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Assessing the Health and Economic Impact of the COVID-19 Pandemic in Palestine

Mohammad Abu-Zaineh[1]
Sameera Awawda[2]

[1] Ph.D, Associate Professor of Economics, Aix-Marseille School of Economics and Faculty of Medical and Paramedical Sciences, Aix-Marseille University, France. E-mail: mohammad.abuzaineh@univ-amu.fr
[2] Ph.D, Assistant Professor of Economics, Economics Department and the Institute of Community and Public Health, Birzeit University, Palestine. E-mail: sawawda@birzeit.edu

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List of abbreviations

CAR	Clinical attack rate
CFR	Case fatality rate
CGE	Computable general equilibrium
CRR	Case recovery rate
DSGE	Dynamic stochastic general equilibrium
LFS	Labor Force Survey
MoH	Ministry of Health
PECS	Palestinian expenditure and consumption survey
PNA	Palestinian National Authority
TCR	Testing capacity rate

Executive Summary

This research seeks to assess the epidemiological and economic impacts of the COVID-19 pandemic in the context of developing countries using the particular case of the Occupied Palestinian Territories (the West Bank, excluding East Jerusalem and Gaza Strip). Unlike previous studies, the modeling strategy uses a dynamic stochastic general equilibrium model (DSGE) that accounts for heterogeneity across different population groups. The DSGE model allows us to introduce an epidemiological shock through a health production function, and to assess *ex ante* the impact of a pandemic under different scenarios. The study calibrates the model and matches it with the available macroeconomic and COVID-19 related data (reported during March-August 2020). The study presents and compares findings about the consequences of the COVID-19 pandemic using a set of purpose-built scenarios that include: (1) a generalized epidemiological shock; (2) a COVID-19 specific shock; (3) a health sector policy response; and (4) a prevention policy response through (i) the implementation of a lockdown and (ii) the administration of a vaccine. We capture and compare the effects of each of these scenarios on a set of micro-level variables, namely individuals' labor supply and their health capital and health expenditures; and a set of macro-level variables, namely the level of government health and non-health expenditures and GDP.

Several interesting implications emerge from the empirical investigation. First, the impact of the COVID-19 pandemic mimics the impact of a *generalized epidemiological shock* (assuming equal risk of exposure for all). However, awareness of the differential impacts across different socio-demographic groups in the population, and particularly the double burden experienced by high-risk and vulnerable groups in the population should be of prime concern. Secondly, results clearly indicate that a policy response to the COVID-19 pandemic that relies on expanding government expenditure on the health sector would help mitigate the adverse impact of the pandemic on the health of the population. Admittedly, such policy may be inadequate to help rescue the economy. This suggests that a comprehensive – rather than an *ad hoc sectoral policy response* – is in order. However, under conditions of a highly constrained budget, a major policy issue is related to the government's available fiscal space. Thirdly, results clearly indicate that a *public health policy response* that specifically targets the health sector may be preferred over the *lockdown policy* which can be associated with disastrous consequences on the economy. This calls for alternative affordable measures that can *target the trees rather than the forest*. Such a policy requires striking the right balance between safeguarding lives (*protecting health*) and livelihoods (*minimizing economic losses*). Lastly, the results confirm that provision of a vaccine will put an end to the ongoing debate about whether policies should be set to either save lives or save economies. The provision of a vaccine appears to have an immediate positive impact at both the micro- and macro-levels.

1- Introduction

1-1 Research Context and Problem

Although other pandemics have been reported in modern human history, such as the 1957-1958 H2N2 virus, the 2009 H1N1 virus, and the 2005-2012 HIV, the COVID-19 pandemic is the most momentous and destructive epidemiological crisis in modern times (Ferguson et al. 2020; Bénassy-Quéré et al. 2020; Gopinath 2020; Furman 2020). Since the first cluster of cases was reported in Wuhan-China in Dec 2019, the COVID-19 pandemic has ravaged humans throughout the world with significant numbers of confirmed cases (circa 71.9 million) and deceased (circa 1.64 million) as of December 16th 2020) (WHO 2020). With the spread of this pandemic across the globe, many experts and international organizations expressed serious concerns with regard to the massive disastrous (health and economic) consequences of such an unprecedented epidemiological crisis (Ayadi et al. 2020; UN 2020; World Bank 2020). Developing countries are expected to be affected disproportionately as compared to the Global North. This is due to a host of reasons, including the vulnerability of the developing countries' economies coupled with the rather limited capacity of their health care systems to cope with infectious diseases (Abu-Zaineh and Awawda 2020; Gilbert et al. 2020; World Bank 2020; World Economic Forum 2020).

The pandemic the world is facing today had already been forecasted by epidemiologists and was known to be imminent in the wake of other epidemics such as the SARS of 2003, the avian flu of 2005, and the swine flu of 2009 (Arino and Watmough 2019; Lutz et al. 2019). However, until now, little theoretical and empirical research work has been done to assess the direct and indirect economic and epidemiological impact of epidemics that may develop into a global health threat (e.g., Vasilakis 2012; Karlsson et al. 2012; Boucekkine et al. 2009). In the few studies that endeavor to assess the economic implications of infectious diseases, the inclusion of an exogenous epidemiological shock has been captured using alternative approaches in the available literature. In some models, the shock is captured by a decrease in the labor supply based on the assumption that the spread of the pandemic has a direct negative impact on the number of working days. Smith and Keogh-Brown, (2013); Smith et al. (2009). Drouhin et al. (2003) applied an endogenous growth model to assess the impact of AIDS in Africa, where the epidemiological shock of AIDS is captured by the human capital which is included as an input in the production function of the firms. Other models consider a direct impact by the epidemiological shock on life expectancy, as captured by the survival rate (Augier and Yaly 2011; Boucekkine et al. 2009). Momota et al (2005) assumed further that the epidemiological shock is captured by an index, which accounts for the prevalence of the disease, affecting the survival probability of individuals. Kelly (2017) introduced an epidemiological shock through the health production function, whereby health capital is subject to an endogenous health depreciation that is affected by, among other factors, the prevalence of infectious diseases. The few studies that have attempted to assess the macroeconomic implications of the latest COVID-19 pandemic have mainly relied on a computable general equilibrium (CGE) analysis (e.g., Aydın and Ari 2020; Keogh-Brown et al (2020); Maliszewska, et al. (2020); MAS (2020 a).

Some key observations that emerge from our review of previous studies are worth highlighting. First, all of the above models have assumed either a single representative household (individual) or a set of homogeneous households. Such an assumption ignores the possible heterogeneity that exists across individuals (groups) in terms of their preferences and health capital endowments; and hence, their possibly varying responses to policy interventions and external shocks. However, previous empirical evidence has already shown that the design of efficient and equitable policy interventions requires taking into account asymmetries between heterogeneous segments of the population (Abu-Zaineh, Awawda and Ventelou 2020; Rampini 2020). Second, the potential economic and health impact of pandemics has rarely been assessed within the broader context of a dynamic stochastic general equilibrium (DSGE) model (e.g., Smith and Keogh-Brown, 2013; Boucekkine et al. 2009; Smith et al. 2009). The DSGE model allows us to introduce an epidemiological shock through a health production function, and to assess *ex ante* the impact of a pandemic on different potential health-policy scenarios. Furthermore, unlike *ex post* methodological approaches, the general equilibrium models allow us to evaluate a proposed policy scenario prior to its implementation while accounting for possible feedback among the main economic outcomes. The inclusion of heterogeneous agents within such models allows the endogenous variables, and hence the overall economic impact, to be functions of parameters that capture heterogeneity of, *inter alia*, health capital depreciation and accumulation across individuals. These two parameters appear to be important factors explaining the differences in the epidemiological statistics across healthy and unhealthy individuals, as well as the young and elderly. Therefore, the model allows us to account for heterogeneous responses that individuals may have following an external epidemiological shock such as the COVID-19 pandemic. Third, the DSGE model also allows to incorporate the dynamics of health capital accumulation using a *Grossman-type health production function*, which assumes that health capital accumulation is a function of health investment and labor. The fact that labor supply is an argument in the health capital function allows for changes in labor supply to be attributed not only to the general equilibrium adjustments, but also to the impact of epidemiological shock.

In this study, we therefore adopt the DSGE model to assess the economic and epidemiological impacts of the COVID-19 pandemic in the specific context of the Occupied Palestinian Territories.

1-2 Research Objectives

This research aims to investigate the economic and epidemiological impacts of the COVID-19 pandemic in developing countries using a DSGE model. The DSGE model is calibrated and contextualized using data from the particular context of the Occupied Palestinian Territories. In contrast to previous studies, we account for heterogeneity across the population by dividing the sample population into eight representative groups based on demographic and health status characteristics. We assume that the epidemiological shock directly affects the accumulation of health capital of the representative individuals. We further assume that the epidemiological shock is a function of pandemic indicators like the infection rate, the recovery rate, the mortality rate, and the testing rate.

The DSGE model shall allow for an exploration of the impact of investment in related health-policies on the health of the overall population, as well as on the economy. More specifically, the goal is to examine the health and economic implications of a set of epidemiological and policy scenarios that include:

1) The spread of a pandemic with different infection and remission rates across heterogeneous groups of the population;
2) A public health policy response through increasing in public health investment;
3) A partial lockdown that mimics the preventive measures implemented in April 2020; and
4) Universal and partial access to a potential prevention (a vaccine).

The model benefits from the latest available macroeconomic data, in addition to the available datasets provided to MAS Institute by the Palestinian Ministry of Health on the spread of COVID-19 (confirmed cases, deaths, and recovered cases). The model parameters related to the epidemiological shock can be easily adapted to reflect the spread of any other potential pandemic in other developing country's contexts.

Results emerging from this study shall provide an estimate of the epidemiological and economic impacts of the COVID-19 pandemic. This can help policy-makers to design the most cost-effective policies to cope with the current and potential future impact of the pandemic and mitigate its adverse effects on both the health of the population and the economy. The proposed framework can be easily adapted and contextualized to other developing-country settings, further validating the methodological approach and scenario analysis employed here.

The remainder of the study is organized as follows. Chapter 2 lays out the method and data used in the analysis. Chapter 3 presents the main results of the simulation scenarios at both the micro- and macro-levels. Chapter 4 discusses the main findings and concludes with some policy recommendations.

2- Methods and Material

2-1 Methods

In this section, we briefly lay out the main elements and mechanics of the DSGE modeling strategy.[1] The technical details and derivations are relegated to the Appendix. The DSGE model combines the elements typical of this model, consisting of a set of representative individual groups, a representative private firm, a government, and a foreign sector. At each period $t = 1,2,\ldots,T$, the population is assumed to grow at a constant rate[2]. Each representative individual maximizes an intertemporal utility function subject to a standard budget constraint, in addition to a Grossman-type health production function (Halliday et al. 2019). The intertemporal utility is assumed to be a function of three arguments: individuals' consumption expenditure, their health capital, and leisure. Representative individuals are assumed to have different preferences towards health capital and leisure, relative to consumption expenditure in the utility function. We assume that each individual is initially endowed with a specific level of health capital. The latter is assumed to be maintained and improved through investment in health as well as leisure, and to depreciate over time (Hartwig and Sturm 2019). The Grossman-type health production function is defined as follows

$$h_{it+1} = \left(1 - \delta_i^h\right)h_{it} + E(\varepsilon_{it})m_{it}^{\chi_i}\left(\underline{l} - l_{it}\right)^{1-\chi_i} \tag{1}$$

where h_i is the health capital for group, i, δ_i^h is the health depreciation rate, m_i is the health investment, l_i is the labor supply, $\underline{l}$ is the maximum amount of labor an individual can supply, and χ_i is the elasticity of health investment in the production of health capital. Health capital is adversely affected by an epidemiological shock, $E(\varepsilon_i)$, such as the spread of a certain pandemic (COVID-19 in our case) and its associated rate of fatalities and remissions. Based on the available data, we assume that there are eight types of representative individuals, $i = 1,\ldots,8$, that differ in their demographic (age/gender) and health status characteristics.

The representative firm is assumed to maximize its profits subject to a Cobb-Douglas production function of labor and capital. The government budget is divided into a non-health account and a health account, which encompasses all revenues and expenditures of the health sector separately from other sectors. For the sake of completeness, we add the foreign sector, which is represented in the model through the trade balance equation. Detailed derivations of the model equations, as well as on the model calibration, are available upon request.

2-2 Data and Computations

The model benefits from the recently available national macro- and micro- level data. The latest available macro data are obtained from the Palestinian Central Bureau of Statistics (PSBS). These data provide information on aggregate annual economic outcomes such as GDP, government expenditure, government revenues, government debt, public and private health expenditure, imports and exports, etc. Per capita monthly values are calculated in order to achieve consistency with the model specification as well as the available micro-level and epidemiological data. The main source of the micro-level data is the Palestinian Expenditure

[1] Refer to the Appendix for full technical details of the DSGE model.

[2] Note that finite time horizons are commonly used in the empirical literature. In general, infinite-horizon continuous-time optimization problems are estimated using finite-horizon discrete-time optimization.

and Consumption Survey (PSBS-PECS 2017). The PECS provides detailed information on household total expenditure, health expenditure, health conditions, age, and income.

For the purpose of the analysis, the sample population is divided into eight representative groups according to their gender, age and health status. As for age groups, individuals are divided into two main groups: the young (those below the age of 60) and elderly (those above the age of 60). Regarding health status, individuals are classified into two groups: healthy and unhealthy, based on health conditions reported in PECS-2017 such as the presence of some illnesses and chronic conditions. Health capital for each individual is calculated using a logistic regression model in which the dependent variable is a binary measure of health status. The latter is estimated using six questions measuring the health conditions of each individual including chronic diseases and the presence of difficulties in seeing, hearing, movement, focus, and communication. The health status variable either registers as zero, if the individual suffers from any health problem (bad health), or one (good health). The FOCs of the optimization problem (see Equations A.7 and A.8 in the Appendix), in addition to the health constraint, are used to calibrate individuals' preference parameters based on the micro-level data from the PECS-2017 on consumption expenditure (c); health expenditure (m); health capital (h); and labor supply (l). As for labor supply, we use data on the wage rates reported in the PCBS Labor Force Survey (PCBS-LFS-2017) to calculate individual's labor supply (l) in terms of hours per month for each gender-economic activity group in the PECS-2017.

Epidemiological data related to the spread of the COVID-19 between March 2020 and August 2020 are directly obtained from the records of the Palestinian Ministry of Health (MoH). The data provides detailed information on confirmed COVID-19 cases, including the gender and age of each case, the date of infection, the date of recovery, and the date of death (if any). The data also provides information on the total daily number of COVID-19 tests. Such data enables us to estimate and incorporate the epidemiological shock into our model. The next sub-section displays the estimation of the epidemiological shock.

2-3 Epidemiological shock

The epidemiological shock is built upon four relevant COVID-19 *indicators* which have been calculated for the purpose of this study, based on epidemiological data obtained from the MoH. The indicators include:

1. The clinical attack rate (CAR) – defined as the share of confirmed COVID-19 cases of the total population;
2. The case recovery/remission rate (CRR) – defined as the share of recovered cases of total confirmed cases;
3. The case fatality rate (CFR) – defined as the share of COVID-19 deaths of total confirmed cases; and
4. The testing capacity rate (TCR) – defined as the ratio of total tests to the total size of the population.

These indicators are calculated on a monthly basis for four age-gender groups (young females, young males, elderly females, and elderly males). Given the lack of detailed information on the testing capacity rate, we assume that this rate is equal across the different socio-demographic groups.

Following Momota et al. (2005), we assume that the epidemiological shock can be captured by a composite index of the incidence of COVID-19 – as measured by the clinical attack rate (CAR). In addition, we assume that this index is a function of other indicators, mainly the CRR, CFR, and TCR. Accordingly, the epidemiological shock for each individual, $E(\varepsilon_i)$, is calculated as follows

$$E(\varepsilon_i) = f(CAR_i, CRR_i, CFR_i, TCR_i) \tag{2}$$

where $E(\varepsilon_i)$ is calculated for the four age-gender groups mentioned above. The data obtained from the Palestinian MoH does not provide information on the health status of individuals. We therefore rely on the observation that the impact of the epidemiological shock on the healthy individuals may be smaller than its impact on the unhealthy by an amount $\Delta > 0$. We express the function f in Eq. 2 as follows

$$\begin{aligned} f(CAR_i, CRR_i, CFR_i, TCR_i) &= \frac{b}{\varepsilon_i} \\ &= \frac{b}{(CAR_i)^{\theta_1} + (CRR_i)^{\theta_2} + (CFR_i)^{\theta_3} + (TCR_i)^{\theta_4}} \end{aligned} \tag{3}$$

where b is a constant, and $\theta_1, \theta_2, \theta_3$ and θ_4 are the weights of, respectively, the epidemiological indicators CAR, CRR, CFR, and TCR, such that $\sum_{i=1}^{4} \theta_i = 1$.

It is worth noting that the literature lacks empirical evidence on the specification of the functional formula that can capture the epidemiological shock, hence the parameters under consideration. Nonetheless, our choice of the weights θ_i is not arbitrary. We first simulate for different values of parameters until we get values of the epidemiological shock that reflects the differences in the COVID-19 pandemic statistics between the different age and health groups. A higher spread of the pandemic (i.e., higher incidence rate and death rate) implies a higher epidemiological shock. Results show that indicators with higher variation amongst groups, such as CAR, shall be assigned a higher weight while indicators with higher homogeneity across groups, such as TCR, shall be given a lower weight. In the current work, the following values were retained for the different weights: $\theta_1 = 0.7$, $\theta_2 = 0.08$, $\theta_3 = 0.2$ and $\theta_4 = 0.02$. In order to construct the epidemiological shock, we introduce a shock to the values of the vector $E = (E_1, \dots, E_8)$. The model parameters related to the epidemiological shock can be easily adapted to reflect the spread of any other potential epidemic.

3- Main Results

3-1 A First Look at the COVID-19 Pandemic in Palestine

We first trace the spread of COVID-19 pandemics in the Occupied Palestinian Territories since its outbreak in March 2020 (Figures 1 and 2). As shown in Figure 1, although the first cases of COVID-19 were reported on March 5th 2020 in the West Bank, the total number of confirmed COVID-19 cases only started to increase rapidly between June and August 2020. As of August 31st 2020, the West Bank had a total of 22,333 confirmed COVID-19 cases. Figure 2 presents the cumulative clinical attack rate of COVID-19 in the West Bank across gender-age groups. Reported figures clearly show that, as elsewhere, the incidence of COVID-19 is higher among the elderly (with no significant differences between male and female) as compared to younger populations.

Figure 1: The evolution of total confirmed COVID-19 cases in Palestine from March to August 2020

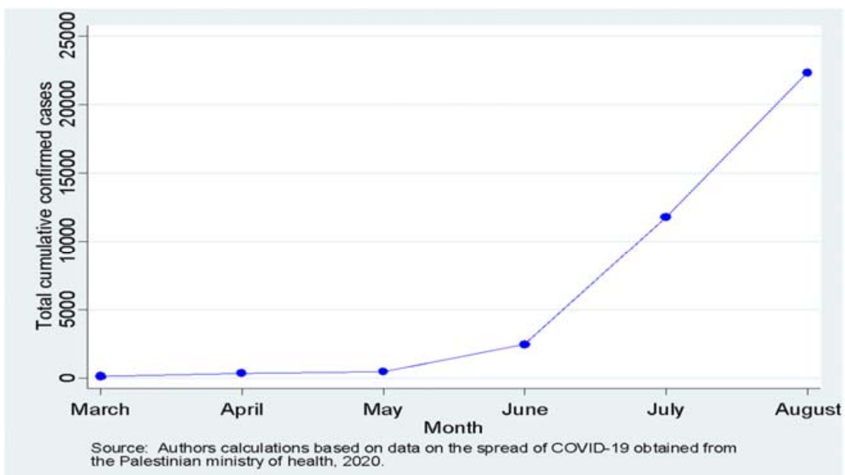

Table 1 summarizes the four indicators for the four representative groups on a monthly basis. As shown, both the CAR and the CFR indicators appear to be higher for the elderly section of the population. Furthermore, the CRR is higher for younger populations. Also of note is that the TCR appears to increase overtime.

In response to the threat of the COVID-19 pandemic, an emergency plan with a set of preventive measures (including preventive lockdowns) was implemented (mainly in Area A of the West Bank) on March 6th 2020 and lasted three months (until June 12th 2020)[3]. Reported figures by the PCBS (2020) show that most economic activity was negatively affected during this period. The decrease in GDP was estimated at about 4.9% and 3.4% (at constant prices) in the first quarter as compared with the fourth quarter of 2019 and the first quarter of 2020, respectively (PCBS 2020). The macroeconomic impact of the pandemic has been assessed under different policy scenarios (e.g., the projections of the Palestinian Central Bureau of Statistics (PCBS) and Palestine Economic Policy Research Institute (MAS) as well as the

[3] It is worth noting that the preventive lockdowns (between March 6th and June 12th 2020) have been mainly implemented in Area A, which represents about 18% of the West Bank and where the Palestinian National Authority (PNA) has full civil and security control. The lockdowns were, however, less restrictive in other Palestinian areas (Areas B and C).

projections of the Palestinian Monetary Authority (PMA) and the World Bank). For example, the World Bank has estimated that GDP will decrease by 8%, while the PCBS-MAS projections estimated a decrease of GDP by about 13.5-20.3% (MAS 2020c, 2020d). In the next section, we assess the economic and health impact of the COVID-19 pandemic under alternative scenarios within a DSGE model.

Table 1: Indicators of the COVID-19 pandemic across age and gender groups

Clinical attack rate (CAR)					
Month	**Young-females**	**Young-males**	**Old-females**	**Old-males**	**West Bank**
March	0.000033	0.000049	0.000050	0.000064	0.000026
April	0.000080	0.000140	0.000078	0.000136	0.000042
May	0.000104	0.000184	0.000120	0.000136	0.000020
June	0.000755	0.000747	0.000968	0.001007	0.000385
July	0.003901	0.003277	0.005342	0.005451	0.001821
August	0.007281	0.005871	0.012768	0.012868	0.002061
Case recovery rate (CRR)*					
March	1.000	1.000	0.857	1.000	0.992
April	0.991	0.995	0.818	1.000	0.988
May	0.993	0.996	0.824	1.000	0.989
June	0.578	0.656	0.569	0.627	0.615
July	0.608	0.604	0.577	0.553	0.601
August	0.413	0.441	0.310	0.320	0.409
Case fatality rate (CFR)					
March	0.000	0.000	0.143	0.000	0.008
April	0.009	0.005	0.182	0.000	0.012
May	0.007	0.004	0.176	0.000	0.011
June	0.003	0.005	0.051	0.024	0.007
July	0.003	0.004	0.033	0.060	0.008
August	0.002	0.003	0.023	0.050	0.008
Testing capacity rate (TCR)					
March	0.0010				
April	0.0037				
May	0.0113				
June	0.0197				
July	0.0386				
August	0.0552				

Source: Authors' calculations based on data on the spread of COVID-19 obtained from the Palestinian Ministry of Health, 2020.

* The CRR is close to one for some groups in the first three months, as most confirmed cases have recovered. Accordingly, these months will not be used to model the epidemiological shocks.

3-2 Simulation Scenarios

We assess the economic and health consequences of the COVID-19 pandemic using a set of epidemiological and policy scenarios. At the steady state, we assume that there is no epidemiological shock; that is, the effect of all pandemic-related indicators in Eq. 2 is normalized to 1 for all individuals; hence, $\varepsilon_i = (1, \ldots, 1)$. A generalized epidemiological shock is first introduced under scenario S1 where the index of epidemiological shock ε_i in Eq. 2 is assumed to be the same for all individuals. All individuals are therefore assumed to be at the same level of risk of contracting the virus regardless of their socio-demographic and health status characteristics. The epidemiological shock in this first scenario can be considered to be a shock resulting from any pandemic and one that can affect the whole population equally. This is not a strong assumption, as the analysis of infection data has already shown that young adults are as likely to be infected by COVID-19 as the elderly (Kang and Jung 2020). However, the rate of recovery appears to be significantly higher amongst the former group as compared to the latter group of the population (Kang and Jung 2020; Snape and Viner 2020) – a fact that is taken into consideration under scenarios S3-S4. Under the second scenario, S2, we continue to assume the persistence of an epidemiological shock that threatens the health of the whole population equally, but in which a policy response to such threats is introduced. This is represented by an increase in public investments in the health sector as an immediate response that governments may undertake following the outbreak of the pandemic, to enhance the protective, preventive, and detective capacities of their health systems. It is worth nothing that private and public investments are both response variables in our model. Hence, this policy scenario is proxied by changing the share of out-of-pocket health expenditure – a health subsidy policy.

The third and fourth scenarios are similar to S1 and S2, except that we now relax the assumption of equal likelihood of infection of the whole population by computing the index of the epidemiological shock $E(\varepsilon_i)$ in Eq. 2 for each individual using the actual COVID-19 data reported for August 2020. These two scenarios are thus labeled S3: *no intervention against COVID-19 (herd immunity for COVID-19)* and S4: *policy response to COVID-19*. This latter scenario implies an increase in public spending on health to enhance the capacity of the health system so that it can cope with the spread of the pandemic.

In the fifth scenario (S5: *universal access to prevention for COVID-19*), we assume that an effective vaccine for COVID-19 is made available to all individuals at zero cost. Depending on its efficacy, the development of such a vaccine is expected to result in a significant reduction in infections (CAR) and, consequently, in deaths (CFR). In our model, the potential implications of S5 are thus captured by a reduction in the overall epidemiological shock of 20%. This scenario may, of course, appear to be optimistic - particularly in the short-run. Therefore, in a sixth scenario (*S6: partial prevention for COVID-19*), we assume that the distribution of the vaccine prioritizes vulnerable population groups (the elderly and the unhealthy). This is captured by a reduction in the epidemiological shock of these groups by 20%. The policy response to COVID-19 may also take the form of a lockdown. In the last scenario (*S7*), we assume that the governments opt for a partial lockdown along the lines of the one implemented in April 2020; hence *S7* is labeled a *lockdown scenario*.

We are interested in assessing the effects of each of the above scenarios (*S1-S7*) on a set of micro-level variables, *viz*., individuals' labor supply, health capital, and health expenditures, and a set of macro-level variables, *viz*., government health and non-health expenditures and the impact on the GDP. Results at the micro-level for each individual group, as well as at the aggregate level, are displayed in Table 2 and Table 3.

Under the first (*default*) scenario S1, in which *no intervention* is implemented in the face of a certain epidemiological shock that can equally threaten everyone's health, results show that the decrease in health capital would be higher amongst the *risk groups* (with a decrease in the health capital of females, the elderly, and the unhealthy by 14.17%, 9.76%, and 11.46%, respectively). These results can be explained by differences in the health capital function parameters. The calibration of the model parameters shows that the health depreciation rate is higher for females, the elderly, and the unhealthy, while the health preference parameter (weight in the utility function) is lower for these groups (refer to the appendix for more details on these parameters). Thus, responses by these high-risk groups to a negative health shock will be higher as compared to males, the young, and the healthy. Such decreases in health capital, driven by the epidemiological shock, lead to an increase in individuals' out-of-pocket health expenditures – and appear to almost double for the elderly section of the population. The generalized epidemiological shock can trigger a contraction in the labor supply (with a decrease of about 13.91 to 19.23% for all individuals). At the macro-level, such an epidemiological shock would result in a decrease in total government non-health expenditure of about 34% and an increase in government health expenditure of about 36%. The net effect of this scenario on GDP is negative, leading to a decrease of about 3.40%.

Results pertaining to S2 show that a policy response represented by an increase in public health spending to cope with the implications of the epidemiological shock would indeed mitigate the negative effects of this epidemiological shock on the health capital of all individuals, with the decrease in health capital being always significantly lower under S2 as compared to that observed under S1 (e.g., under S2 the decrease for the unhealthy amounts to 8.55%, as compared to -11.46 % in S1). Consequently, the impact on individuals' out-of-pocket expenditures and labor supply appear to be lower under S2 as compared to S1, due to the lower decrease in health capital in S2. The macroeconomic impact of this scenario is as expected: the assumed increase in public health spending would reduce government resources available for other sectors (with an additional decrease in government (non-health) expenditures of 8.3%, as compared to S1). The net effect on the GDP of this scenario, however, remains similar to that observed under S1 (a decrease of about 3.65%).

Here we turn to S3 and S4, which mimic S1 and S2 but allow for different levels of risk as per the actual infection data on COVID-19. Overall, results pertaining to S3 clearly reveal that the adverse effects on individuals' health capital of the COVID-19 pandemic are indeed fairly similar to that induced by a generalized epidemiological shock. For instance, the loss in health capital among high-risk groups due to the COVID-19 pandemic is estimated to be in the range of 9.2-13.3% under S3, as compared to 9.8-14.2% under the generalized epidemiological shock scenario (S1). Interestingly, a noticeable difference is observed for the low-risk groups. Results reported in Table 2 clearly show that the health capital of healthy populations would decrease by only 2.7% under S3, as compared to a decrease of 7.12% under S1. This is not surprising given that healthy individuals are generally less likely to have severe cases of COVID-19, as compared to unhealthy individuals who are at a higher risk of developing severe illness from COVID-19 – and may consequently incur the double disease burden (i.e. simultaneous health and economic losses). This is due to the significant increases in their direct health expenditures (an increase in the range of 158.8-208.7%), coupled with a decrease in the labor supply of about 13.1-14.3%. With regard to the macroeconomic impact of COVID-19 pandemic, there are similar adverse effects of those observed under a generalized epidemiological shock scenario

(S1) emerge. The net loss in GDP amounts to 3.2% as compared to 3.4 % under S1, while the decrease in government (non-health) expenditure is estimated at 35.5% as compared to 34.2 % under S1. The government health expenditure would, in turn, increase by 33.2% as compared to 36.2% under S1.

A policy response to COVID-19 introduced under S4 appears to significantly mitigate the loss in health capital for the whole population. The decrease is particularly noticeable for high-risk groups. For instance, the decrease in health capital for the elderly is estimated at 6.9% under S4 as compared to 9.2% under S3, while it is estimated at 7.9% for the unhealthy as compared to 10.8% under S3. The macroeconomic impact of such a scenario would, of course, be characterized by a substantial increase in the total government expenditure on health (an increase of about 239.1%, as compared with only 33.2% under S3). This increase comes at the cost of reduced government expenditure on other (non-health) sectors, which fall by 40.1%. Overall, however, the net loss in GDP remains comparable to that observed under the non-intervention scenario (3.40% under S4 *vs*. 3.2% under S3).

Results from scenario S5 and S6, under which an effective prevention mechanism (a COVID-19 vaccine) is made available to the whole population and to high-risk groups, are also displayed in Table 2 and Table 3. As is shown, the provision of a vaccine against COVID-19 would have an immediate positive impact at both the micro- and macro-levels. At the micro level, there would be a significant improvement in the health capital of all individuals. Expectedly, the health gain would, on average, be significantly higher if all individuals were vaccinated for COVID-19 (S5). The average health gain appears to be three times higher under S5 (*the full coverage scenario*) as compared to S6 (*the partial coverage scenario*). As a result, *the full coverage* appears to reduce the potential burden of direct health expenditure on individuals by an average of 19%, as compared to an average decrease of 3.6% under the *partial coverage scenario*. In addition to these direct health gains, *the full coverage* scenario also appears to be associated with significant economic gains, with an average increase in individuals' labor supply of 5.4% as compared with an average increase of 1.5% under the partial coverage scenario (S6). Overall, these two scenarios would entail a net positive impact on GDP, which as compared to S3, appears to increase by about 1.3% under S5 and about 0.4% under S6. As regards government expenditure, a decrease of 0.96% and 0.35% is observed in government health expenditure, while an increase of 16.05% and 4.6% is observed in government non-health expenditure under both scenarios S5 and S6, respectively.

Under the *lockdown scenario* (S7), the epidemiological shock is captured in COVID-19 statistics from April 2020. Results from this scenario, which are displayed in Table 2, show that the negative impact on health capital would be lower under S7 (by 4.2%, on average) as compared to S3, a situation with no policy intervention (an average of 7.16%). Interestingly, but not surprisingly, the *lockdown* appears to mostly favor high-risk groups. The decrease in their health capital is estimated at 6.25% under S7 as compared with 8.3% under S3, while the health capital of low risk-groups is estimated at only 2.05% under S7 as compared with 2.8% under S3. Nonetheless, the *partial lockdown* scenario would reduce labor supply by an average of 7.86%, as compared by an average of 15.31% under S3. It is worth noting that the net impact on labor supply is a result of changes in health capital, health expenditure, as well as the overall economic impact of the partial lockdown. In addition, the overall decrease in the GDP would be about 1.3% lower under S7 as compared to S3 (1.9% *vs*. 3.2%), while the government non-health expenditure would decrease by 23.5% as compared to 35% under S3. Government health expenditure would increase by only 3.4%, as compared to 33.16% under S3.

Table 2: The epidemiological and economic impact of COVID-19 at the micro-level under different simulation scenarios in the West Bank*

Indicator	Group	Scenarios						
		S1	S2	S3	S4	S5	S6	S7
		Generalized epidemiological shock	Policy response	COVID-19 pandemic specific shock	Policy response to COVID-19	Universal prevention (vaccine)	Partial Prevention (vaccine)	Lockdown
Labor	Males	-17.133	-16.021	-16.084	-14.944	5.946	1.701	-8.621
	Females	-13.908	-13.414	-13.196	-12.682	4.831	1.357	-6.971
	Young	-19.227	-17.839	-18.040	-16.619	5.641	1.614	-8.178
	Elderly	-15.110	-14.375	-14.265	-13.506	5.340	1.514	-7.724
	Healthy	-17.752	-16.782	-16.759	-15.762	5.561	1.573	-8.038
	Unhealthy	-14.329	-13.627	-13.513	-12.789	5.269	1.497	-7.626
	Low-risk	-18.037	-16.881	-16.961	-15.775	5.716	1.629	-8.279
	High-risk	-14.449	-13.805	-13.658	-12.992	5.147	1.456	-7.440
	Overall	-16.243	-15.343	-15.309	-14.384	5.431	1.543	-7.860
Health capital	Males	-6.904	-5.854	-2.637	-2.239	1.584	0.446	-2.287
	Females	-14.173	-10.661	-13.293	-9.935	5.031	1.441	-7.296
	Young	-7.044	-6.091	-4.408	-3.823	1.364	0.389	-1.976
	Elderly	-9.761	-7.431	-9.174	-6.947	3.749	1.071	-5.433
	Healthy	-7.124	-5.759	-2.658	-2.430	1.296	0.375	-1.884
	Unhealthy	-11.462	-8.550	-10.779	-7.986	4.146	1.183	-6.007
	Low-risk	-7.024	-5.901	-3.234	-2.831	1.415	0.403	-2.049
	High-risk	-11.799	-8.881	-11.082	-8.289	4.309	1.232	-6.245
	Overall	-9.411	-7.391	-7.158	-5.560	2.862	0.817	-4.147
Health expenditure	Males	186.663	164.228	154.601	122.568	-17.333	-3.325	23.009
	Females	192.856	165.175	158.779	122.674	-22.618	-4.966	30.838
	Young	59.640	66.952	48.736	41.346	-8.486	-2.032	11.790

Indicator	Group	Scenarios						
		S1	S2	S3	S4	S5	S6	S7
		Generalized epidemiological shock	Policy response	COVID-19 pandemic specific shock	Policy response to COVID-19	Universal prevention (vaccine)	Partial Prevention (vaccine)	Lockdown
	Elderly	210.345	179.489	173.594	133.555	-22.659	-4.761	30.617
	Healthy	127.379	118.313	105.062	88.054	-13.897	-2.945	18.810
	Unhealthy	252.979	210.561	208.714	156.604	-27.611	-5.841	37.359
	Low-risk	124.561	116.498	102.800	83.990	-13.239	-2.767	17.870
	High-risk	218.727	185.075	180.362	137.611	-24.296	-5.189	32.938
	Overall	171.644	150.786	141.581	110.800	-18.767	-3.978	25.404

* The figures in S1 and S3 indicate the percentage change with respect to the steady state scenario, while the figures under S2 and S4-S7 indicate changes with respect to S1 and S3, respectively

Table 3: The macroeconomic impact of COVID-19 under different simulation scenarios in the West Bank

Indicator	Scenarios						
	S1	S2	S3	S4	S5	S6	S7
	Generalized epidemiological shock	Policy response	COVID-19 pandemic specific shock	Policy response to COVID-19	Universal prevention (vaccine)	Partial Prevention (vaccine)	Lockdown
Government (non-health) expenditure	-34.224	-42.511	-35.492	-40.071	16.051	4.635	-23.464
Government health expenditure	36.157	297.460	33.157	239.099	-0.962	-0.381	3.373
GDP	-3.402	-3.654	-3.186	-3.444	1.287	0.372	-1.883

4- Discussion

In this research, we construct a dynamic stochastic general equilibrium (DSGE) model that enables us to assess the epidemiological and economic impact of the current COVID-19 pandemic. We calibrate the model and match it to economic and infection data from the Occupied Palestinian Territories (the West Bank). We present and compare findings on the impacts of the COVID-19 pandemic in the West Bank using a set of purpose-built epidemiological and policy-related scenarios. These scenarios include: (1) a *generalized epidemiological shock;* (2) a COVID-19 specific pandemic shock; (3) a health sector policy response; and (4) a prevention policy response through (i) lockdown and (ii) vaccination. We capture and compare the effects of each of these scenarios on a set of micro-level variables, specifically individuals' labor supply and their health capital and health expenditures; as well as on a set of macro-level variables, namely the level of government health and non-health expenditures and the GDP. We begin with a discussion of the major findings and their main implications (sub-section 4-1). This is followed by a discussion and comparison of our findings with those reported in other similar studies (sub-section 4-2). The last sub-section (4-3) concludes with some policy recommendations.

4-1 Main Findings

Several interesting findings and key implications from the empirical investigation are worth making in light of the practical policy questions raised following the outbreak of the COVID-19 pandemic. First, the epidemiological impacts of the COVID-19 pandemic appear to be fairly comparable to the impact that would have been observed under a generalized epidemiological shock (S1). The latter assumes that all the population is faced with equal risk of exposure to a given pandemic. However, awareness of the differential impacts across different socio-demographic groups, and particularly the double burden impact experienced by high-risk and vulnerable groups should be of prime concern. Indeed, the results clearly reveal that even with the assumption of equal risk of contracting the virus (S1) and by relying on the actual infection data (S3), the losses in health capital emerge to be significantly higher amongst specific segments of the population, namely, the unhealthy, the elderly, and female adults. This suggests that even if the exposure to the pandemic is uniform, its potential consequences on individuals' health, and more generally on wellbeing, can be substantially uneven. The high-risk groups would suffer from an average decrease in health capital of about 11% and 11.8%, under S1 and S3, respectively, whereas the average decrease in health capital for the low-risk groups under S1 appears to be twofold of that observed under S3 (7.0% vs. 3.2%). Furthermore, in as much as the observed increases in household direct health expenditures reflect their actual need for, and use of, health care services driven by the pandemic, the significant increases in household health expenditures under the two situations of a *generalized* and the *COVID-19-specific pandemic* signal the increased exposure to catastrophic and impoverishing health expenditures borne by Palestinian households (an average increase in household health expenditure of 171.64% and 141.58%, under S1 and S3, respectively).

Secondly, the macroeconomic impact of the COVID-19 pandemic appears to be also comparable to that observed under the *generalized epidemiological shock scenario* (with an estimated drop in GDP of 3.40% under S1 as compared with a drop of 3.20% under S3). This is also confirmed in relation to government expenditures where similar effects can also be observed under both the *generalized pandemic* and the *COVID-19 specific pandemic* (an estimated drop in government non-health spending of approximately 34.22% and 35.50%

under S1 and S3, respectively, and a drop in government health spending of approximately 36.15% and 33.16%, under S1 and S3, respectively). This can be explained by the fact that both the generalized and the COVID-19 specific shocks have similar effects on labor, which is the major input in the production function that is susceptible to be directly affected by the pandemics: the average drop in labor supply is estimated at 16% and 15.31% under S1 and S3, respectively. These results are alarming as they reveal the severity of the current pandemic, which largely mimics the impact of any *generalized exogenous shock* to the economy.

Thirdly, results clearly indicate that a policy response against the COVID-19 pandemic that relies on expanding government expenditure on the health sector (S4) would help mitigate the adverse impact of the pandemic on the health of the population, in particular for high-risk and vulnerable groups. It is therefore not surprising to find the incremental burden of household direct health expenditures to be lower under S4 as compared to S3 (an average increase in household health expenditure of 110.80% under S4 as compared to 141.58% under the non-intervention scenario, S3). It is worth noting that such policy interventions involve a reallocation of government resources in favor of the health sector, rather than an expansionary fiscal policy. The latter may be unfeasible given the highly constrained budget setting that the Palestinian government faces. Such budget constraints are reflected in the model by the assumption of a constant share of public debt to GDP (estimated at 16.2% in 2018).[4] Accordingly, government expenditure is assumed to be endogenous in the model.[5] However, such reallocation in government spending may be inadequate to help rescue the economy from the potentially devastating impact of the pandemic. In fact, the net loss in GDP appears to be only slightly lower under S4 (the fiscal policy response against COVID-19) as compared with the non-intervention/herd immunity situation (S3). This suggests that a comprehensive, rather than an *ad hoc* and *sectoral policy response* against COVID-19, is in order. Indeed, under conditions of a highly constrained budget setting for large increases in public spending, a major policy issue is the government's available fiscal space. That is, the extent to which the government can create additional fiscal space to confront the pandemic and mitigate against its consequences in order to protect the most severely affected groups, sectors, and economic activities.

Fourth, the active spread of the COVID-19 virus and the rising daily COVID-19 infection rates and fatalities, which both peaked at the time of writing (during the latest months November-December 2020)[6], brings back the thorny policy question of *whether (or not) to re-impose tighter, strict public-health measures by implementing a complete lockdown to rein in COVID-19*. By comparing *the lockdown scenario* (S7) to *the do nothing scenario* (S3), our results suggest that *S7* may indeed be a preferred policy option over S3 in terms of both *micro-level* and *macro-level* outcomes under consideration. The lockdown policy appears to reduce the labor supply by almost half of the reduction that would have been observed under *the do nothing scenario* (S3) and induce a reduction of GDP by about 2% as compared to 3% under *the do nothing scenario* (S3). However, caution is needed when translating such results into policy recommendations. Indeed, it is worth noting that the ensuing shock from a lockdown is captured in our model by comparing the COVID-19 specific infection data reported for different months, rather than by introducing some arbitrary changes in labor supply. The latter is assumed to endogenously depend on health capital in our model. The relatively lower

4 https://tradingeconomics.com/palestine/government-debt-to-gdp.

5 Note that the assumption of a constant debt-GDP ratio implies that in the DSGE model when GDP decreases, the government expenditure would also decrease in order to keep the debt-GDP ratio fixed, other things being equal.

6 During September-December 2020, there has been a significant increase in both the number of COVID-19 confirmed cases and the associated deaths as compared to the period before September 2020. We thus expect higher values of CAR and CFR. The values of the epidemiological shock would be therefore higher resulting in a higher negative impact at both the micro and the macro levels.

negative impact on GDP induced by the lockdown shock can, thus, be explained by the fact that the health capital of the high-risk group is lower under S7 as compared to S4, hence, the decreases in labor supply and GDP are lower under S7. Another important factor is related to the composition of GDP, where household consumption expenditure, which constitutes more than 70% of GDP, has only slightly dropped during the lockdown (about 2.5%) (PCBS 2020). However, implementing a tight lockdown over a long period, which can in fact help prevent the rapid spread of the virus, can be associated with disastrous, adverse consequences on the economy overall, and thus, may not be the best policy option to pursue. Indeed, findings reported elsewhere have already shown that developing countries may be neither able to afford in the immediate term a tight and lengthy lockdown nor can they bear the prohibitive longer-term economic and health losses of the pandemic (Abu-Zaineh and Awawda 2020). Furthermore, it is worth noting that, in practice, the PNA has only notional power and little authority over Areas B and C, which represent approximately 82% of the West Bank, hence a complete lockdown has not been successfully implemented.

This calls for alternative, affordable (least possible cost) measures that are more targeted in their approach. Such policy requires striking the right balance between safeguarding lives (protecting health) and livelihoods (minimizing economic losses). Of course, in order to keep the virus under control until a vaccine is available, different combinations or types of preventative and protective measures are feasible and have been shown to be effective to slow, or even halt, the transmission of COVID-19 (WHO 2020). These include using actual daily reported infection data to draw evidence-based and epidemiologically-supported indicators that enable policy-makers to better identify, map out, and isolate the clusters (chains of infection) and super-spreaders, instead of imposing a full lockdown or carrying out widespread, massive testing.

Interestingly, our simulation results clearly indicate that a *public health policy response* (S4) that specifically targets the health sector may be preferred over the *lockdown policy response* (S7). In effect, the *public health policy response* appears to be as effective as the lockdown policy in terms of its overall protective effect on individuals' health (an overall decrease in health capital that amounts to 5.6% under S4 as compared to 4.2% under S7). Furthermore, a closer look at the disaggregated results by socio-demographic groups reveals that the implementation of a lockdown is particularly protective for the high-risk groups (a decrease in health capital by 6.3% under S7 as compared to 8.3% under S4). By contrast, the impact of the lockdown on the health capital of the low-risk groups seems to be relatively modest as compared with S4 (a decrease of 2.1% under S7 *vs*. 2.8% under S4). Although beyond the scope of this assessment, this finding alludes again to the importance of taking into consideration the differential impacts that such protective measures may have on the different socio-economic groups of the population. Although the pandemic does not discriminate between the worse-off and the better-off in terms of contracting the virus, its consequences can be highly uneven, particularly in the low-coverage, low-income settings, where access to affordable and quality health care can be highly compromised by the (in)ability-to-pay. Previous empirical evidence has shown that the lockdown can indeed result in a significant decline in the earnings of the most economically disadvantaged groups of the population such as informal sector employees and low-income households (ILO 2020; PCBS 2020; Enriquez and Goldstein 2020).

Fifth, also of note, the implementation of the lockdown appears to be associated with only small increases in government health expenditure (an increase of only 3.4% under S7 *vs*. an increase by 239.1 % under S4) and a reduction of 23.5% in government (non-health) expenditure (as compared to 40.1% under S4). It is worth noting that this result is in line with preliminary estimates on the potential impacts of the COVID-19 pandemic on the Palestinian economy (MAS 2020 b). Overall, this seems to suggest that the implementation of a COVID-19 lockdown would mainly help the government not to foot the potentially prohibitive bill of the pandemic in the event that the virus spreads rapidly. Of course, a more comprehensive assessment of the costs and benefits of a COVID-19 lockdown shall address the questions of *how many lives can be saved (lost) by such tight protective measure* and importantly *whether and to what extent it exacerbates both health inequalities and socio-economic inequalities* (Nicola et al 2020; Sardar et al 2020).

Lastly, our results confirm the vital role of a vaccine in providing effective and safe prevention against COVID-19 (scenarios S5 and S6). Of course, the provision of such a vaccine will put an end to the ongoing debate about *whether policies should be set to either save lives or save economies*. The provision of a vaccine appears to have immediate positive impacts at both the micro- and macro-levels. However, the limited doses of the vaccine that can be made available in the first phase raises the question of which priority groups of the population are to receive it first. Although it is beyond the scope of this study to provide an adequate answer to this question, our results shed light on the positive public health and economic effects of the provision of the vaccine to the high-risk groups of the population; *viz*., the elderly, unhealthy individuals, and female adults.

4-2 Comparison with other estimates

The estimated results on the overall impact of the COVID-19 pandemic on the Palestinian economy are generally fairly close to those reported by the PCBS and the MAS quarterly economic monitor. Accordingly, the decrease in GDP for the first quarter 2020 is estimated at 3.4% and 4.9% as compared with the first and last quarters of 2019 (MAS 2020a). However, it is worth noting that some of the results differ from previous projections regarding the impact of COVID-19 on the Palestinian economy which have employed a computable general equilibrium (CGE) model (MAS 2020b). These differences are due mainly to the different working hypotheses and modeling strategies. First, previous efforts estimated the economic effects of the COVID-19 lockdown under two scenarios: the first assumes a lifting of the lockdown one and a half months after its implementation, while the second assumes an extension of the COVID-19 lockdown after one and a half months. Accordingly, the effect on mobility was captured through changes in the productivity of the different economic sectors while the effect on labor supply was measured by changes in income transfers from employees (MAS 2020b). Secondly, unlike previous estimates, the model captures both the direct and indirect (*through the health production function*) epidemiological and economic effects of the COVID-19 pandemic. This implies that the net effect on, for instance, labor supply – the main input in the production function – is a result of changes in both health capital and health expenditure. Thirdly, the model assumes *complementarily* between consumption expenditure and health investment in the individual's utility and health production functions, whereby the two variables move in the same direction. This assumption is motivated by the fact that during a pandemic (or any external shock), the level of household consumption expenditure may slightly decrease or even increase (cf. e.g., Gabria et al 2020; Ben Hassen, El Bilali, and Allahyari 2020). Indeed, the drop in Palestinian household consumption expenditure, which represents the lion's share of GDP (about 70%), is estimated at 2.5% by the PCBS (2020). The detailed results (which are available upon request) show that both consumption expenditure and health investment go in the same direction. Therefore, the observed decrease in GDP (in the range of 2-3.7% as compared with previous estimates of 20.3% (MAS 2020b)) is mainly driven by the fall in total government expenditure (in the range of 23.5-42.5%).

4-3 Conclusions

Although relying on data pertaining to a rather short period of time (March-August 2020), the results reported in this study may provide useful information upon which a set of economic and public health policy responses to the COVID-19 pandemic can be advanced. Overall, reported results suggest that the Occupied Palestinian Territories are at a moderate to high risk of the pandemic. In the absence of an effective vaccine, lockdown policies may be vital in curbing the spread of the disease and mitigate its adverse effects on the health of the population. However, the implementation of a tight, complete lockdown over a long period may be unaffordable. Hence, as argued above, a policy response that targets the trees (i.e., the clusters/chains of infection) rather than the forest (the mass) is in order. Such a policy response shall be oriented towards enhancing the overall capacity of the health systems (the health workforce, expenditures, and infrastructure) (Falah, Meshal, and Betawi 2020 Abu-Zaineh and Awawda 2020). This also entails using the daily reported infection data to implement a set of targeted emergency responses that involve identifying, evaluating, and properly addressing all risk factors that are susceptible to the spread of the COVID-19 pandemic. Facing the disastrous economic consequences of the COVID-19 pandemic also requires going beyond direct health sector policy measures towards devising a set of proper economic policy measures. Amongst the immediate economic measures, the implementation of a *means-tested benefits* principle (i.e., targeting the most economically affected groups) can help mitigate the adverse economic consequences of the pandemic on the most affected sectors of the economy as well as on the most vulnerable groups of the populations who incur the double disease burden (health and economic losses). Thus, in addition to reprioritizing the most vulnerable groups such as the elderly, people living with chronic health conditions, and women, the best policymakers can do is to use administrative means to evaluate the benefits as some function of losses induced by the pandemic and previous earnings.

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Appendix

In this technical appendix, we describe the details of the dynamic general equilibrium (DSGE) model. The DSGE model combines the typical ingredients consisting of a set of representative individuals, a representative firm, a government, and a foreign sector. At each period $t = 1,2,\ldots,T$. Each representative individual maximizes an intertemporal utility function subject to a standard budget constraint in addition to a Grossman-type health production function. The utility of each representative agent, u_{it}, is a function of total consumption, c_{it}, health (human) capital, h_{it}, and labor supply, l_{it}. Each agent maximizes her utility function as follows,

$$u_{it} = log\ log\ c_{it} + v_i\ log\ log\ h_{it} + e_i\ log\ log\ (\underline{l} - l_{it}) \qquad (A.1)$$

Subject to respectively, a budget constraint and a health production function

$$(1 - \tau_t^l - \pi_t)w_t l_{it} + (1 + r_t)a_{it} = (1 + \tau_t^c)c_{it} + oop_t m_{it} + a_{it+1} \qquad (A.2)$$

$$h_{it+1} = (1 - \delta_i^h)h_{it} + E(\varepsilon_{it})m_{it}^{\chi_i}(\underline{l} - l_{it})^{1-\chi_i} \qquad (A.3)$$

where v_i and e_i are the weights each agent assign to health capital and labor, respectively, relative to the consumption in the utility function. Each agent is assumed to supply a maximum amount of labor, $\underline{l}$. Assets are denoted by a_t while medical expenditures are denoted by m_t. The parameters π_t and oop_t refer to health insurance premiums and the share of out-of-pocket health expenditures, respectively. τ^l and τ^c denote the labor income and consumption taxes, respectively while w_t and r_t denote the wage rate and interest rate, respectively. Eq. 3 represents the health production function where health capital depreciates over time at a constant rate δ^h, and improves as a function of health expenditure and leisure with χ denoting the elasticity of health expenditure in the health production function. We further assume that health capital can be affected by an epidemiological shock, ε_{it} where $\frac{\partial h_{it+1}}{\partial \varepsilon_{it}} < 0$ (an epidemiological shock destroys human capital). We can look at $E(\varepsilon_{it})$ as a technology parameter which improves the impact of m and l on h and that the epidemiological shock (for example increase in the prevalence rate of COVID-19) reduces this impact. Unlike the bulk of the literature where the epidemiological shock is captured through labor supply or life expectancy, our shock is captured through the health (human) production function. Following Momota et al. (2005), we assume that the epidemiological shock can be captured by a composite (mash-up) index of the incidence of COVID-19 – as measured by the clinical attack rate (CAR). In addition, we assume that this index is a function of other indicators, mainly, the CRR, the CFR and the TCR. Accordingly, the epidemiological shock for each individual, $E(\varepsilon_i)$, is calculated as follows

$$E(\varepsilon_i) = f(CAR_i, CRR_i, CFR_i, TCR_i) \qquad (A.4)$$

where $E(\varepsilon_i)$ is calculated for the four age-gender groups mentioned above. The data obtained from the MoH does not provide information on the health status of individuals. We therefore assume that the epidemiological shock of healthy individuals is smaller than that of unhealthy by an amount $\Delta > 0$. We express the function f in Eq. A.4 as follows:

$$f(CAR_i, CRR_i, CFR_i, TCR_i) = \frac{b}{\varepsilon_i} = \frac{b}{(CAR_i)^{\theta_1} + (CRR_i)^{\theta_2} + (CFR_i)^{\theta_3} + (TCR_i)^{\theta_4}} \tag{A.5}$$

where b is a constant, and θ_1, θ_2, θ_3 and θ_4 are the weights of the epidemiological indicators CAR, CRR, CFR, and TCR, respectively, such that $\sum_{i=1}^{4} \theta_i = 1$. It is worth noting that there is no specification of the functional formula that can capture the impact of an epidemiological shock, hence the values of the parameters under consideration. The choice of the weights, θ_i, is however, not arbitrary. We first simulate for different values of parameters until we get values of the epidemiological shock that reflects the differences in the COVID-19 pandemic statistics between the different age and health groups. That is a higher spread of the pandemic (captured by a higher incidence rate and a higher death rate) implies a higher epidemiological shock. Results show that indicators with higher variation amongst groups such as CAR shall be attributed a higher weight while indicators with higher homogeneity across groups, such as the TCR shall be given a lower weight. In the current work, the following values were retained for the different weights: $\theta_1 = 0.7$, $\theta_2 = 0.08$, $\theta_3 = 0.2$ and $\theta_4 = 0.02$.

The first order conditions (FOCs) of individual's optimization problem include

$$\frac{1}{(1+\tau_t^c)c_{it}} = \frac{\beta(1+r_{t+1})}{(1+\tau_{t+1}^c)c_{it+1}} \tag{A.6}$$

$$-e_i(1+\tau_t^c)c_{it} + \left(1-\tau_t^l-\pi_t\right)w_t\left(\underline{l}-l_{it}\right) = \frac{1-\chi}{\chi} oop_t m_{it} \tag{A.7}$$

$$\frac{oop_t}{\chi_i(1+\tau_t^c)c_{it}E(\varepsilon_{it})m_{it}^{\chi_i-1}\left(\underline{l}-l_{it}\right)^{1-\chi_i}} = \beta\left[\frac{v_i}{h_{it+1}} + \frac{\left(1-\delta_i^h\right)oop_{t+1}}{\chi_i(1+\tau_{t+1}^c)c_{it+1}E(\varepsilon_{it+1})m_{it+1}^{\chi_i-1}\left(\underline{l}-l_{it+1}\right)^{1-\chi_i}}\right] \tag{A.8}$$

We assume that every individual group is assigned a value of health capital depreciation with an average value of 0.056 as in Scholz and Seshadri (2011). The FOCs of the optimization problem (A.7 and A.8), in addition to the health constraint, are used to calibrate the other individual preference parameters (e_i, v_i and χ_i) based on the micro-level data on consumption expenditure, health expenditure, health capital and labor supply obtained from the PCPS PECS-2017. Health capital is estimated using a logistic regression where the dependent variable is a binary measure of health status. The latter is estimated using six questions measuring the health conditions of each individual including chronic diseases and the presence of difficulties in seeing, hearing, movement, focus, and communication. The health status variable takes zero if the individual suffers from any health problem (bad health) and one otherwise (good health). As for labor supply, we use the wage rates reported in the PCBS Labor Force Survey (PCBS-LFS-2017) to calculate individuals' labor supply in terms of hours per month for each gender-economic activity group in the PECS-2017. With regards to simulation scenarios, we assume that the aggregate wage at the firm level is adjusted following changes in individual's behavior. The values of the parameters for the eight individual groups are summarized in Table A1.

Table A1: The preference parameters of individuals optimization problem

Gender	Age group	Health status	v_i	e_i	δ_i^h	χ_i
Female	Elderly	Bad	0.0038	0.3592	0.0850	0.6621
Female	Elderly	Good	0.0007	0.3863	0.0720	0.5623
Female	Young	Bad	0.0031	0.3616	0.0470	0.6067
Female	Young	Good	0.0019	0.3447	0.0150	0.6217
Male	Elderly	Bad	0.0052	0.3098	0.0870	0.5741
Male	Elderly	Good	0.0039	0.2583	0.0730	0.4824
Male	Young	Bad	0.0082	0.2913	0.0490	0.5723
Male	Young	Good	0.0044	0.2675	0.0180	0.5790

In general, the value of v is found to be less than one percent with greater values being observed for unhealthy individuals compared to healthy individual groups. This indicates that the unhealthy individuals value health more than the healthy in order to improve their overall well-being. Results of the parameter e show that, in general, the elderly and unhealthy individuals attribute higher weights to leisure as compared to the young and healthy individuals. As mentioned above, the average value of δ^h is chosen based on the literature. Then based on the existing empirical evidence, different values were assigned to each group where the unhealthy and elderly have higher depreciation rates as compared to the young and healthy individuals. Lastly, the elasticity of health investment in the health production function is shown to be generally higher for the most disadvantaged groups (females, elderly, and the unhealthy). This indicates that health investment is more important than leisure in improving health for the disadvantaged groups.

The representative firm maximizes its output, Y, subject to the cost constraint as follows

$$Y_t = Z_t K_t^{\alpha} L_t^{(1-\alpha)} = Z_t F(K_t, L_t) \tag{A.9}$$

$s.t$

$$C_t = w_t L_t - \left(r_t\left(1+\tau_t^k\right) - \delta^k\right) K_t \tag{A.10}$$

where K and L denote the capital investment and total labor input, respectively, with α being the share of capital investment in total output. Z is a technology parameter. The cost function is denoted by, C, where τ^k is capital tax and δ^k id capital depreciation. The wage and interest rates can be written as follows:

$$w_t = (1-\alpha) Z_t k_t^{\alpha} l_t^{-\alpha} \tag{A.11}$$

$$r_t = \frac{\alpha Z_t k_t^{\alpha-1} l_t^{1-\alpha} - \delta^k}{\left(1+\tau_t^k\right)} \tag{A.12}$$

with $k_t = \frac{K_t}{N_t}$, $y_t = \frac{Y_t}{N_t}$ denoting per capita capital and output and N_t is the size of the population. The budget constraint for the government is given by:

$$B_{t+1} - (1 + r_t)B_t = G_t + (1 - oop_t)M_t - (\tau_t^l + \pi_t)w_t L_t - \tau_t^c C_t - \tau_t^k r_t K_t - \tau_t^m IM_t - D_t^f \tag{A.13}$$

$$B_t = \gamma_t Y_t \tag{A.14}$$

where B is the cumulative debt, G is the government expenditure, and D^f is the foreign aid while IM denotes the value of imports and τ^m is import tax. The debt-GDP ratio is denoted by γ. Writing all variables in per capita terms yields:

$$(1 + n)b_{t+1} - (1 + r_t)b_t = g_t + (1 - oop_t)m_t - (\tau_t^l + \pi_t)w_t l_t - \tau_t^c c_t - \tau_t^k r_t k_t - \tau_t^m im_t - d_t^f \tag{A.15}$$

$$b_t = \gamma_t y_t \tag{A.16}$$

where n is the population growth rate and $N_{t+1} = (1 + n)N_t$. The trade balance equation is:

$$A_{t+1}^f - (1 + r_t)A_t^f - D_t^f = TB_t \tag{A.17}$$

where A^f is net foreign direct investments (outflow-inflow) and TB is the trade balance such that $TB_t = EX_t - (1 + \tau_t^m)IM_t$ with E denoting exports. The trade balance equation (Eq. A.17) can be expressed in per capita terms as follows:

$$(1 + n)a_{t+1}^f - (1 + r_t)a_t^f - d_t^f = ex_t - (1 + \tau_t^m)im_t \tag{A.18}$$

Market clearing equations in per capita terms are:

$$y_t = c_t + m_t + g_t + i_t + ex_t - im_t \tag{A.19}$$

$$(1 + n)k_{t+1} = (1 - \delta^k)k_t + i_t \tag{A.20}$$

$$k_t = a_t + a_t^f - b_t \tag{A.21}$$

where

$$c_t = \sum_{i=1}^{8} \omega_i c_{it} \tag{A.22}$$

$$m_t = \sum_{i=1}^{8} \omega_i m_{it} \tag{A.23}$$

The parameter ω_i is the weight of each individual group $i = 1, \dots, 8$. This weight is based on the population weight of each demographic group (gender and age) as well as the corresponding weight of each health group obtained from PECS-2017. Accordingly, the shares of the young and the elderly are 91.6% and 8.4%, respectively. The share of females is 49.3%, while the share of healthy individuals is 66.8%.