Optimal lockdown policy during the election period

Jan Acedański[1]

November 5, 2020

Abstract

This study theoretically examines to what extent a perspective of political election affects optimal lockdown policy at the outbreak of an epidemic. We employ the SIR-macro model in which the incumbent government aims at optimizing social welfare in the periods before polling day to maximize its election result. As a novelty, the substantial uncertainty with regard to the true characteristics of the epidemic faced by the economic agents is taken into account. The results reveal that the optimal lockdown policy crucially depends on the time to the polling day. If it is not longer than several months, the government tends to introduce immediate and more severe restrictions compared to the no-election case. On the other hand, if the election day is later, the optimal policy is to delay launching containment measures. Interestingly, it is difficult to assess which strategy is better in terms of lives saved. While postponing the reaction may result in a significant rise in casualties, an immediate and strict lockdown may also be inefficient in restraining the epidemic.

Keywords: lockdown, optimal policy, SARS-COV-2, political support, election

JEL classification: E61, E65, H12, I18

[1]University of Economics in Katowice, 1-go Maja St. 50, 40-287 Katowice, Poland, jan.acedanski@ue.katowice.pl.

1 The introduction

The ongoing SARS-COV-2 pandemic has forced policymakers all over the world to lockdown their economies. The best strategies require a skillful balance between reduction in the virus transmission rate and the drop in economic activity. Timing also plays an important role as a delay in introducing containment measures may result in a significant rise in casualties, especially if the healthcare system is not prepared to serve the rapidly growing number of infected people. On the other hand, premature restrictions are also likely to be inefficient.

As shown in the next section, these issues have already been extensively analyzed in the literature. However, the discussion seems to miss at least one important factor that is likely to influence the design of lockdown policies, the perspective of political election. The optimal lockdown for a government who is going to face an election in the near future, and therefore aims at maximizing the election result, may differ from the policy designed without the election perspective. This can happen because both economic and epidemic situations are undoubtedly the important factors affecting the election results of the incumbent government that is likely to be biased towards the expected situation in the period prior to the election in designing the policy. Without the election perspective, policymakers rather take the more balanced approach.

This study theoretically investigates how the election perspective affects the optimal lockdown policy. More specifically, it seeks to answer the follwing two questions:

1. What are the differences in the optimal lockdown policies when a government is going to face an election within a year from the epidemic outbreak compared to the no-election case?

2. In terms of welfare and lives, what are the costs and benefits of a policy that aims to maximize the future election result instead of current social welfare at the outbreak of the epidemic?

To answer these questions, I use the macro-SIR model developed by Eichenbaum et al. (2020a). I assume that the government sets the containment measures to maximize expected social welfare with the highest weights assigned to the periods before the scheduled election day. In the no-election case, the government simply optimizes the expected social welfare at the outbreak of the epidemic.

Contrary to existing studies, the model accounts for the fact that decisions on lockdown policies are taken under substantial uncertainty regarding the characteristics governing the dynamics of the epidemic, such as the real fraction of initially infected agents or the basic reproduction number of the virus. I consider various sets of realistic values of the coefficients and assume that the optimal policies maximize the expected welfare under the different scenarios. In addition to the standard, unrestricted policy case, I also examine more realistic, restricted policies. Given the simple structure of the model, it is unable to account for the fact that the prolonged and severe lockdown may become socially unacceptable and, as a consequence, ineffective. Therefore, the exogenous restrictions should be imposed on the policy.

The results confirm the important role of the election for the optimal lockdown, which crucially depends on the time distance between the polling day and the outbreak of the epidemic. If it is short, the optimal lockdown is initially much stricter than in the no-election case. On the other hand, if the election day is distant, the strategy of restraining the epidemic from the very beginning fails. Instead, the simulations suggest delaying the restrictions to accelerate the epidemic so the election takes place after the peak of the epidemic. This strategy may be costly in terms of welfare and lives as compared to the no-election case. Interestingly, if the admissible lockdown policy cannot last too long, the delayed restrictions save more lives that the quick lockdown in the early election and no-election cases.

The remainder of this paper is organized as follows. The next section reviews the literature. The model and its calibration are presented in sections 3 and 4, respectively. The results are discussed in section 5. The cases of countries where important elections are scheduled after the outbreak of the epidemic are briefly presented in section 6. Finally, concluding remarks are provided in section 7.

2 The literature review

The study is primarily related to two strands of literature. First, it contributes to the already extensive literature on the optimal lockdown policy. Atkeson (2020) presented the early prediction of the spread of the epidemic in the United States using the basic SIR model. Simple extensions of this model accounting for the trade-off between the speed of virus transmission and the economic activity level were subsequently developed by Eichenbaum et al. (2020a) in discrete time as well as Alvarez et al. (2020), Toda (2020), and Gonzalez-Eiras and Niepelt (2020) in continuous time, among others. Most of these studies suggest that the optimal lockdown policy should be rather strict, resulting in severe economic costs, exceeding 20% or even 30% of GDP in the first year of the epidemic. However, the results are likely to be biased by the relatively high assumed fraction of initially infected agents of 1%, which exceeds the estimates reported in the literature by at least one order of magnitude. Toda (2020), who considers much smaller values, advocates for milder, gradually adjusted containment measures.

Subsequent works stress the important role of actions that can substantially reduce the lockdown costs, such as efficient testing and quarantining procedures (Eichenbaum et al., 2020b; Pollinger, 2020), age-specific policies (Glover et al., 2020; Acemoglu et al., 2020; Kaplan et al., 2020; Brotherhood et al., 2020; Makris, 2020), and reallocation consumption from socially-consumed goods to those that can be consumed at home (Krueger et al., 2020). Moser and Yared (2020) argues that credible rules that limit the government's ability to lockdown the economy in the future can improve the efficiency of lockdown policy.

Many studies consider alternative models of the epidemic, which include distinguishing between symptomatic and asymptomatic infections (Vandenbroucke, 2020), possibility of reinfections (SIRS model; Eichenbaum et al., 2020b; Bethune and Korinek, 2020), a behavioral SIR model with endogenous social distancing (Engle et al., 2020; Makris, 2020; Azzimonti-Renzo et al., 2020), SEIR (Piguillem and Shi, 2020), and SEIRAD models (Aspri et al., 2020), as well as introducing a search-and-matching mechanism into the macro-SIR model (Garibaldi et al., 2020). The general predictions on the optimal lockdown policy of the studies with the alternative epidemic setups do not differ substantially from the works discussed earlier.

Studies that focus on the role of health care capacity present a somewhat different view on the optimal lockdown policy (Miclo et al., 2020; Andersson et al., 2020). The authors argue that the lockdown policy should not allow for overwhelming the health care systems, but the containment measures should be adjusted gradually.

Faria-e-Castro (2020), Guerrieri et al. (2020), and Birinci et al. (2020) conduct a more detailed analysis of labor market and fiscal policy measures during the lockdown. These authors stress the important role of unemployment insurance for minimizing the welfare costs of the lockdown. Çakmakli et al. (2020) examine the short-term consequences of the pandemic for small open economies with international input-output linkages. They document that sectors with stronger international input-output linkages and higher external debt suffer worse epidemic losses and have larger fiscal needs as a result.

However, none of these studies account for the election perspective that is likely to influence the design of the introduced lockdown policy. Costa-Filho and Neto (2020) can be viewed, to some extent, as an exception here. These authors empirically examine the relationship between democracy quality and the economic response to the epidemic in a cross-section of 152 countries. Their results suggest that "countries with a higher degree of democracy have stronger economic policy responses than their peers. However, when we separate monetary and financial policies from fiscal policy, democracy is not associated with the latter when we control for the income level of a country. Finally, for countries with lower levels of labor participation, high levels of income inequality are associated with weaker policy responses." In contrast, the current study is rather theoretically-oriented and therefore much closer to the studies on the optimal lockdown policy presented above.

In terms of the second strand, the study borrows from the literature on the impact of economic conditions on political preferences and results of political elections launched by the seminal study of Fair (1978) and nicely summarized by Fair (2012), Lewis-Beck and Stegmaier (2018), and J. Carville's famous phrase "It's the economy, stupid!" This area of research, which also includes the studies by Lewis-Beck and Rice (1982), Abramowitz (1988), Wlezien and Erikson (2004), De Neve (2014), Abramowitz (2016), Erikson and Wlezien (2016), and Zolghadr et al. (2018), among others, argues that economic conditions are important determinants of political support, particularly for an incumbent party or president, and, as a consequence, results of the incoming election.

3 The model

The study is based on the simple, discrete-time SIR-macro model developed by Eichenbaum et al. (2020a) using a version that accounts for the possibility of developing a vaccine and a treatment. I extend the model assuming that both agents and the government do not know the true values of the parameters describing the evolution of the epidemics. Instead, they consider different scenarios and aim at maximizing the expected value of the discounted lifetime utility with respect to these scenarios. I think that this is a plausible approximation of the real decision problems faced by governments and households at the outbreak of an epidemic. It also enables consideration of very different scenarios of the development of epidemics that impact on the optimal policy is reasonably limited.

The model focuses on the decisions made at the outbreak of the epidemics. I do not consider any form of learning in terms of the characteristics of the epidemic as more data are available. As a consequence, the agents do not revise their decisions over time. While this does not seem to be a realistic assumption, it is currently very difficult to introduce an empirically sound learning process in the model. Moreover, despite huge worldwide research efforts, there is still high uncertainty regarding many characteristics of the epidemics, especially if one is interested in excluding the effects of the lockdown policies.

3.1 The SIR model

To describe dynamics of the epidemics, the discrete version of the slightly modified classic SIR model (Kermack and McKendrick, 1927) is considered. The population of consumers is divided into three subgroups: susceptible (s), infected (i), and recovered (r).

In the starting point, there is a small fraction ϵ of infected consumers. The remaining $1-\epsilon$ consumers are susceptible. The latter may become infected by interacting with the infected agents. Eventually, the infected consumers either recover or die. The model assumes there are no reinfections, which means that once recovered, the agents cannot become susceptible again.

The evolution of the total number of susceptible (S_t), infected (I_t), and recovered

(R_t) agents, as well as new infections (T_t), total population (Pop_t), and the cumulative number of deceased (D_t) is described by the following set of equations:

$$Pop_0 = 1, \quad S_0 = 1 - \epsilon, \quad I_0 = \epsilon, \quad R_0 = 0, \quad D_0 = 0 \tag{1}$$

$$S_t = S_{t-1} - T_t \tag{2}$$

$$I_t = (1 - \pi_r - \pi_d)I_{t-1} + T_t \tag{3}$$

$$R_t = R_{t-1} + \pi_r I_t \tag{4}$$

$$D_t = D_{t-1} + \pi_d I_t \tag{5}$$

$$Pop_t = Pop_{t-1} - \pi_d I_t \tag{6}$$

where π_r and π_d denote probabilities of recovering and death, respectively.

I use a version of the model that accounts for the possibility of developing a vaccine and a treatment. If the former happens in some period, all susceptible agents become recovered in the next period. Analogously, if a treatment is introduced, then all infected agents recover in the next period.

The key equation of the model is concerned with the infection process. Following (Eichenbaum et al., 2020a), three different ways of becoming infected are considered: during consumption, work, and other activities. The probability of becoming infected during consumption is proportional to the product of aggregate consumption of infected ($c_{i,t}I_t$) and susceptible ($c_{s,t}S_t$) consumers. Similarly, the likelihood of becoming infected during work is proportional to the product of aggregate labor supply of infected ($n_{i,t}I_t$) and susceptible ($n_{s,t}S_t$) agents. The symbols $c_{i,t}$, $c_{s,t}$, $n_{i,t}$, and $n_{s,t}$ denote consumption and labor supply of the representative susceptible and infected consumers, respectively. Finally, the probability of becoming infected during other activities simply depends on the total number of infected and susceptible consumers. As a result, the number of new infections (T_t) is described by the following formula:

$$T_t = \pi_1(c_{i,t}I_t)(c_{s,t}S_t) + \pi_2(n_{i,t}I_t)(n_{s,t}S_t) + \pi_3 I_t S_t \tag{7}$$

where π_1, π_2, and π_3 represent the probabilities discussed above. In the remaining part of the paper, the six parameters governing dynamics of the epidemics are denoted by

$\boldsymbol{\pi} = [\epsilon, \pi_r, \pi_d, \pi_1, \pi_2, \pi_3]$.

The development speed of an epidemic is usually characterized by the basic reproduction number $\mathcal{R}_0$, which indicates the expected number of infections caused by one person. This number for a given period of time can be calculated in the model as:

$$\mathcal{R}_0 = \frac{T_t/I_t}{\pi_r + \pi_d} \tag{8}$$

3.2 The macroeconomic part of the model

The three standard types of economic agents are considered: consumers, firms, and the government. At the outbreak of the epidemics ($t = 0$), the consumers do not know how the epidemics will evolve and consider different scenarios $\boldsymbol{\pi}_j$ with assigned probabilities p_j. Given the sequence of the consumption tax rates $\{\mu_t\}_{t=0}^{\infty}$, they maximize the expected value of the discounted lifetime utility over the different scenarios $\boldsymbol{\pi}_j$:

$$\mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t u(c_{h,t}, n_{h,t})\right] = \sum_{j=1}^{m}\left[\sum_{t=0}^{\infty} \beta^t u(c_{h,t}, n_{h,t})\right] p_j, \tag{9}$$

where β represents the discount factor and $h \in \{s, i, r\}, h \equiv h_t = h(h_{t-1}, \boldsymbol{\pi}_j)$ is the current health status of a consumer, which depends on the consumer's health in the previous period and the epidemic development scenario $\boldsymbol{\pi}_j$[1]. The consumers treat the scenarios as realizations of a time-invariant random variable with a known probability distribution.

The momentarily utility $u(c_{h,t}, n_{h,t})$ depends on consumption $c_{h,t}$ and working hours $n_{h,t}$:

$$u(c_{h,t}, n_{h,t}) = \ln(c_{h,t}) - \frac{\theta}{2}(n_{h,t})^2, \tag{10}$$

where θ governs the marginal rate of substitution between consumption and leisure.

The sequence of budget constraints takes the following form:

$$(1 + \mu_t)c_{h,t} = (1 - \phi_h)W_t n_{h,t} + \Gamma_t \quad \text{for} \quad t = 0, 1, ... \tag{11}$$

where W_t is the hourly wage in the economy, μ_t is the consumption tax rate imposed

[1] For brevity, the time index in the health status variable h is omitted.

by the government, which is the only measure of the lockdown policy in the model, Γ_t is the lump-sum transfer from the government, and ϕ_h is the labor efficiency parameter that depends on the health status of a consumer. It is assumed that:

$$\phi_h = \begin{cases} 0 & \text{if } h = i \\ \phi & \text{if } h \in \{i\} \end{cases} \tag{12}$$

3.2.1 The optimization problems of the consumers

Below, I characterize the optimization problems faced by the consumers with different health status. The discounted lifetime utilities at the period t of agents with the health status h under the epidemic dynamics scenario j are denoted by $U_{h,j,t}$.

Susceptible consumers The optimal path of consumption and labor supply of susceptible consumers solves the following optimization problem:

$$\max_{c_{s,t},n_{s,t}} u(c_{s,t}, n_{s,t}) + \beta \mathbb{E}\left[(1-\pi_v)\left((1-\tau_{j,t})U_{s,j,t+1} + \tau_{j,t}U_{i,j,t+1}\right) + \pi_v U_{r,j,t+1}\right] \tag{13}$$

subject to (11), where $\tau_{j,t}$ represents the probability that a susceptible consumer becomes infected:

$$\tau_{j,t} = \pi_{1,j}(C_{i,t}I_{j,t})c_{s,t} + \pi_{2,j}(N_{i,t}I_{j,t})n_{s,t} + \pi_{3,j}I_{j,t} \tag{14}$$

and π_v denotes the probability of developing a vaccine. In this case, all susceptible agents become immune to the disease in the subsequent period and are treated as recovered. The term $(1-\tau_{j,t})U_{s,j,t+1} + \tau_{j,t}U_{i,j,t+1}$ represents the expected value of the next-period value function of a susceptible consumer when no vaccine is found.

The first-order conditions for consumption and hours are as follows:

$$c_{s,t}^{-1} - (1+\mu_t)\lambda_{s,t} + \beta(1-\pi_v)\mathbb{E}\left[\pi_{1,j}C_{i,t}I_{j,t}\left(U_{i,j,t+1} - U_{s,j,t+1}\right)\right] = 0 \tag{15}$$

$$-\theta n_{s,t} + W_t\lambda_{s,t} + \beta(1-\pi_v)\mathbb{E}\left[\pi_{2,j}N_{i,t}I_{j,t}\left(U_{i,j,t+1} - U_{s,j,t+1}\right)\right] = 0 \tag{16}$$

where $\lambda_{s,t}$ is the Lagrange multiplier associated with the budget constraint (11).

Infected consumers The decision problem for the representative infected agent takes the following form:

$$\max_{c_{i,t},n_{i,t}} u(c_{i,t}, n_{i,t}) + \beta\mathbb{E}\left[(1-\pi_{tr})\left((1-\pi_{r,j}-\pi_{d,j})U_{i,j,t+1} + \pi_{r,j}U_{r,j,t+1}\right) + \pi_{tr}U_{r,j,t+1}\right] \tag{17}$$

subject to (11), where π_{tr} is the probability of developing a treatment. The first-order conditions are:

$$c_{i,t}^{-1} - (1+\mu_t)\lambda_{i,t} = 0 \tag{18}$$

$$-\theta n_{i,t} + \phi W_t \lambda_{i,t} = 0 \tag{19}$$

Recovered consumers Similar to the other types of consumers, the decision problem for a representative recovered agent is:

$$\max_{c_{r,t},n_{r,t}} u(c_{r,t}, n_{r,t}) + \beta\mathbb{E}U_{r,j,t+1} \tag{20}$$

subject to (11). The first-order conditions are:

$$c_{r,t}^{-1} - (1+\mu_t)\lambda_{r,t} = 0 \tag{21}$$

$$-\theta n_{r,t} + W_t \lambda_{r,t} = 0 \tag{22}$$

3.2.2 Firms

The model is also populated by a continuum of identical firms that use labor to produce the consumption good. The production function of the representative firm is linear in labor:

$$C_t = AN_t \tag{23}$$

where A is the productivity parameter and C_t and N_t denote supply of the consumption good and the firm demand for labor, respectively. The zero-profit equilibrium condition implies that:

$$W_t = A \tag{24}$$

3.2.3 The government and the market clearing conditions

The government budget is on average balanced, which means that:

$$\Gamma_t \mathbb{E}(S_{j,t} + I_{j,t} + R_{j,t}) = \mu_t \mathbb{E}(S_{j,t}c_{s,t} + I_{j,t}c_{i,t} + R_{j,t}c_{r,t}) \tag{25}$$

The markets clear under every epidemic development scenario:

$$AN_{j,t} = S_{j,t}c_{s,t} + I_{j,t}c_{i,t} + R_{j,t}c_{r,t} \tag{26}$$

$$N_{j,t} = S_{j,t}n_{s,t} + I_{j,t}\phi n_{i,t} + R_{j,t}n_{r,t} \tag{27}$$

3.3 The lockdown policy and political election

The consumers are aware of the positive relationship between their own economic activity and the risk of getting infected and are therefore willing to decrease consumption and working hours to reduce the risk of infection, which would inevitably result in utility loss. However, they do not internalize the risk of infecting other people as the result of their own economic activity. The optimal social welfare can only be achieved by further restriction of economic activity through the consumption tax μ_t. In the baseline version, when the political election does not influence the government, it aims at maximizing the expected social welfare normalized by the population size defined as:

$$U_t = \mathbb{E}\left(\frac{S_{j,t}U_{s,j,t} + I_{j,t}U_{i,j,t} + R_{j,t}U_{r,j,t}}{S_{j,t} + I_{j,t} + R_{j,t}}\right) \tag{28}$$

at the outbreak of the epidemics:

$$\max_{\{\mu_t\}_{t=0}^{T}} U_0 \tag{29}$$

The expected social welfare represents the expected mean value of the lifetime utility of all consumers living in a given period, where the expectation is calculated over the different scenarios of epidemic development.

In the case of incoming political election, the government aims at maximizing political support in the period prior to the polling day. I assume that political support depends on the moving average of the social welfare in periods prior to the election day:

$$PS_{t_0} = \sum_{h=0}^{t_0} \gamma^h U_{t_0-h} \tag{30}$$

where $0 \leq \gamma < 1$ governs the decay rate of political support.

4 The calibration

One period in the model corresponds to a week. The model is calibrated to the US data. Different approaches are taken to calibrate the parameters of the epidemic and macroeconomic parts of the model. For the former, as previously mentioned, the parameters are treated as discrete random variables and several possible realizations are considered. Additionally, different probability distributions for the parameters corresponding to the mild, medium (baseline), and severe spread of the epidemics are examined. The calibration is summarized in table 1. The details are discussed below.

Table 1: Model calibration

Symbol	Description	Value
	Epidemic part	
ϵ	initial fraction of infected consumers	$\{0.00001, 0.00004, 0.00016\}$
π_d	probability of death	$\{0.001, 0.006, 0.01\} \cdot 7/18$
$\mathcal{R}_0$	basic reproduction number target at period 0	$\{1.3, 1.5, 2\}$
	Probability distributions	
	medium (baseline) variant	$\{1/3, 1/3, 1/3\}$
	mild variant	$\{0.6, 0.3, 0.1\}$
	severe variant	$\{0.1, 0.3, 0.6\}$
	Macroeconomic part	
π_v	probability of developing a vaccine	$1/52$
π_{tr}	probability of developing a treatment	$1/52$
β	discount coefficient	$0.96^{1/52}$
θ	disutility from labor	0.001275
A	labor efficiency (weekly wage)	39.835
ϕ	labor efficiency loss of infected agents	0.2
	Political election	
t_0	election period	$\{0, 13, 26, 39, 52\}$
γ	political support persistence	$\{0.9, 0.95, 0.98\}$

4.1 The epidemic parameters

To calibrate the initial fraction of infected consumers ϵ, I focus on the situation in the United States on March 8, 2020, a few days before most schools and universities suspended classes and moved to remote teaching and the national emergency state was declared. The total number of reported COVID-19 infections on that day was equal to 541. Obviously, the total number of all infections was much higher as most were undetected. Using the covariation in initial reported infections across U.S. regions and the number of travelers to these regions from the epicenter, along with the results of an early randomized testing study in Iceland, Hortaçsu et al. (2020) estimated that the fraction of reported to total infections up to March 16 in the United States was equal to 4-14%. It means that the total number of infections was 7-25 times higher than the number of reported cases. The results of the seroprevalence tests in Santa Clara County in California suggest than the rate was 25-95 at the beginning of April (Bendavid et al., 2020). Combining the three estimated rates of total to reported infections, 7, 25, and 95, with the number of reported infections on March 8 and the U.S. total population of 330 million gives the initial infected population fractions considered herein of 0.00001, 0.00004, and 0.00016, respectively.

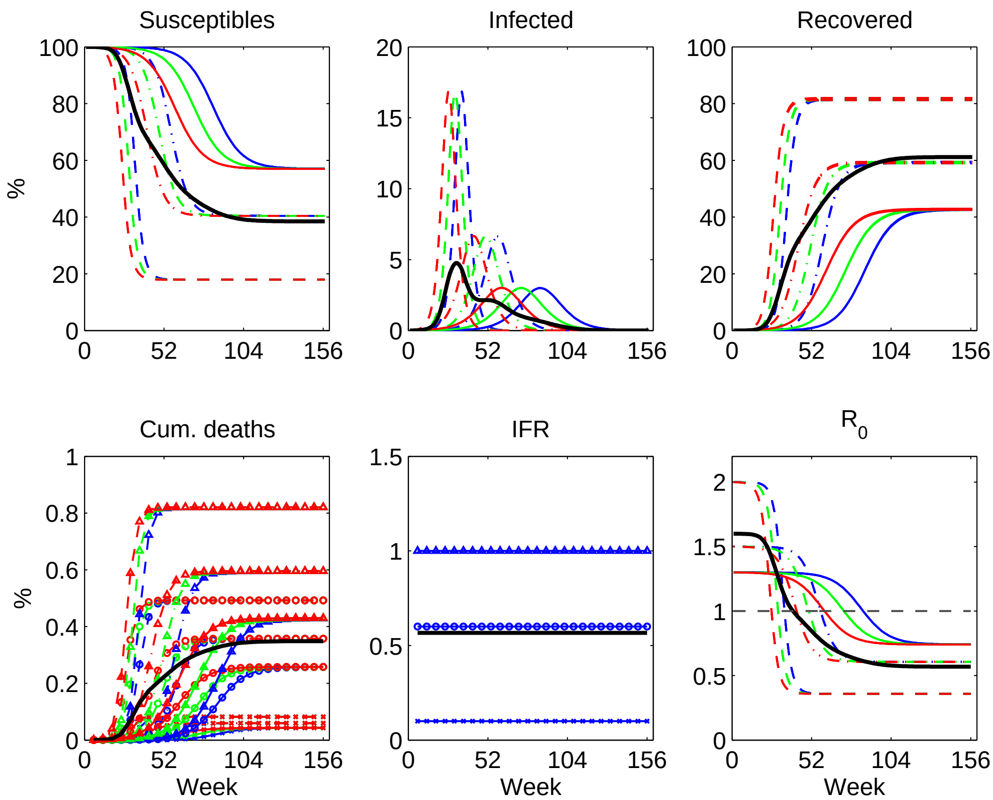
The probability of death π_d is primarily driven by the infection fatality rate (IFR, the ratio of deaths and total infections). Contrary to the easily available estimates of the case fatality rates (the ratio of deaths and reported cases), there is high uncertainty related to this parameter, primarily due to the large fraction of unreported cases, as discussed above. A meta-analysis performed by Meyerowitz-Katz and Merone (2020) provides the mean IFR for both Americas equal to 0.58%, with the minimum value reported by Bendavid et al. (2020) of 0.18% and the largest numbers of 1.01% and 0.92% reported by Hallal et al. (2020) for Brazil and Wilson (2020) for New York, respectively. In the current study, the central value of the IFR is set to 0.6%, while the two extremes are equal to 0.1% and 1%.

Calibrating π_d in the model also requires setting the mean duration of infection. In the study, it is equal to 18 days, which is in line with empirical estimates (Peirlinck et al., 2020) and the assumptions made in other works (Atkeson, 2020; Eichenbaum et al., 2020a).

The parameters π_1, π_2, and π_3 governing intensity of the infection process are calibrated using a similar procedure as in Eichenbaum et al. (2020a). They use the data on the relative importance of the different modes of virus transmission and estimate that about two thirds of the total transmissions occur during activities that are not related to consumption and work. The shares of infections during consumption and work are the same and these sources each account for roughly 1/6 of total infections. The transmission probabilities are set so that these shares are matched in the pure SIR version of the model. Additionally, I assume that they should match the basic reproduction number $\mathcal{R}_0$ of the disease at the outbreak of the epidemic. The estimates of this parameter exhibit substantial heterogeneity. The early estimates for the United States range from 3.3 to 5.3 (Aleta et al., 2020; Gunzler and Sehgal, 2020; Kuhl, 2020; Kwok et al., 2020). The later studies that account for the effects of early containment measures report much lower values, below 2 (Gunzler and Sehgal, 2020), and even less than 1 for some states (Ives and Bozzuto, 2020). Because the model accounts exclusively for the containment measures that reduce economic activity, the high estimates of the basic reproduction number do not seem to be suitable for calibrating the infection probabilities. Many forms of social distancing such as remote work or teaching and other measures like wearing masks in public places or mass disinfection do not lower economic performance considerably but significantly reduce the spread of the epidemic. Of course, these measures alone are insufficient to put an end to the epidemic. Therefore, I consider the three possible values for the basic reproduction number from the range [1, 2]. The central value is 1.5, which is also close to the value implied by the calibration in Eichenbaum et al. (2020a). The two extremes are equal to 1.3 and 2.

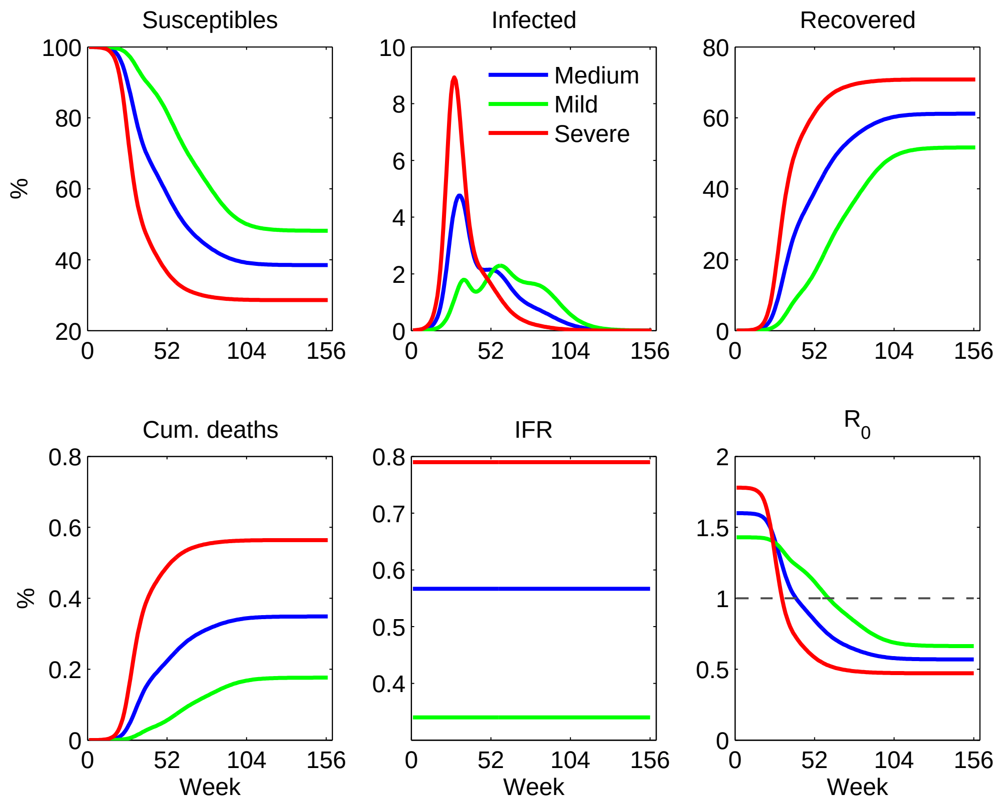
Figure 1 illustrates the dynamics of the epidemic for the considered parametrizations in the pure SIR model. The plots show the possible developments of the epidemic in the case when no countermeasures are introduced, either by the consumers or by the government. The plots document that the basic reproduction number at the outbreak of the epidemic is likely to have the most influence on the results as the epidemic development is highly sensitive to changes to this parameter. For the highest considered value $\mathcal{R}_0 = 2$, the epidemic peaks between the second and third quarter after the outbreak and expires within a year. On the other hand, for the lowest value of $\mathcal{R}_0 = 1.3$,

Figure 1: The epidemic dynamics for the different parametrizations (pure SIR model)



The colors represent the initial fractions of infected population: $\epsilon = 0.00001$ (red), $\epsilon = 0.00004$ (green), $\epsilon = 0.00016$ (blue). The line types represent the basic reproduction numbers: $\mathcal{R}_0 = 1.3$ (solid), $\mathcal{R}_0 = 1.5$ (dashed and dotted), $\mathcal{R}_0 = 2$ (dashed). The markers indicate the fatality rates: 0.1 (crosses), 0.6 (circles), 1 (triangles); in practice, they affect cumulative deaths only. The thick black solid lines represent the expected values of the parameters under the medium variant.

Figure 2: The epidemic dynamics for the three variants of the epidemic development



the peak is expected in the second year and the epidemic may last more than two years. The initial fraction of the infected agents has a smaller impact on the expected development of the epidemic. Its impact is further reduced by the higher values of the basic reproduction number. Finally, the death probabilities affect the cumulative number of deaths but have no noticeable impact on the other characteristics of the epidemic development.

Figure 2 presents the expected values for the epidemic characteristics under the three variants of the epidemic development. In the baseline variant, all the considered parameter values are equally probable. The mild variant assumes the lower speed of the epidemic development and the lower fatality of the disease by putting more weights on the lower values of the parameters. On the other hand, the severe variant considers the opposite situation.

4.2 The macroeconomic parameters

The calibration of the macroeconomic parameters of the model closely follows Eichenbaum et al. (2020a). The probabilities of developing a vaccine and a treatment are equal and imply that it takes a year, on average, to develop them. This study takes the standard value of the discount coefficient of 0.96, adjusted for the weekly characteristic of the model. The labor disutility parameter θ and the labor efficiency parameter A are set so that the representative person works 28 hours per week and earns a yearly income of \$58 000 in the pre-epidemic steady state of the model. The labor efficiency loss of infected agents is equal to 0.2, which reflects the fact that approximately 20% of infected people shows symptoms of the disease and cannot work.

4.3 The election-related parameters

Along with the no-election case, I consider four different polling days, after: 1, 2, 3, and 4 quarters from the outbreak of the epidemic. Because of the lack of reliable data on the high-frequency political support persistence, I analyze three values of γ equal to 0.9, 0.95, and 0.98. These numbers imply that the importance of past social welfare halves after 7, 14, and 35 weeks, respectively. The low value of γ means that the government aims at maximizing the social welfare in the relatively short period before the polling day. For the higher values, the government takes longer periods into account.

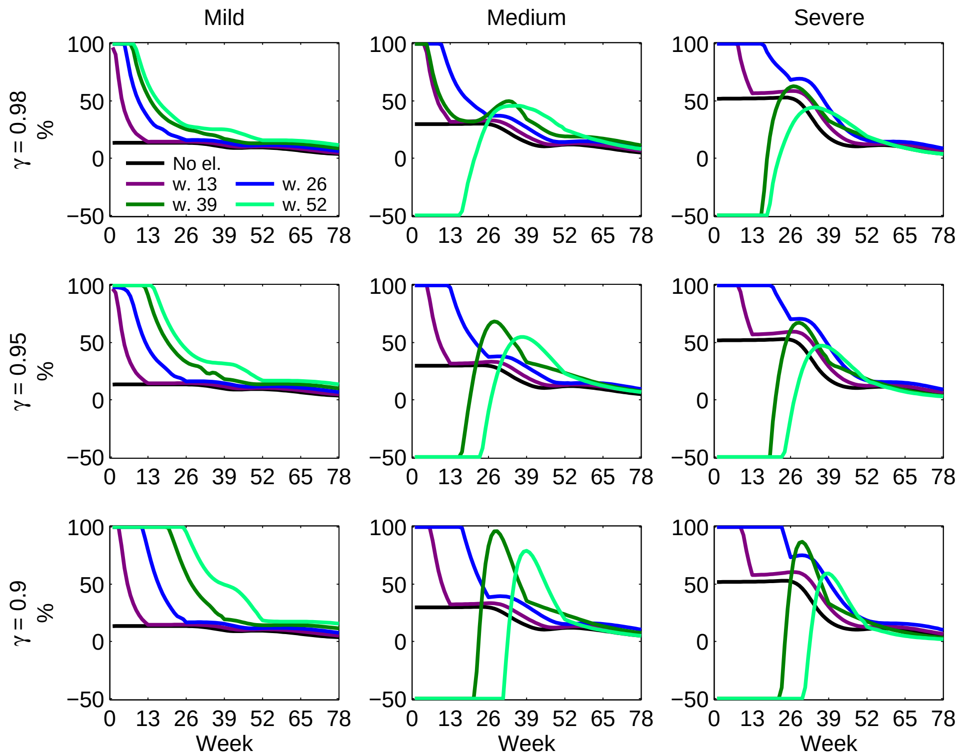
5 The results

In the simulations, the horizon for the lockdown policy is set to three years, which implies $T = 156$. First, I consider the unrestricted lockdown policy when the government can choose the containment rates μ_t from the wide range of possible values. Next, I examine the more realistic, restricted policy case when the lockdown cannot be too long and too strict. Finally, the results of some robustness check exercises are presented.

5.1 The unrestricted policy

In this case, I assume that the government can freely choose the containment rates from a wide range: $\mu_t \in [-0.5, 1]$. The optimal policies are illustrated in Figure 3; it covers

Figure 3: The optimal containment rates (μ_t)



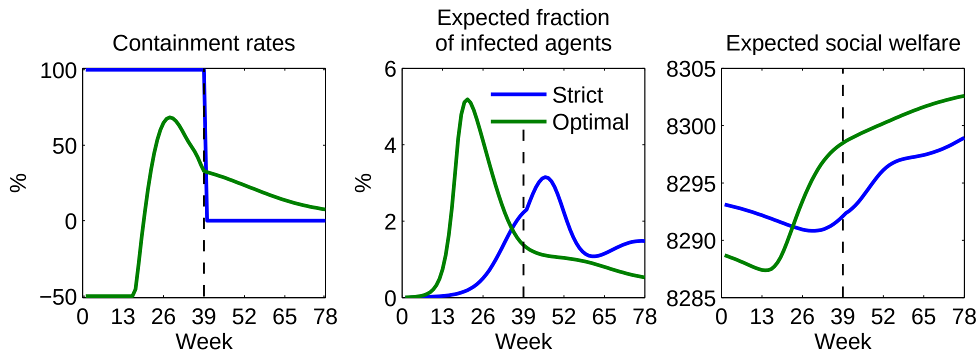
The colors refer to different election weeks, where black indicates the no-election case.

only the first, most interesting, six quarters of the studied period. In the subsequent weeks, the rates simply converge to zero.

The figure reveals the fundamental differences in the lockdown policies under the different election perspectives. In the no-election case, the optimal policy is to impose immediate and long, but relatively moderate, restrictions. If the election perspective is short, the optimal initial containment rates are much higher and converge to the no-election rates around the polling week. However, if the election is scheduled three or four quarters after the outbreak of the epidemic, the optimal policy is to keep the containment rates as low as possible at the beginning and to lockdown the economy and stifle the epidemic before the election. This effect does not occur in the mild variant of the epidemic development.

The policy of boosting the economy and accelerating the epidemic development may, at first sight, appear counter intuitive. Of course, the ”standard” approach is to slow the

Figure 4: The comparison of the optimal – delayed and immediate, strict lockdown policies in the long election perspective



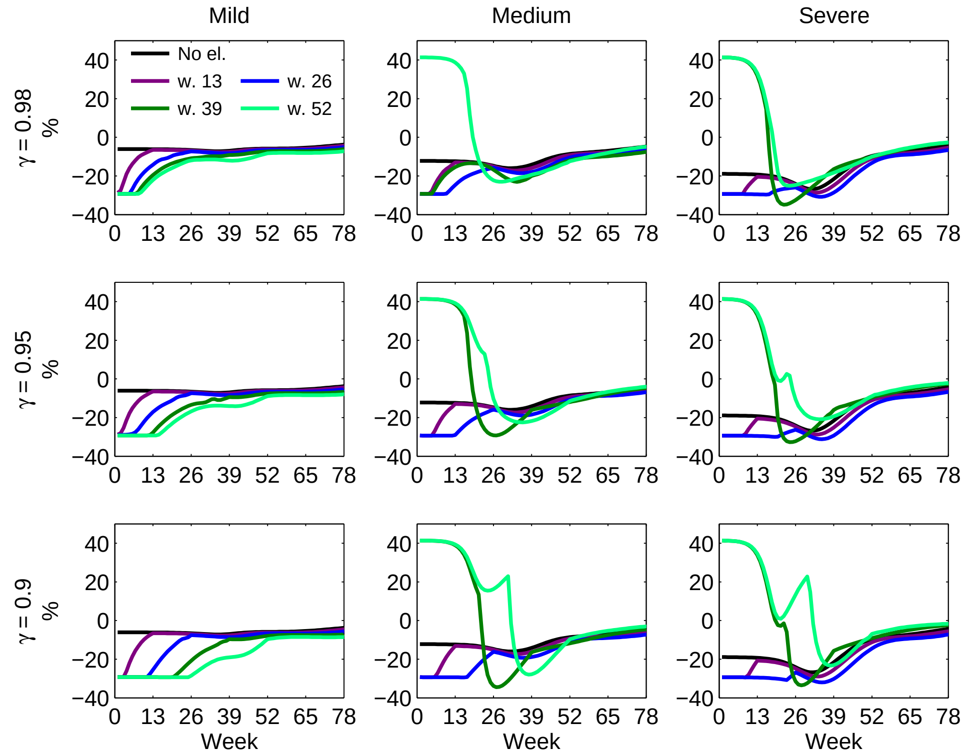
The plots compare the optimal (green) and the immediate, strict (blue) lockdown policies if the election is scheduled in week 39 (the medium variant of the epidemic development, $\gamma = 0.95$). The black dashed lines indicate the polling week.

virus spread as much as possible since the current lifetime social welfare is negatively related to the infection probability. If the expected development of the epidemic is slow, the high containment rates can keep the infection probability low even after three or four quarters from the outbreak, when the election is scheduled. However, if the epidemic is going to develop much faster, even strict lockdown policy cannot stop the virus long enough and the election may fall around the peak of the epidemic. In such cases, the better alternative is to accelerate the epidemic so the election will take place after the peak. This idea is illustrated in Figure 4, which compares the optimal policy of accelerating the epidemic peak with the immediate and strict lockdown when the election is scheduled at week 39 from the epidemic outbreak.

Figure 3 also illustrates the role of the political support decay parameter γ. Its lower values imply that the changes in the containment rates occur later as the impact of the economic situation on political support just before the election week becomes larger.

The effects of the discussed lockdown policies for the aggregate consumption are shown in Figure 5. Of course, a negative relationship exists between consumption and the containment rates. In the no-election case, the optimal policy results in a prolonged recession when the first-year consumption drops by 7-25% depending on the variant of the epidemic development. The stricter lockdown decreases consumption by more than 30%, whereas the negative containment rates lead to the economic booms.

Figure 5: The expected aggregate consumption under the optimal lockdown policies



The plots show the expected level of the aggregate consumption as compared with the no-epidemic steady-state level.

Table 2: The outcomes of the optimal lockdown policies

Variant	El. week	Welfare loss [% of cons.]			Lives saved [%]		
		$\gamma = 0.98$	$\gamma = 0.95$	$\gamma = 0.9$	$\gamma = 0.98$	$\gamma = 0.95$	$\gamma = 0.9$
Mild	13	-0.14	-0.16	-0.22	0.58	0.63	0.87
	26	-0.38	-0.47	-0.68	1.53	1.92	2.35
	39	-0.58	-0.84	-1.21	3.03	4.22	5.85
	52	-0.72	-1.09	-1.67	5.09	7.45	11.50
Medium	13	-0.17	-0.19	-0.22	0.66	0.74	0.77
	26	-0.42	-0.50	-0.61	1.71	2.06	2.53
	39	-0.30	-4.11	-5.00	3.26	3.22	0.49
	52	-4.20	-5.34	-6.48	2.08	-4.19	-11.58
Severe	13	-0.12	-0.13	-0.14	0.80	0.87	0.97
	26	-0.31	-0.35	-0.40	1.98	2.28	2.71
	39	-5.45	-6.14	-6.83	0.12	-3.05	-6.38
	52	-6.10	-7.04	-8.08	-4.04	-9.40	-14.75

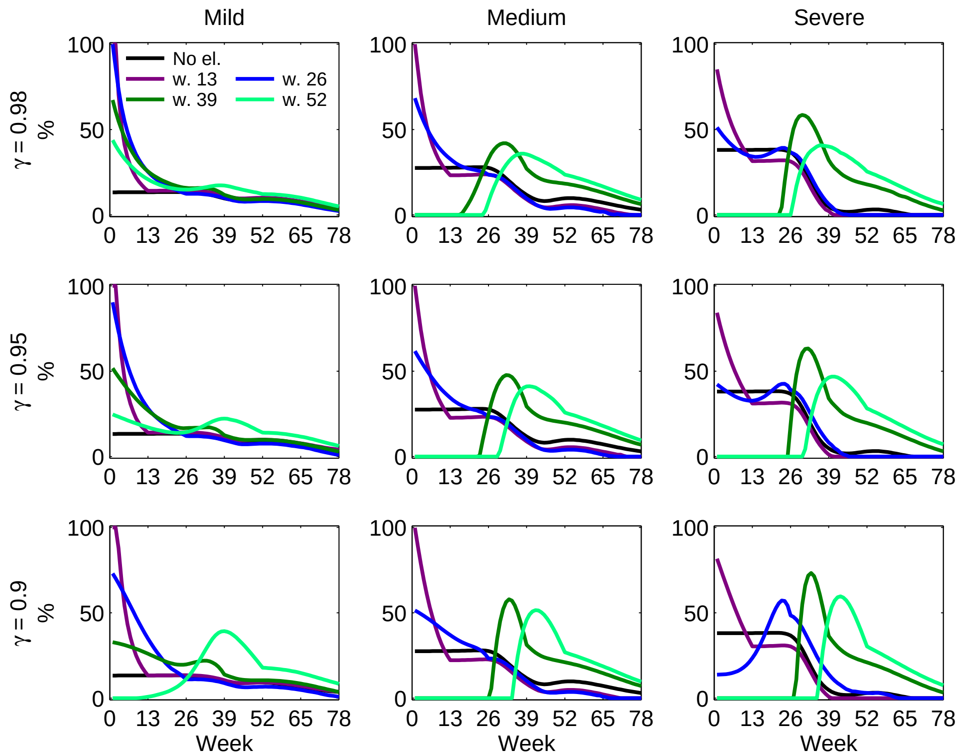
The table shows the welfare losses and expected lives saved for the optimal lockdown policies under the election perspective compared to the no-election case; the welfare losses are calculated for $t = 0$ and expressed as a proportional decrease in consumption in the whole period of three years.

The consequences of the lockdown policies for livelihoods and lives under the different election perspectives in relation to the no-election case are reported in Table 2. The welfare losses due to stricter lockdown in the case of short election perspective are rather small, especially if compared to the consumption drop caused by the lockdown itself, and do not exceed 1% of annual consumption in most cases. Only the prolonged lockdown in the case of the mild variant of the epidemic development coupled with the distant election perspective leads to losses exceeding 1%. The reduction of the death tolls resulting from the stricter lockdowns ranges from 0.5-2.5% for the short election perspective to even 11.5% in the case of the longest lockdown. The accelerating-the-peak policies lead to severe welfare (always) and losses (usually) of lives. The former ranges from -4% to -8% of annual consumption, whereas the latter from 3% to -15%.

5.2 The restricted policy

The unrestricted policy case considered in the previous subsection is useful for investigating the role of election for lockdown policy, but it is not very realistic. The severe and prolonged restrictions are likely to eventually become socially unacceptable and inefficient. These effects are difficult to capture in the model employed in this study.

Figure 6: The optimal restricted containment rates (μ_t)

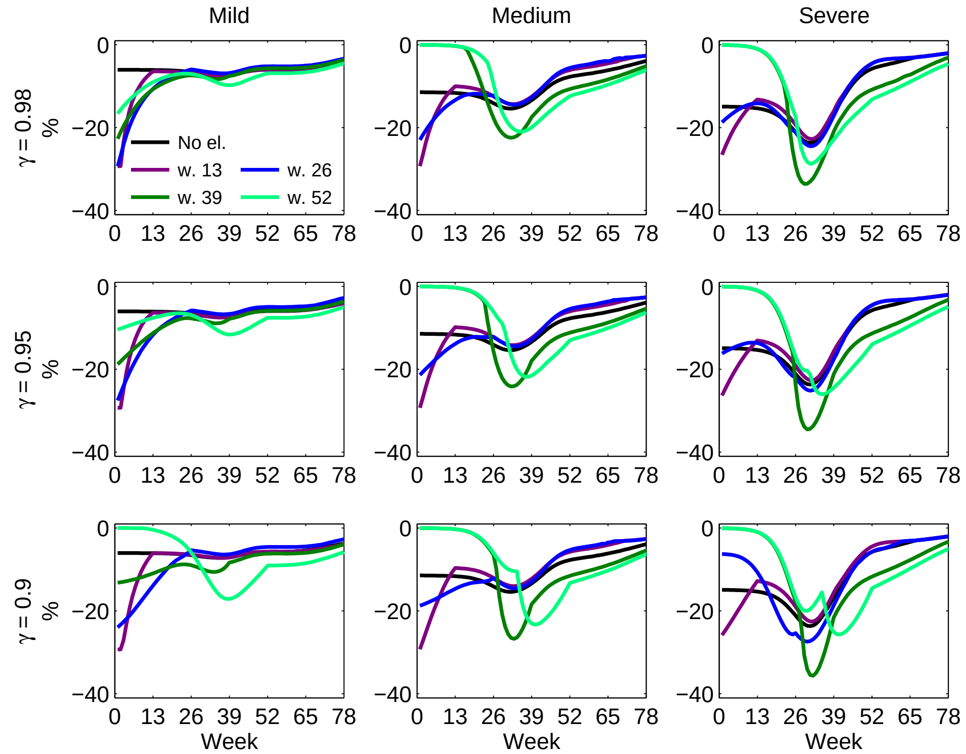


Therefore, I examine the optimal policy problem if it is exogenously restricted. More precisely, I assume that the expansionary policy is not possible and the lockdown cannot be more severe than the strict lockdown (when $\mu_t = 1$) lasting a quarter. Formally, the admissible containment rates satisfy the following conditions: $\mu_t \geq 0$ and $\sum_{t=0}^{T} \mu_t \leq 13$.

The optimal policies are depicted in Figures 6. The containment rates generally follow the similar pattern as in the unrestricted cases, that is, the restrictions are stricter if the polling week is close and delayed when the time to election is longer. As illustrated in Figure 7, the aggregate consumption is governed by the changes in the containment policy but the drops resulting from the voluntary reduction of consumers' activity due to insufficient containment measures when the epidemic peaks are also visible.

Table 3summarizes the effects of the restricted lockdown policies for welfare and lives. The welfare losses due to election are much lower compared to the unrestricted case. For the short election perspective, the losses do not exceed 0.2% of permanent consumption. If the election is distant, the losses barely exceed 1%, which stays in sharp

Figure 7: The expected aggregate consumption under the restricted lockdown policies



The plots show the expected level of the aggregate consumption as compared with the no-epidemic steady-state level.

Table 3: The outcomes of the optimal, restricted lockdown policies

Variant	El. week	Welfare loss [% of cons.]			Lives saved [%]		
		$\gamma = 0.98$	$\gamma = 0.95$	$\gamma = 0.9$	$\gamma = 0.98$	$\gamma = 0.95$	$\gamma = 0.9$
Mild	13	-0.15	-0.16	-0.18	0.36	0.17	-0.05
	26	-0.19	-0.20	-0.21	-0.79	-1.06	-1.29
	39	-0.12	-0.10	-0.06	-0.39	-0.27	0.07
	52	-0.06	-0.04	-0.18	0.64	1.36	3.09
Medium	13	-0.10	-0.11	-0.13	-1.27	-1.34	-1.49
	26	-0.07	-0.07	-0.06	-1.44	-1.48	-1.49
	39	-0.30	-0.38	-0.45	2.71	2.94	2.91
	52	-0.42	-0.49	-0.56	3.07	2.90	2.59
Severe	13	-0.06	-0.06	-0.07	-0.65	-0.69	-0.73
	26	-0.01	-0.01	-0.13	-0.05	0.21	1.37
	39	-0.81	-0.90	-0.99	3.65	3.44	3.12
	52	-0.94	-1.04	-1.12	3.00	2.44	1.96

The table reports the welfare losses and expected lives saved for the optimal lockdown policies under the election perspective compared to the no-election case; the welfare losses are calculated for $t = 0$ and expressed as a proportional decrease in consumption in the whole period of three years.

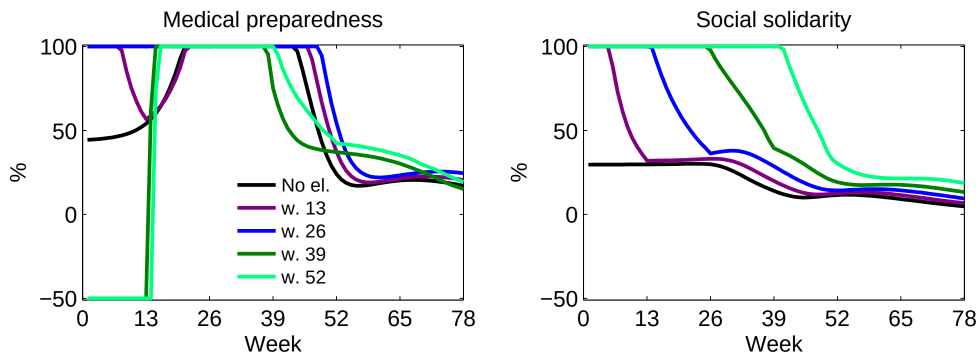
contrast with the corresponding high losses for the unrestricted policies.

The most interesting, however, are the results on the lives saved. Contrary to the unrestricted policy case, the early strict lockdown results in higher total deaths at the end when compared to the no-election case. On the other hand, the delayed lockdowns are lifesaving. The life gains and losses are rather small and never exceed 4%. These results can be easily explained in that if the lockdown cannot last long, its timing becomes very important. Early and strict lockdown is simply unnecessary because it should be introduced when the number of infected agents is sufficiently high. Late election favors delaying lockdown until the number of infections is sufficiently high and the containment measures are more effective for reducing the number of deaths.

5.3 The robustness checks

This subsection presents the results of two robustness checks. First, I examine the medical preparedness version of the model, where the fatality rate is positively related to the number of infected agents. This captures the effect of the healthcare failure in the case of a large number of infections. I use the quadratic specification of the IFR function proposed by Eichenbaum et al. (2020a) with the parameter $\kappa = 0.9$. Under

Figure 8: The optimal containment rates (μ_t) for the alternative variants of the model



The medium variant of the epidemic spread and $\gamma = 0.95$ are assumed everywhere.

this specification, the virus is much more lethal, with the IFRs reaching even 4% locally in the worst case.

The second modification is related to the specification of the political support function. So far, the social welfare in a given period was normalized by the total population, as shown by formula (28). This specification does not directly account for the disutility resulting from agent deaths. As the alternative, I consider a model where the social utility is not normalized by the total population. In this specification, labelled as ”social solidarity,” political support is very sensitive to the welfare losses caused by deceases.

The optimal containment policies for the two alternative variants are illustrated in Figure 8. The higher IFRs under the ”medical preparedness” model increase the optimal containment rates, but do not affect the general impact of election. The lockdown should be stricter if the election is close and delayed if the time from the outbreak to the election is long.

However, this is not the case in the ”social solidarity” version of the model. Here, the optimal policy is to impose the strict measures immediately and maintain them until the election. Of course, this is the direct consequence of assuming the extremely high value of life.

The costs and benefits of the having the election under the alternative versions of the model are summarized in Table 4. Under the ”medical preparedness” scheme, they generally follow the same scheme as in the baseline case. The strict and prolonged lockdowns in the ”social solidarity” model, save a moderate fraction of lives at relatively

Table 4: The outcomes of the optimal lockdown policies for the alternative variants of the model

Variant	El. week	Welfare loss [% of cons.]	Lives saved [%]
Medical preparedness	13	-0.15	1.93
	26	-0.29	4.39
	39	-6.05	-5.12
	52	-7.56	-9.20
Social solidarity	13	-0.19	0.76
	26	-0.52	2.13
	39	-0.98	4.78
	52	-1.48	9.27

The table reports the welfare losses and expected lives saved for the optimal lockdown policies under the election perspective compared to the no-election case; the welfare losses are calculated for $t = 0$ and expressed as a proportional decrease in consumption in the whole period of three years. The medium variant of the epidemic spread and $\gamma = 0.95$ are assumed everywhere.

small welfare costs.

6 Some evidence on the lockdown policies in countries with the scheduled elections

Due to the lack of sufficient empirical data, this study is theoretical in nature. In 2020 and early 2021, presidential or parliamentary elections were scheduled in only a few developed countries: the United States, South Korea, Singapore, and Poland.

In the United States, where the first cases of COVID-19 were reported in January and the election was scheduled for early November, the incumbent president D. Trump had long and purposefully downplayed the seriousness of the epidemic and was reluctant to lockdown the economy. Eventually, e restrictions were imposed in mid-March when the number of reported cases exceeded 1000. This slowed the epidemic but it accelerated again as the restrictions were lifted. The epidemic peaked in summer but in autumn, just before polling day, the daily number of infections started to increase once more as the strict restrictions were not reimposed.

The first cases in South Korea were also diagnosed in January but the parliamentary election was scheduled much earlier, in mid-April. Instead of locking down businesses, the government quickly launched a strategy of social distancing, widespread contact tracing, testing, and quarantining, which brought the epidemic under control almost immediately, gaining worldwide recognition. The number of new daily cases dropped from almost 1000 at the turn of February and March to less than 30 on polling day.

The situation in Singapore was similar to that of Korea although the general election was planned for July. The first cases were reported in January and the early phase of the epidemic was successfully controlled with the same strategy as in South Korea. Unfortunately, the virus eventually managed to spread rapidly in crowded migrant dormitories and a strict general lockdown had to be introduced.

The epidemic in Poland started much later as the first case was reported in early March whereas the presidential election was planned for May. After just a week, the government introduced a quick and strict lockdown including stay-at-home orders. The election was rescheduled to June and July, when most restrictions were lifted.

Of course, these examples are not intended to prove that governments follow the scheme proposed in this study. Instead, the results can be used to assess the lockdown policies from the perspective of incoming election. It is therefore worth noting that both the delayed lockdown in the case of the distant election in the United States as well as almost immediate reaction in Poland and South Korea, where the time to election was much shorter, are in line with the advice provided by this study.

7 Concluding remarks

This study theoretically analyzes how the design of lockdown policy is affected by the perspective of incoming political election. The results, obtained from the simple macro-SIR model suggest that if the election is scheduled shortly after the epidemic outbreak, the incumbent government tends to introduce quick and stricter lockdown compared to the no-election situation. On the other hand, if the election is distant it should be better to delay introducing the containment measures. In other words, the optimal strategy would be trying to steer the course of the epidemic so that the election would be held far from the epidemic peak.

Of course, the model used herein is unable to capture many important factors affecting results of political elections and linkages between economic activity and development of the epidemic. Nonetheless, the main message of the study should be robust to many missing features. In particular, this should apply to the stricter lockdown in the case of the short election perspective. In the short term, the benefit of slower development of the epidemic is likely to outweigh the costs resulting from the severe economic contraction. Because of the labor market rigidities and the generous fiscal programs, the negative effects of the lockdown for households can be delayed. Moreover, the social acceptance and effectiveness of a lockdown policy is likely to be higher at the epidemic outbreak. With time, societies become less responsive to the death tolls due to the epidemic and the acceptance of the severe containment measures that directly affect most of their members is likely to decline.

In the case of the distant election, the situation of an incumbent government is much more difficult because the strategy of delayed lockdown is definitely riskier. Given the high uncertainty regarding the key characteristics of the epidemic and the time-varying effectiveness of containment measures, the epidemic is difficult to manage. It is therefore possible that, contrary to the government's intention, the election will fall in a period of high and rapidly increasing number of infections. However, given the recurring waves of the epidemic currently observed in many countries, which, due to social and budgetary reasons, are difficult to restrain using the full lockdowns similar to those imposed during the first wave, the strategy of delaying containment measures is definitely worth considering.

As previously mentioned, the current lack of sufficient empirical data makes it impossible to verify the study's predictions. However, it is likely to change if no vaccine is developed soon. In 2021, important elections are scheduled to take place in many developed countries including the United States, Japan, Germany, South Africa, and Argentina, among others. Balancing economic and epidemic conditions and perspectives before the election would undoubtedly be one of the most important objectives for the incumbent governments.

References

Abramowitz, Alan I. (1988) "An Improved Model for Predicting Presidential Election Outcomes," *PS: Political Science & Politics*, Vol. 21, p. 843–847.

——— (2016) “Will Time for Change Mean Time for Trump?” *PS: Political Science & Politics*, Vol. 49, p. 659–660.

Acemoglu, Daron, Victor Chernozhukovz, Ivan Werning, and Michael D. Whinston (2020) “Optimal Targeted Lockdowns in a Multi-Group SIR Model,” Working Papers 826, Economic Research Southern Africa.

Aleta, Alberto, David Martin-Corral, Ana Pastore y Piontti, Marco Ajelli, Maria Litvinova, Matteo Chinazzi, Natalie E. Dean, M. Elizabeth Halloran, Ira M. Longini, Stefano Merler, Alex Pentland, Alessandro Vespignani, Esteban Moro, and Yamir Moreno (2020) “Modeling the impact of social distancing, testing, contact tracing and household quarantine on second-wave scenarios of the COVID-19 epidemic,” *Nature Human Behaviour*, Vol. 4, pp. 964–971.

Alvarez, Fernando E., David Argente, and Francesco Lippi (2020) “A Simple Planning Problem for COVID-19 Lockdown,” NBER Working Papers 26981, National Bureau of Economic Research.

Andersson, Tommy, Albin Erlanson, Daniel Spiro, and Robert Östling (2020) “Optimal Trade-Off between Economic Activity and Health during an Epidemic,” Working Papers 2020:8, Lund University, Department of Economics.

Aspri, Andrea, Elena Beretta, Alberto Gandolfi, and Etienne Wasmer (2020) “Mortality containment vs. economics opening: optimal policies in a SEIARD model,” Papers 2006.00085, arXiv.org.

Atkeson, Andrew (2020) “What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios,” NBER Working Papers 26867, National Bureau of Economic Research.

Azzimonti-Renzo, Marina, Alessandra Fogli, Fabrizio Perri, and Mark Ponder (2020) “Pandemic Control in ECON-EPI Networks,” Staff Report 609, Federal Reserve Bank of Minneapolis.

Bendavid, Eran, Bianca Mulaney, Neeraj Sood, Soleil Shah, Emilia Ling, Rebecca Bromley-Dulfano, Cara Lai, Zoe Weissberg, Rodrigo Saavedra-Walker, James Tedrow, Dona Tversky, Andrew Bogan, Thomas Kupiec, Daniel Eichner, Ribhav Gupta, John Ioannidis, and Jay Bhattacharya (2020) "COVID-19 Antibody Seroprevalence in Santa Clara County, California," *medRxiv*, https://www.medrxiv.org/content/early/2020/04/30/2020.04.14.20062463.

Bethune, Zachary and Anton Korinek (2020) "COVID-19 infection externalities: Pursuing herd immunity or containment?" *Covid Economics. Vetted and Real Time Papers*, Vol. 11, pp. 1–34.

Birinci, Serdar, Fatih Karahan, Yusuf Mercan, and Kurt See (2020) "Labor Market Policies During an Epidemic," Working Papers 2020-024, Federal Reserve Bank of St. Louis.

Brotherhood, Luiz, Philipp Kircher, Cezar Santos, and Michèle Tertilt (2020) "An Economic Model of the Covid-19 Epidemic: The Importance of Testing and Age-Specific Policies," CESifo Working Paper Series 8316, CESifo.

Çakmakli, Cem, Selva Demiralp, Şebnem Kalemli-Özcan, Sevcan Yeşiltaş, and Muhammed A. Yildirim (2020) "COVID-19 and Emerging Markets: An Epidemiological Model with International Production Networks and Capital Flows," NBER Working Papers 27191, National Bureau of Economic Research, Inc.

Costa-Filho, Joao and António Neto (2020) "Is democracy affecting the economic policy responses to COVID-19? A cross-country analysis," MPRA Paper 101235, University Library of Munich, Germany.

De Neve, Jan-Emmanuel (2014) "Ideological change and the economics of voting behavior in the US, 1920-2008," *Electoral Studies*, Vol. 34, pp. 27–38.

Eichenbaum, Martin S, Sergio Rebelo, and Mathias Trabandt (2020a) "The Macroeconomics of Epidemics," NBER Working Paper 26882, National Bureau of Economic Research.

——— (2020b) "The Macroeconomics of Testing and Quarantining," NBER Working Paper 27104, National Bureau of Economic Research.

Engle, Samuel, Jussi Keppo, Marianna Kudlyak, Elena Quercioli, Lones Smith, and Andrea Wilson (2020) "The Behavioral SIR Model, with Applications to the Swine Flu and COVID-19 Pandemics," manuscript.

Erikson, Robert S. and Christopher Wlezien (2016) "Forecasting the Presidential Vote with Leading Economic Indicators and the Polls," *PS: Political Science & Politics*, Vol. 49, p. 669–672.

Fair, Ray C. (1978) "The Effect of Economic Events on Votes for President," *The Review of Economics and Statistics*, Vol. 60, pp. 159–173.

——— (2012) *Predicting Presidential Elections and Other Things. Second Edition*, Stanford: Stanford University Press.

Faria-e-Castro, Miguel (2020) "Fiscal Policy During a Pandemic," FRB St. Louis Working Paper 2020-006, Federal Reserve Board St. Louis.

Garibaldi, Pietro, Espen R. Moen, and Christopher A. Pissarides (2020) "Modelling contacts and transitions in the SIR epidemics model," *Covid Economics. Vetted and Real-Time Papers*, Vol. 5, pp. 1–20.

Glover, Andrew, Jonathan Heathcote, Dirk Krueger, and José-Víctor Ríos-Rull (2020) "Health versus Wealth: On the Distributional Effects of Controlling a Pandemic," NBER Working Papers 27046, National Bureau of Economic Research.

Gonzalez-Eiras, Martín and Dirk Niepelt (2020) "On the Optimal "Lockdown" during an Epidemic," CESifo Working Paper Series 8240, CESifo.

Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Iván Werning (2020) "Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?" NBER Working Paper 26918, National Bureau of Economic Research.

Gunzler, Douglas and Ashwini R Sehgal (2020) "Time-Varying COVID-19 Reproduction Number in the United States," *medRxiv*, https://www.medrxiv.org/content/10.1101/2020.04.10.20060863v1.

Hallal, Pedro, Fernando Hartwig, Bernardo Horta, Gabriel D Victora, Mariangela Silveira, Claudio Struchiner, Luis Paulo Vidaletti, Nelson Neumann, Lucia C Pellanda, Odir A Dellagostin, Marcelo N Burattini, Ana M Menezes, Fernando C Barros, Aluisio J Barros, and Cesar G Victora (2020) "Remarkable variability in SARS-CoV-2 antibodies across Brazilian regions: nationwide serological household survey in 27 states," *medRxiv*, https://www.medrxiv.org/content/early/2020/05/30/2020.05.30.20117531.

Hortaçsu, Ali, Jiarui Liu, and Timothy Schwieg (2020) "Estimating the Fraction of Unreported Infections in Epidemics with a Known Epicenter: an Application to COVID-19," *Journal of Econometrics*, in press.

Ives, Anthony R and Claudio Bozzuto (2020) "State-by-State estimates of R0 at the start of COVID-19 outbreaks in the USA," *medRxiv*, https://www.medrxiv.org/content/early/2020/05/27/2020.05.17.20104653.

Kaplan, Greg, Benjamin Moll, and Giovanni L Violante (2020) "The Great Lockdown and the Big Stimulus: Tracing the Pandemic Possibility Frontier for the U.S.," NBER Working Paper 27794, National Bureau of Economic Research.

Kermack, William Ogilvy and Anderson G. McKendrick (1927) "A Contribution to the Mathematical Theory of Epidemics," *Proceedings of the Royal Society of London. Series A*, Vol. 115, pp. 700–721.

Krueger, Dirk, Harald Uhlig, and Taojun Xie (2020) "Macroeconomic Dynamics and Reallocation in an Epidemic," NBER Working Paper 27047, National Bureau of Economic Research.

Kuhl, Ellen (2020) "Data driven modelling of COVID-19 — Lessons learned," *Extreme Mechanics Letters*, Vol. 40, p. 100921, https://doi.org/10.1016/j.eml.2020.100921.

Kwok, Kin On, Florence Lai, Wan In Wei, Samuel Yeung Shan Wong, and Julian W.T. Tang (2020) "Herd immunity — estimating the level required to halt the COVID-19 epidemics in affected countries," *Journal of Infection*, Vol. 80, pp. e32–e33, in press.

Lewis-Beck, Michael S. and Tom W. Rice (1982) "Presidential Popularity and Presidential Vote," *Public Opinion Quarterly*, Vol. 46, pp. 534–537.

Lewis-Beck, Michael S. and Mary Stegmaier (2018) *Election Forecasting: Scientific Approaches*, pp. 742–749, New York, NY: Springer New York.

Makris, Miltiadis (2020) "Covid and Social Distancing with a Heterogenous Population," Studies in Economics 2002, School of Economics, University of Kent.

Meyerowitz-Katz, Gideon and Lea Merone (2020) "A systematic review and meta-analysis of published research data on COVID-19 infection-fatality rates," *medRxiv*, https://www.medrxiv.org/content/early/2020/07/07/2020.05.03.20089854.

Miclo, Laurent, Jörgen W. Weibull, and Daniel Spiro (2020) "Optimal epidemic suppression under an ICU constraint," TSE Working Papers 20-1111, Toulouse School of Economics (TSE).

Moser, Christian A. and Pierre Yared (2020) "Pandemic Lockdown: The Role of Government Commitment," NBER Working Papers 27062, National Bureau of Economic Research.

Peirlinck, Mathias, Kevin Linka, Francisco Sahli Costabal, and Ellen Kuhl (2020) "Outbreak dynamics of COVID-19 in China and the United States," *Biomechanics and Modeling in Mechanobiology*, pp. 1–15.

Piguillem, Facundo and Liyan Shi (2020) "Optimal COVID-19 Quarantine and Testing Policies," EIEF Working Papers Series 2004, Einaudi Institute for Economics and Finance (EIEF).

Pollinger, Stefan (2020) "Optimal Case Detection and Social Distancing Policies to Suppress COVID-19," TSE Working Papers 20-1109, Toulouse School of Economics (TSE).

Toda, Alexis Akira (2020) "Susceptible-Infected-Recovered (SIR) Dynamics of COVID-19 and Economic Impact," manuscript, University of California San Diego.

Vandenbroucke, Guillaume (2020) "Endogenous Social Distancing in an Epidemic," Working Papers 2020-013, Federal Reserve Bank of St. Louis.

Wilson, Linus (2020) "SARS-CoV-2, COVID-19, Infection Fatality Rate (IFR) Implied by the Serology, Antibody, Testing in New York City," manuscript, SSRN.

Wlezien, Christopher and Robert S. Erikson (2004) "The Fundamentals, the Polls, and the Presidential Vote," *PS: Political Science & Politics*, Vol. 37, pp. 747–751.

Zolghadr, Mohammad, Seyed Armin Akhavan Niaki, and S. T. A. Niaki (2018) "Modeling and forecasting US presidential election using learning algorithms," *Journal of Industrial Engineering International*, Vol. 14, pp. 491–500.