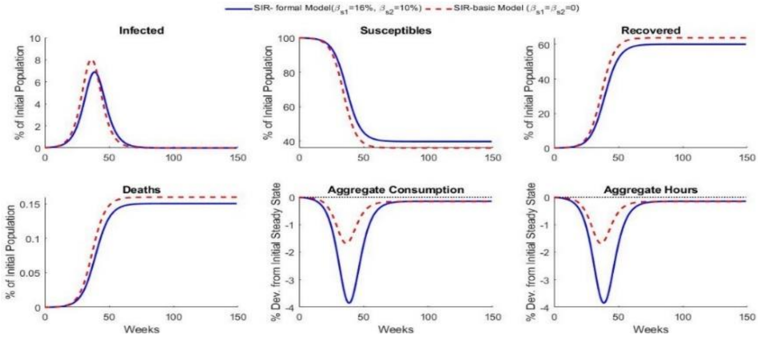
4- RESULTS

In this section, empirical results for the three SIR models implied to study the impact of informal economy on COVID-19 dynamics are presented. At first, results of the basic SIR model is provided in addition to the modified SIR-formal model and the SIR-all model which is the general model that counts for both formal and informal economic decisions. Second robustness check is done by using different parameters values. Third, the results of optimal confinement policy associated with SIR-all model is provided.

4.1- basic SIR model

Figure 1 shows that the infection is more severe in the basic SIR model than in the SIR-formal model. However, the economic impact is less severe in basic SIR model. the red dashed lines in below represents the equilibrium population dynamics implied by the SIR-formal model. The share of the initial population that is infected peaks at 8.04%. Subsequently, this share falls because there are less susceptible individuals to infect. Theoretically, 64% of the population ultimately becomes infected; meaning roughly 27.52 million Algerian eventually become infected. A mortality rate of 0.25% implies that the virus kills roughly 6880 individuals in Algeria. Turning to aggregate consumption the plot shows a recession of 1.68%. In the post-pandemic steady state, real GDP and population are both 0.2% lower than in the initial steady state. Depending on these changes, the average aggregate consumption in the first year of the pandemic falls by 0.64%. similarly, hours worked decline by 0.2% in the post-pandemic steady state.

Figure 1:SIR-formal against basic SIR model



Source: Authors own construction

4.2. SIR-formal model

Unlick the basic SIR model the modified SIR-formal model catches the impact of individual's economic decision on the dynamics of the pandemic. From the blue contusions curve in figure 1 it's clear that individuals reduce the likelihood of getting infected by lowering their consumption and hours worked 3.8%. The share of the initial population that is infected peaks at 6.89% which is less than the predicted peak by basic SIR model. Theoretically, 61% of the population ultimately becomes infected, meaning roughly 26.23 million Algerian eventually become infected. A mortality rate of 0.25% implies that the virus kills roughly 6480 individuals in Algeria. Average aggregate consumption in the first year of the pandemic falls by 1.54%, hours worked decline smoothly falling by 3.85%.

4.3- SIR-all

When the SIR model takes in consideration the size of the informal economy. The share of the initial population that is infected peaks at 6.71%. Subsequently, this share falls because there are less susceptible individuals to infect. Theoretically, 60% of the population ultimately becomes infected, meaning roughly 25.8 million Algerian eventually become infected. A mortality rate of 0.25% implies that the virus kills roughly 6350 individuals in Algeria. Turning to aggregate consumption the plot shows a recession of 2.15%. hours worked decline smoothly falling by 10.5% in the post-pandemic steady state.

4.4- Robustness Check

The table below represents robustness check where a variation of key parameters in SIR-all model is used. First, the mortality rate is changed to 0.5% and 0.7%. This variation raises the severity of the recession as individuals reduce their consumption and work to decrease the chances of being infected. Despite the concomitant fall in peak infection rates, the cumulative death rate, and the number of deaths rise. Second, the Long-run probability to either recovers from the COVID-19 or dies is changed to 54% and 74%. The results suggest that the higher long-run infection rate, the larger is the decrease in consumption. Third, the control parameter for productivity of infected workers is changed to 70% and 90%. Summarily, the lower is ϑ^iThe larger is the average consumption decline, the peak infection rate.

Table 3: robustness check

Values %	Consumption%	Peak infection%	Death%
		Mortality rate β_d	
2.5	-2.15	6.61	0.15
5	-3.6	6.25	0.28
7	-4	6	0.39
	Long-run probability to either recovers from the COVID-19 or dies		
54	-1.29	4.13	0.12
64	-2.15	6.61	0.15
74	-2.5	10.26	0.17
		productivity of infected workers ϑ^i	
70	-2.29	6.18	0.14

80	-2.15	6.61	0.15
90	-1.96	7.07	0.15

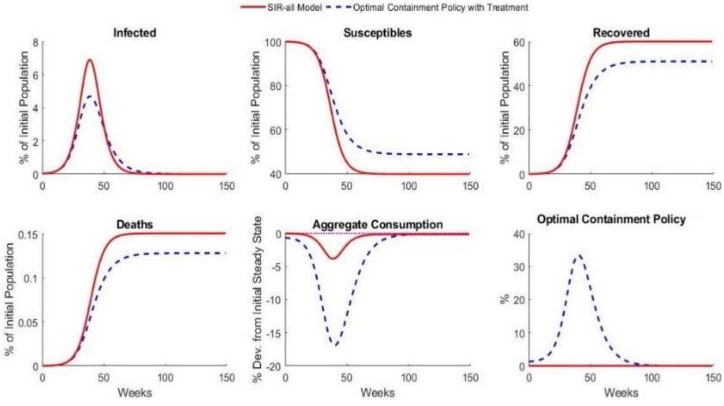
Source: Authors own construction

4.5- Optimal containment policy

Similarly, as with every Ramsey problem, it's important to stand on the policy tools available. There are many ways in which governments can decrease social interactions. Examples of containment measures such as closing down of stores and cafes … etc. to maximize social welfare a sequence of 150 containment rate was computed. The iteration was carried until the optimum solution was found.

As shown in the figure 2 the optimal containment rate increases from 1.5% at the start of the period to reach maximum of 33% in week 37. This increase reduces the infection rates to reach a maximum of 4.7% after it was 6.85% and reduces the mortality rate of 0.13%; this containment roughly saves the life of 8300 persons. However, a much severe recession is associated with containment policy. As shown aggregate consumption falls 16.5%, and in the first year it falls to 7.87%

Figure 2: SIR-all with optimal containment policy



Source: Authors own construction

5- DISCUSSION

To show that economic discussions to reduce consumption and work has many impacts on the dynamics of COVID-19 pandemics in

Algeria. This paper provides a comparison between basic SIR model and modified model named SIR-formal; This decision shrinks the severity of the pandemic in terms of infected individuals and death numbers. This is a direct result of susceptible individuals lowering the likelihood of getting infected; These same decisions sever the size of recession caused by the pandemic measured by the fall in aggregate consumption and aggregate hours worked. This decrease reflects two major factors:

- the COVID-19 virus causes infected individuals to be less productive at work. The associated negative income effect pulls down the consumption of infected people;
- the death toll caused by the pandemic permanently reduces the size of the workforce.

And this can be seen in figure 1 where the infection is less severe in the SIR-formal model than in the basic SIR model. These results are in line with the finding of (Buera, Fattal-Jaef, & Hopenhayn, 2020) and (Hall, Jones, & Klenow, 2020)

Furthermore, to demonstrate the interaction of informal economy and COVID-19 pandemic. SIR-all model is constructed. It combines economic decision and actions made by individuals in both formal and informal economy. In comparison between SIR-formal and SIR-all empirical results showed less infection peak in SIR-all. This can be explained by the individuals to cut back their interaction in informal economy to reduce the probability of getting infected. However, the degree of recession in the SIR-all is more severe.

This results highlights the importance of counting for the size of informal economy when analyzing the interaction of COVID-19 pandemic and economy. This raises the importance of paying intention to the size of informal economy. Especially workers in the informal economy are more vulnerable to this shock because they don't have an alternative source of income this point was highlighted (ILO, 2020b).

The previous results are validated by choosing different parameters values validate this result, a higher mortality rates push individuals to lower their consumption and working hours. More cut back by individuals more severe economic rescission. The same outcomes are associated with productivity rates and long-run mortality rates.

The intensity of containment is strongly correlated with the behavior of infected individuals (Correia, Luck, & Verner, 2020) Hence, the rise of the infected individuals stimulate government to tighten up the rules of containment. However, the intensify containment measures make consumption much costly, so individuals lower their consumption and work. Causing severe recession (Eichenbaum, Rebelo, & Trabandt, 2020).

To reduce the impact of COVID-19 the Algerian government applied many actions starting by closing schools and universities (12/03/2020), releasing half of the government workers (17/03/2020) not much later the government declared total confinement. This Procedure was followed by social transfers to workers, unemployed and retired people. However, this financial support was only given to the registered workers in the official statistics excluding the workers in the informal economy that suffered the same or more damage from the containment measures.

On 14\06\2020 the Algerian government toke the decision to begin reducing the containment policy. However, based on the optimal containment policy results it is too early for such a decision because in this period the optimal containment policy was not optimal and still increasing. As result of this decision the number of infected individuals started to increase again reaching 441 new cases on 05\07\2020 after knowing a significant lessening from 26\05\2020 to 14\06\2020. Another important factor for this significant rise in cases is non-compliance to the confinement rules by individuals and continuing practicing their activities informally decreasing the efficiency of confinement policy adopted by the Algerian government.

The current study has some empirical limitations due to the uncertainty covering the COVID-19 pandemic, and the adopted empirical methodology.

The main limitation of the empirical result is the infection percentages adopted in the study. Due to cultural and geographical differences between countries these percentages can change leading to a certain uncertainty in the results. In addition to the incapability to distinguish between the individuals that were infected in the formal from those who were infected in the informal economy.

The study did not consider the scenario where the vaccine of COVID-19 is discovered. This can change the progress of the pandemic in all over the world.

Due to the limitations of the SIR models the current analysis does not enable us to determine the impact of the negative oil choc on the Algerian economy. especially that our economy is sensitive to such chocks.

CONCLUSION

The main objective of the article is to study the interaction between COVID-19 pandemic and the informal economy and its impact on the Algerian economy using SIR epidemiologic model. The article expands SIR model to count for economic decision made by individuals and the availability of treatment. Unlike the previous literature, this article takes in consideration the size of informal economy.

The results show that counting for the size of informal economy is critical when analyzing the impact of COVID-19 pandemic in the Algerian economy. the optimal containment policy increases the severity of the recession from 1.83% to 7.87% in the first year of the pandemic. However, it saves 8300 lives in Algeria. It's also showing that

- the COVID-19 virus causes infected individuals to be less productive at work. The associated negative income effect pulls down the consumption of infected people;
- the death toll caused by the pandemic permanently reduces the size of the workforce.

Based on the best containment policy, the study suggests that starting reducing containment policy on 14\06\2020 is too early because in this period the optimal containment policy was not optimal, and as result of this decision the number of infected individuals started to increase again. If the increase in cases keep increasing it is inevitable for the Algerian government to return to total containment.

Further research will be needed especially with the limitation of the study. It is proposed to further develop the study model to count for the negative oil price shock on the Algerian economy, and allowing for the viability of a vaccine.

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