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An Assessment of the Macroeconomic Implications of COVID-19 in Nepal: Evidence from SIR-Macro Model Analysis

Khagendra Katuwal[1], Manab Prakash[2], Naveen Adhikari[1], Nirmal Kumar Raut[1], Shiva Raj Adhikari[3]

Abstract

This paper assesses the macroeconomic implications of COVID-19 in the context of Nepal. The study uses a susceptible, infected, and recovered macro model (SIR-Macro model) where epidemiological variables are interacted with macroeconomic variables namely consumption and working hours to simulate the implication. The model estimates show that the containment measures of the government reduced the spread of the disease by 17 percent. However, the COVID-19 pandemic had a significant negative impact on macroeconomic outputs. On average, both consumption and working hours declined by 20 percent which otherwise would be more serious if no containment measures were adopted. In addition, the study also finds that the impact has been heterogeneous across susceptible, infected, and recovered population. Interestingly, the study also indicates that the individual utility lowered while societal utility improved with containment policies.

Keywords: *COVID-19, Containment policies, Consumption, Working hours, Nepal*
JEL Classification: *E21, E23, C15, C30*

Introduction

The COVID-19 pandemic had a serious effect on health and the economy. With the rising cases of COVID-19 infections, the Government of Nepal

[1]**Mr. Katuwal** is a Lecturer at the Central Department of Economics, Tribhuvan University, Kirtipur. Nepal Email: khagendra.katuwal@cdec.tu.edu.np.; ORCID: https://orcid.org/0009-0006-0784-7927; **Mr. Adhikari** (Corresponding author) is a Lecturer at the Central Department of Economics, T.U., Kirtipur, Email: naveen.adhikari@cdec.tu.edu.np.; ORCID: https://orcid.org/0000-0003-0347-4108; **Dr. Raut** is a Lecturer at the Central Department of Economics, T.U, Kirtipur, Email: nirmal.raut@cdec.tu.edu.np. ORCID: https://orcid.org/0000-0002-4234-4739

[2]**Mr. Prakash** is a Graduate Student at the Central Department of Economics, T.U., Kirtipur, Nepal. Email: manab2678@gmail.com; ORCID: https://orcid.org/0000-0002-9958-2981

[3]**Dr. Adhikari** is a Professor at the Central Department of Economics, T.U., Kirtipur, Nepal. Email: shiva.adhikari@cdec.tu.edu.np. ORCID: https://orcid.org/0000-0002-4642-8606

imposed a nationwide lockdown from 24th March 2020 in order to contain the spread of the virus. This disrupted the supply chain and restricted the availability of essential goods and services. Many businesses ceased to operate due to the fall in demand for non-essential goods. The pandemic caused many to lose their jobs such that they faced difficulty managing basic household supplies such as food and medical care. This led to an increase in poverty and insecurity, putting an additional strain on an already fragile healthcare system (Shrestha et al., 2021). There was a sharp decline in consumer spending, resulting in a decrease in the demand for goods and services, as well as a decrease in employment in the private sector. Consequently, income declined that led to decrease in the purchasing power of individuals and households, which further led to a decline in consumption and subdued household welfare (Egger et al., 2021; Eftimov, 2020; Chenarides et al., 2021). All sectors, from health and education to trade, experienced the brunt of the pandemic and prolonged lockdown. The service sector including transportation, tourism, hotel and restaurant, and wholesale and retail businesses were more affected than others. Consequently, the economic growth plummeted to 2.27 percent against the estimated growth of 8.5 percent during the Fiscal Year 2019/20. This indicates serious economic implications of COVID-19 both at micro and macro levels.

Research indicates that COVID-19 has had significant effects on the consumption patterns, savings habits, and working hours of all segments of the affected population, including those who are infected, vulnerable, and have recovered from the illness (Toda, 2020; Martin et al., 2020). The infected population experienced a remarkable reduction in their consumption, saving, and working hours since they were unable to work and were mostly confined to quarantine facilities. This seriously affected their financial situation and ability to buy goods and services. Additionally, many of those infected had to take unpaid leave and work fewer hours due to health concerns. In particular, many workers in the informal sectors lost their jobs thus affecting their livelihood disproportionately (Katuwal et al., 2020). The susceptible had their consumption and saving habits altered due to the fear of infection and the economic downturn caused by the pandemic. Many cut back their spending and saved more in order to prepare for potential job loss or reduced hours. Additionally, many of those susceptible adjusted their working hours to accommodate their need to stay safe while fulfilling their work obligations. Individuals who have recovered from COVID-19 have also modified patterns of consumption, saving, and working habits. Many of those who recovered took shorter working hours or less demanding jobs in order to avoid any kind of adverse health consequences. Additionally, those who recovered had to cut back spending in order to make up for any lost income or to save for future medical expenses (Jin et al., 2021; Immordino et al., 2021; Achou et al., 2020). Given the unprecedented nature of the pandemic, it is important to assess the macroeconomic implications of the epidemiology of COVID-19 in the context of Nepal.

This paper examines the macroeconomic implications of COVID-19 and containment policies in Nepal. In particular, the study assesses the implication of three epidemiological variables (susceptible, infected, and recovered) on consumption and working hours/ labor supply. It is important to understand the macroeconomic implications of COVID-19 and containment policies for the following reasons: First, understanding the implications of these variables can be useful to evaluate the implications on the livelihood of vulnerable sections of society. Second, it will be helpful to design both macro and micro policies during periods of health emergencies like COVID-19. Third, this also helps evaluate the effectiveness of containment measures adopted by the Government. Fourth, the assessment will also help set the specific context of the country's situation for the international community so that they can better design their support measures and mechanisms both in terms of health and financial aid.

This paper is divided into five sections. Section 1 introduces the about the study. Section 2 provides a brief review of policies, containment measures, and a review of the past empirical literature. Section 3 discusses the methodology. Section 4 presents data and discusses the results and section 5 concludes.

Review of Literature

This section briefly reviews the policies and containment measures followed by the Government of Nepal during COVID-19. The section also provides a succinct review of the literature analyzing the macroeconomic implications of COVID-19.

Policies and Containment Measures

Various policies and containment measures were adopted by the Government of Nepal to maintain the balance between life and livelihood. The government faced the dual challenge of saving the lives of people by containing the spread of the virus on the one hand and smoothening the consumption standard by fueling the economy on the other. The following subsections provide a brief overview of the economic policies and containment measures adopted by the government of Nepal during the COVID-19 period.

Economic Policies

The government implemented some macroeconomic policies in order to keep the economy afloat. Various fiscal and monetary measures were adopted at national and subnational levels with a focus on increasing spending, reducing taxes, and providing assistance to households and businesses (Srivastava et al., 2021; Raut, 2020).

In terms of fiscal policy, the government increased health expenditure in order to expand insurance coverage to medical personnel, increase additional supplies, and set up quarantine and temporary hospitals. Likewise, social assistance was also provided to the vulnerable sections, utility bills were subsidized, tax-filing deadlines were extended, and partial compensation was provided to the low-wage workers. Wage employment was also provided to the workers in the informal sector. The workers could otherwise receive 25 percent of the local daily wage in case there was no wage employment. Also, the government extended support to business communities by providing loans to the cottage and small-scale industries as well as to the entities operating in the tourism sector.

In terms of monetary policy, the Central Bank injected additional liquidity into the financial system by lowering the cash reserve ratio as well as the interest rate on the standard liquidity facility rate. The Central Bank also relaxed reporting norms and withdrew penalties for non-compliance with regulatory and supervisory requirements from Banks and Financial institutions. Likewise, loans and other working capital loans of business entities were deferred to a later date. The need-based additional working capital loan was provided to the affected sectors with a relaxed repayment schedule.

Various fiscal measures were also adopted at the provincial and local levels to fight against the adverse effect of COVID-19 on the local economy. Some provinces allocated a budget for developing infrastructure to create employment while others adopted several austerity measures by cutting allowance and other unnecessary expenses of government employees. Some provinces even focused on economic recovery and job creation. Some provinces and local governments also created COVID-19 relief funds and developed their own standard and relief protocols.

Containment Measures

The Government of Nepal enforced a lockdown, closed the borders with India and China, and imposed travel restrictions both within and outside the country (Yadav & Jha, 2020). Besides a large number of migrants returning from India, Nepal also experienced internal migration where the urban population started moving back to their hometowns and villages (Gautam, 2020). However, prolonged lockdown during the first wave made people's life miserable by limiting earning opportunities. As a lesson learned, during the second wave, the federal government instructed the sub-national government to enforce lockdown depending upon the COVID-19 cases at the local level (Rajbhandari et al., 2020).

The government also started disseminating messages related to COVID-19 status and messages related to its preparedness, precaution, and awareness utilizing all forms of media. Local government also used local media to broadcast the messages; they also made the door-to-door announcement with a message relating to preparedness, precaution, and awareness (Sharma et al., 2021). Besides these containment measures, several other measures were adopted. The government at all levels increased the pace of contact tracing the infected individuals and increased the testing capacity. Likewise, social distancing was made effective by increasing the isolation and quarantine facilities. Later, after the vaccine was developed to prevent COVID-19 infections, the government ramped up the vaccination campaign throughout the nation.

Review of the Empirical Literature

A review of the literature on the macroeconomic effects of epidemics sheds light on various channels through which economic costs can escalate. These studies in general find that the loss of a productive workforce through mortality and illness remains a key channel, particularly during big pandemics such as 1918 influenza. However, key insights can be drawn from past studies about the economic consequences, including cost due to weak consumer sentiment, high exposure of the services sector, the impact of social distancing policies, and potential financial amplification (Boissay & Rungcharoenkitkul, 2020). First, the costs of epidemics vary widely, depending upon the severity and the control measures undertaken to contain the spread (Barro & Weng, 2020; Correia et al., 2020). Second, the economic costs emanate through both supply and demand side changes (Arnold et al., 2006; Baker et al., 2020; Guerrieri et al., 2021). For example, in response to the risk of infection, workers may follow social distancing measures thereby reducing the supply of their labor on the one hand and consumption on the other (Lemieux et al. 2020; Power, 2020).

There are two major approaches to examining the macroeconomic impact of a pandemic like COVID-19. One is to use past historical data or time series techniques to learn about the dynamics of the pandemic like COVID-19 and its implication on the economy. However, there is no recent history of the pandemic comparable to COVID-19 in terms of scale and severity in the economy. The 'Spanish Influenza' of 1918 is an example of pandemic in recent human history though the empirical evidences on this front is missing. However, some of the literatures, for example, Barro et al., 2020; Barro, 2021; Velde, 2020, have attempted to use this approach for linking the relationship between pandemic and economic activities. The other approaches as suggested by Eichenbaum et al., 2020; Acemoglu et al., 2021, Baqaee & Farhi, 2021;Ichinoet al., 2020 are to model the dynamics of the epidemic and its impact using some explicit economic assumptions. In this respect, the closest paper to ours is Eichenbaum et al. (2020) which uses the SIR-Macro model to examine the macroeconomic impact of the COVID-19 pandemic in the USA.

This study adds to the limited literature that investigates the macroeconomic impact of COVID-19 using the SIR-Macro model. Besides, to our knowledge, studies that assess the macroeconomic impact using this level of mathematical rigor have not been conducted in the case of Nepal. In that respect, this study provides a fresh quantitative assessment of the impact that is useful not only for policymaking purposes but also for validating the findings of qualitative assessments made in the past.

Methodology

In this study, the SIR-Macro model is used to examine the relationship between the epidemiology of COVID-19 and the major macroeconomic variables in the context of Nepal. The SIR-Macro model makes it possible to examine an individual's behavioral response to epidemic dynamics and its impact on the economy. The COVID-19 pandemic changed individual behavior as individuals cut down on consumption and working hours to minimize the risk of being infected. The SIR-Macro model was used to analyze the impact of an HIV/AIDS epidemic on the macro economy. The model has since been used to study the macroeconomic impact of other infectious diseases including SARS (Liu et al., 2005). Recent studies have applied the SIR-Macro model to analyze the macroeconomic impact of COVID-19 (Eichenbaumet al., 2021; Rabelo & Soares, 2020). In developing a theoretical model, we therefore closely follow the recent work by Eichenbaum et al. (2021).

Theoretical Model

Similar to the classical SIR model, agents are in one of the four stages: susceptible, infected, recovered, and dead. The macro-SIR model extends the classical SIR model where the economists use the statistics relating to the probability of being infected due to increased participation in economic activity to compute the lifetime utility. In this macro-SIR formulation, pandemics end naturally by herd immunity through mass vaccination, the natural arrival of immunity following infection, or the arrival of medicine that cures the disease. Based on these presumptions, we develop our macro-SIR model in the following sub-sections.

Pre-infection Economy

All economic agents are identical and maximize the lifetime utility function. The per-period utility and budget constraints are defined as follows.

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

Per Period Utility Function: $$u(c_t, n_t) = \ln c_t - \frac{\theta}{2} n_t^2 \tag{2}$$

Budget Constraint: $$(1 + \mu_t)c_t = w_t n_t + \Gamma_t \tag{3}$$

Here, β denotes the discount factor and c_t and n_t denote consumption and hours worked, respectively. Similarly, w_t denotes the real wage rate, μ_t is the tax rate on consumption, and τ_t denotes lump-sum transfers from the government. The firms in the economy produce goods C_t and aim to maximize profits. This is represented by the following sets of equations:

Production Technology: $$C_t = AN_t \tag{4}$$

Profit Equation: $$\Pi_t = AN_t - w_t N_t \tag{5}$$

The government is simplified and treated as an agent who collects tax at a fixed rate μ_t on consumption and distributes that revenue in form of transfers Γ_t to households. This results in the government's budget constraint as follows:

Government. Budget Constraint: $$\mu_t c_t = \Gamma_t \tag{6}$$

We only consider the real side of the economy. As a result, at equilibrium conditions, goods produced are equal to the total consumed and all labor demands are equally supplied.

Goods Market Equilibrium: $$c_t = C_t \tag{7}$$

Labor Market Equilibrium: $$n_t = N_t \tag{8}$$

Pandemic Economy

After the outbreak of the pandemic, its dynamics are governed by both the SIR model and modified utility functions. At the initial stage of an economy with the population Pop_0, all households are in the susceptible stage. We introduce the infection to the model by assigning an ε fraction of the total population as infected. As a result, the rest $1 - \varepsilon$ are in the susceptible stage. Initial conditions are:

Initial Population: $$Pop_0 = 1 \tag{9}$$

Initial Infected: $$I_0 = \varepsilon \tag{10}$$

Initial Susceptible: $$S_0 = 1 - \varepsilon \tag{11}$$

During a pandemic, infection is transmitted by consumption, work, and random meetings. These infection dynamics results in a different definition of newly infected compared to classical SIR.

Newly Infected in t Period: $$T_t = \pi_1(S_t C_t^s)(I_t C_t^i) + \pi_2(S_t N_t^s)(I_t N_t^i) + \pi_3 S_t I_t \tag{12}$$

Where, S_t and I_t are susceptible and infected at period t. Similarly,(C_t^s, N_t^s), (C_t^i, N_t^i) are consumption and work hours paired by susceptible and infected respectively. By multiplying the aggregate consumption of susceptible and infected, and weighing it with a probability of being infected through consumption π_1, we compute the total number of new infections that originated by consumption in the economy. Similarly, we compute new infections through work (second term) and random chance (third term), and aggregate all sources to get the total newly infected in the period t. Classical SIR can be thought of as a special case of equation 12 when π_1 and π_2 are equal to zero, i.e., new infections only arise from random chances. With this new infection in hand, we can write the dynamics of the pandemic as follows:

Susceptible Dynamics: $S_{t+1} = S_t - T_t$ **(13)**

Infected Dynamics: $I_{t+1} = I_t + T_t - (\pi_r + \pi_d)I_t$ **(14)**

Recovered Dynamics: $R_{t+1} = R_t + \pi_r I_t$ **(15)**

Death Dynamics: $D_{t+1} = D_t + \pi_d I_t$ **(16)**

Population Dynamics: $Pop_{t+1} = Pop_t - \pi_d I_t$ **(17)**

Where, π_r is the recovery rate and π_d is the mortality rate.
We can now write the optimization problem for each group of susceptible, infected, and recovered populations ($j = s,\ i,\ r$).

Budget Constraint: $(1 + \mu_t)c_t^j = w_t \phi^j n_t^j + \Gamma_t$ **(18)**

Where, labor productivity parameter ϕ^j is such that $\phi^s = \phi^r = 1$ and $\phi^i < 1$, or, susceptible and recovered are at their original productivity, but infected are less productive than their original state. A susceptible individual changes his decision-making by including the probability of being infected in its utility function. The probability of being infected if one is susceptible, is:

Probability of s to be i: $\tau_t = \pi_1 c_t^s (I_t C_t^I) + \pi_2 n_t^s (I_t N_t^I) + \pi_3 I_t$ **(19)**

The new utility function with infection risk included is:

Modified Utility Function: $U_t^s = u(c_t^s,\ n_t^s) + \beta[(1 - \tau_t)U_{t+1}^s + \tau_t U_{t+1}^i]$ **(20)**

Now, we can find an optimal solution to the above equations and get the following first-order conditions (FOCs) for susceptible agents.

FOCs for $j = s$

$$u_1(c_t^s, n_t^s) - (1+\mu_t)\lambda_{bt}^s + \lambda_{\tau t}\pi_1(I_t C_t^I) = 0$$
$$u_2(c_t^s, n_t^s) + w_t\lambda_{bt}^s + \lambda_{\tau t}\pi_2(I_t N_t^I) = 0 \qquad \textbf{(21)}$$
$$\beta(U_{t+1}^i - U_{t+1}^s) - \lambda_{\tau t} = 0$$

Similarly, we can compute the probability of the infected recovering, use it to modify the utility function of the infected, and derive FOCs for the infected.

Probability of i to be r: $1 - \pi_r - \pi_d$ **(22)**

Modified Utility Function: $U_t^i = u(c_t^i, n_t^i) + \beta[(1-\pi_r-\pi_d)U_{t+1}^i + \pi_r U_{t+1}^r]$ **(23)**

FOCs for $j = i$ **(24)**

$$u_1(c_t^i, n_t^i) = \lambda_{bt}^i(1+\mu_t)$$
$$u_2(c_t^i, n_t^i) = -\phi^i w_t \lambda_{bt}^i$$

A notable feature of equation 23 is that we have assigned being dead with zero utility – a standard assumption in health economics. Lastly, we compute the utility for the recovered person

Modified Utility Function: $U_t^r = u(c_t^r, n_t^r) + \beta U_{t+1}^r$ **(25)**

FOCs for $j = r$ **(26)**

$$u_1(c_t^r, n_t^r) = \lambda_{bt}^r(1+\mu_t)$$
$$u_2(c_t^r, n_t^r) = -w_t \lambda_{bt}^r$$

New equilibriums in the economy under the pandemic are:

Govt. Budget Constraint: $\mu_t(S_t c_t^s + I_t c_t^i + R_t c_t^r) = \Gamma_t(S_t + I_t + R_t)$ **(27)**

Goods Market equilibrium: $S_t C_t^s + I_t C_t^i + R_t C_t^r = AN_t$ **(28)**

Labor Market Equilibrium: $S_t N_t^s + I_t N_t^i \phi^i + R_t N_t^r = N_t$ **(29)**

To account for the medical preparedness of the economy, we endogenize the death rates by pandemic as a convex function of infection in the population. This formulation models a shortage of medical beds during the height of the pandemic leading to higher deaths than due to death only.

Endogenous Death Rate: $\pi_{dt} = \pi + \kappa I_t^2$ **(30)**

Based on this theoretical approach, we developed a benchmark model to fit the Nepalese context. We compiled the parameters to calibrate the SIR-Macro model from the pieces of literature as shown in Table 1 below. The data relating to the epidemiological dynamics of COVID-19 were complied from the WHO COVID-19 Dashboard[4].

[4] https://covid19.who.int/data

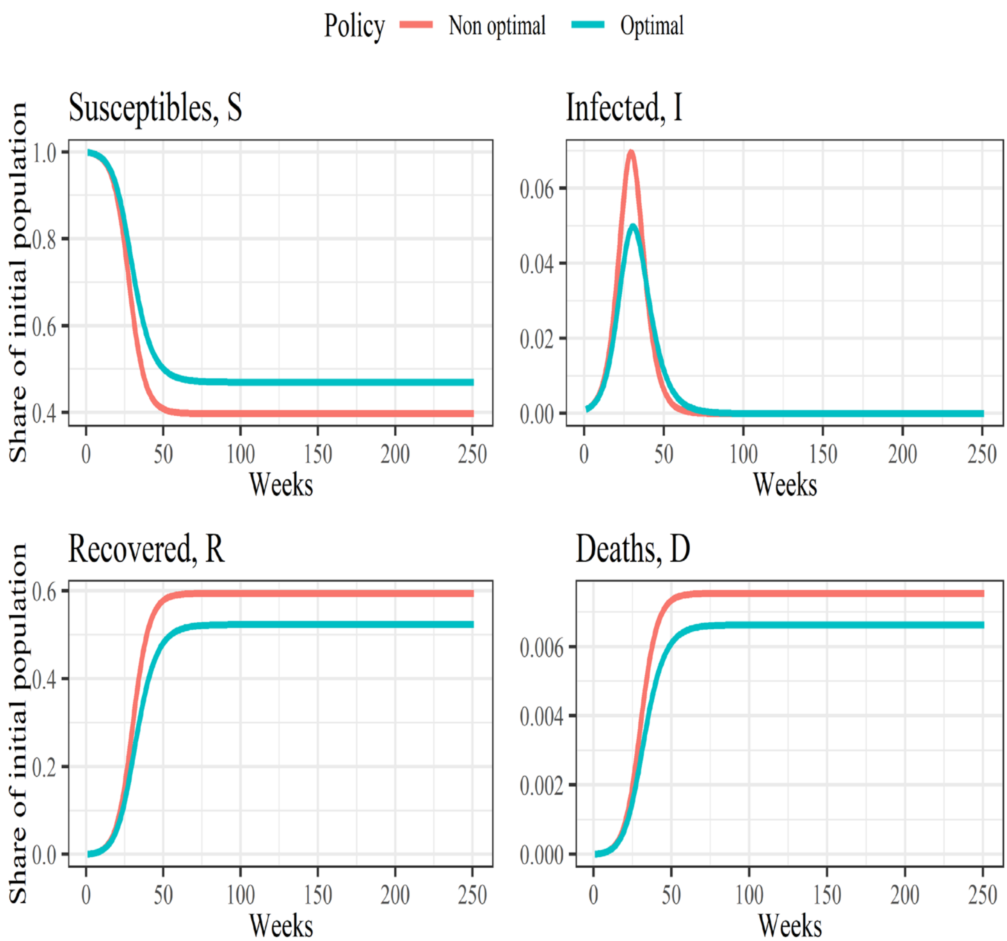
Table 1: Parameterization of the SIR-Macro Model

Parameters	Description	Value	Sources
π_d	Mortality rate after contracting the disease	CFR = 1.25 %	https://covid19.mohp.gov.np/
π_r	Recovery rate after contracting disease	17 days to recover	Adhikari et al. (2021)
ϕ_i	Productivity of infected	0.8	Dhakal & Karki (2020); Sharma et al. (2020)
κ	The slope of endogenous π_d	K = 0.0048	Own estimation of the function $\pi_{dt} = \pi_d + \kappa I_t^2$
π_1, π_2, π_3	Different infection probabilities	0.3,0.33,0.37	Halloran et al. (2008)
$\text{Max}\,(R + D)$	Maximum effect of COVID-19onthe economy	0.648	White et al. (2020)
N_S, N_W	Number of students and workers	7558202, 18748500	MoF (2020); CBS (2019)
Y	Weekly income target	34515.58/52	MoF (2020)
N	Weekly work hours target	44	CBS (2019)

Results and Discussion

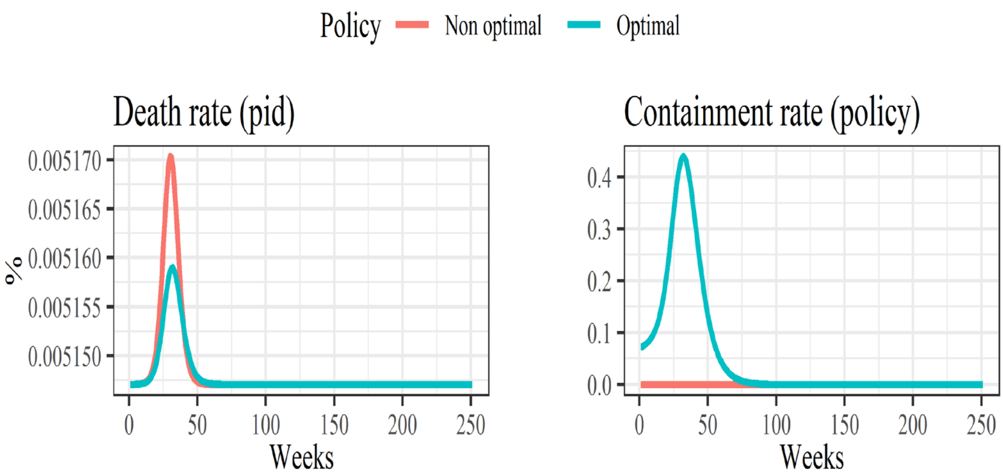
The COVID-19 pandemic has caused to change the individual's behavior voluntarily or due to government-enforced lockdowns and travel restrictions to avoid infection or to reduce the possible spread of the COVID-19 pandemic. To analyze the impact of these changes on the economy, we used the SIR-Macro model to assess individual behavioral responses to the pandemic and its implications. Compared to the no-policy SIR model, the SIR-Macro model with containment measures shows a flatter profile at the peak of the infection, resulting in a 28 percent reduction in peak infections.

Figure 1: SIR Dynamics in No-policy vs Containment Policy



In Figure 1, the optimal result is a solution path of SIR-macro dynamics with optimal containment policy, whereas, the non-optimal solution is basic SIR with no containment policy. The impact of the lockdown is seen in the number of deaths and the total recovered population. Overall, the implementation of lockdown policies reduced the spread by 17 percent of the population.

Figure 2: Death Rate and Containment Strength in Pandemic



The main factor behind the lower death rate in the model with containment is the implementation of containment measures that gradually increased as the number of infections in the population rises. This results in a hump-shaped containment policy. The mortality rate exhibits a direct relationship with the number of infected individuals, indicating the presence of health capacity constraints. The optimal containment policy peaks when there are more infections in the population. This means that it is preferable to introduce stricter lockdown measures as infections increase and to loosen them as the number of infections decreases.

According to a study by Flaxman et al. (2020), the implementation of non-pharmaceutical interventions, such as lockdowns, social distancing, and case isolation, was found to have a significant impact on reducing the number of COVID-19 cases and deaths. The study found that the rapid implementation of stringent measures was associated with significantly lower COVID-19 incidence and mortality compared with the later implementation of similar measures (Flaxman et al., 2020). This supports the idea that containment measures can be effective in reducing the spread of the virus and lowering the mortality rate.

Moreover, a study by Lai et al. (2020) also found that early implementation of containment measures, including lockdowns and social distancing, was associated with a lower mortality rate in different countries. The study concluded that strict containment measures, including lockdowns and school closures, are needed to prevent the rapid spread of COVID-19 and reduce the mortality rate. This is consistent with the idea that the optimal containment policy should peak when there are more infections in the population, and stricter measures should be introduced as infections increase and loosen as infections decrease.

During the peak of containment, around 44 percent of total consumption is reduced to prevent the spread of the virus, which is assumed to be enforced by the government. This leads to a lower level of engagement of people in the economy, resulting in a decrease in both work and consumption, leading to a further decrease in the rate of new infections. The study also finds that the pandemic harmed both consumption and working hours, with both declining by 20 percent from the initial steady state of the economy. The decline in consumption was more severe than the decline in working hours, which may be due to the omission of the savings component in the model. The study also shows that susceptible individuals reduce their consumption by 21 percent of the steady-state value, while the infected reduce their consumption the most, with a decline of about 30 percent from the steady state. The majority of the decline in working hours is driven primarily by susceptible and infected individuals. However, it is important to note that the omission of the savings component in the model may have led to an underestimation of the decline in working hours, as households may resort to saving to smooth out their consumption during the pandemic peak.

Figure 3: Effect of COVID-19 on Consumption and Working Hours

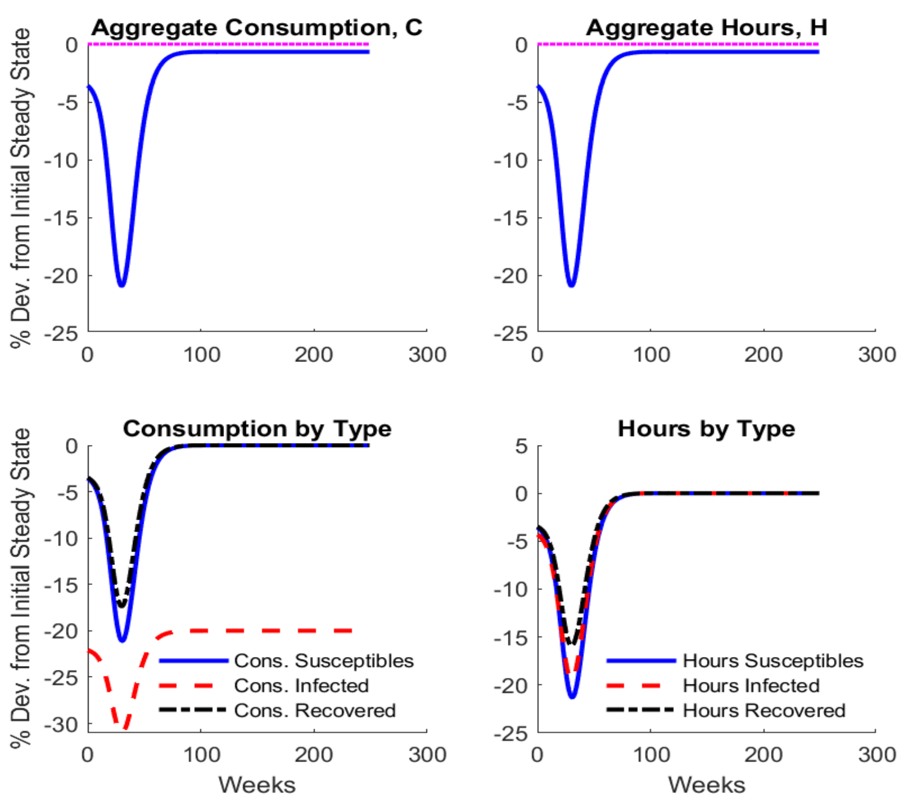
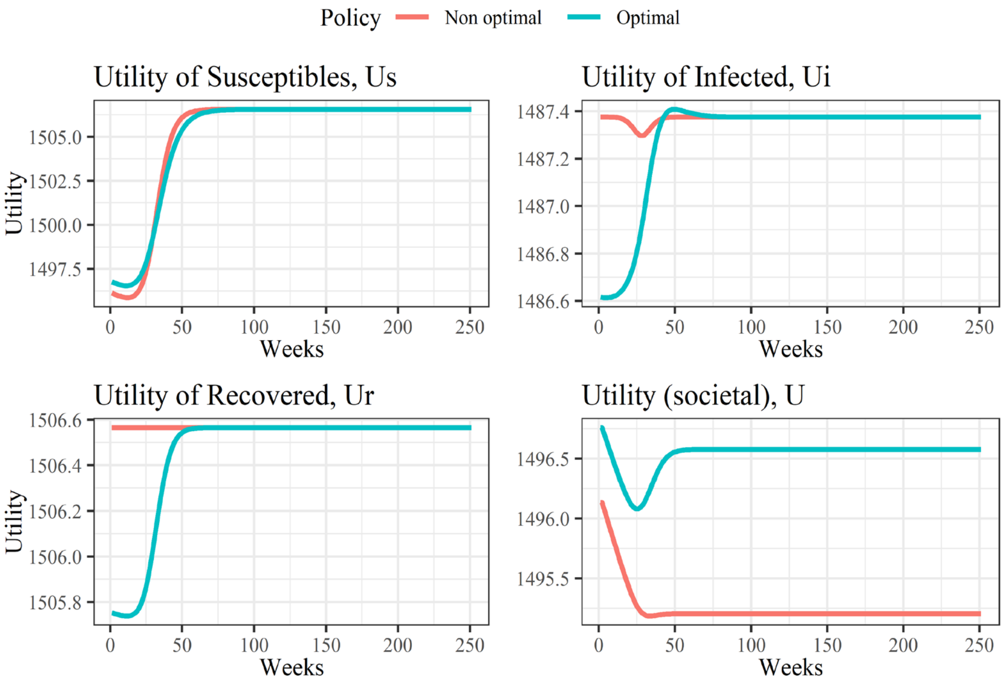


Figure 4: Effect of COVID-19 on Individual and Societal Utility



The finding that the decline in utility is larger during a pandemic without containment compared to the decline during containment is consistent with the results of other studies. In a study by Acemoglu et al. (2020), it was found that the effectiveness of containment policies, such as social distancing and lockdowns, in reducing the spread of the virus was critical in limiting the decline in economic activity and welfare. Furthermore, the composition of the decline in utility is different between the two scenarios, as reported in the present study. In a pandemic without containment, the decline in utility is primarily driven by death, resulting in a lower level of societal utility after the pandemic compared to a scenario with containment. However, in a containment scenario, the decline in utility is experienced by both recovered and susceptible/infected populations. Still, the recovered population returns to its original level of utility at the end of the containment. This characteristic supports the argument that despite the severe short-term pain caused by containment policies, their ability to limit the permanent decline in societal welfare means that they are a preferable option compared to non-optimal policies without any containment measures.

Conclusions

This study focuses on examining the relationship between COVID-19 epidemiological variables and major macroeconomic variables such as consumption and working hour loss in Nepal. The study also evaluates the effectiveness of containment policies such as quarantine, social distancing, lockdowns, restriction of labor mobility, and business closures in controlling the spread of the virus, as these policies affected individual decisions to consume and work. To assess the impact of these policies on consumption and labor supply, the SIR-Macro model was used. The study found that the containment policy reduced the spread of the disease by 17 percent. However, due to health capacity constraints, there was a direct relationship between the death rate and the number of infected population.

The study reveals that the pandemic harmed both consumption and working hours; both declined by 20 percent as compared to the economy's initial steady state. The impact varied across different sections of the population due to the nature of the disease. The study also measured the welfare loss of both individuals and society in terms of the loss in utility and found that the containment policies were effective in reducing this loss. The decline in utility was higher in the pandemic without containment measures compared to the pandemic with containment measures.

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