On the Economic Benefits and Costs of COVID-19 Mitigation Measures in Mexico

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Abstract

In this paper I calculate the daily flows of COVID-19 cases under the current scenario of recommended social distance and restricted economic activity, and under a counterfactual uncontrolled scenario with no mitigation measures. Using official sources, I quantify the supply of hospital beds and ICUs to project the fatality of cases under both scenarios. I estimate that social distance will reduce the number of COVID-19 cases in 65%. The benefits of mitigation measures amount to a reduction of over 119,000 direct fatalities and about 121,000 deaths due to healthcare system overflow. The benefits of these measures are monetized as 697 billion USD. I estimate that the net cost of mitigation in terms of output gap over a 60-months recovery period represents 29% of 2019 Mexico's GDP. This cost would be reduced if a faster recovery occurs or if the government stimulates the economy enough to reduce output gap between the mitigation scenario and the uncontrolled scenario, making a case for an active role of fiscal policies.

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Introduction

The 2019 coronavirus disease (COVID-19) has caused more than 212,000 deaths over the course of 2020. The pandemic has spread over 210 countries and produced vast health, economic and social impacts. In the absence of a clinical approved treatment and the long development periods of vaccines, social distance measures have been implemented around the World with the objective of slowing the virus transmission, reducing the pressure on the healthcare system, and minimizing the effects in terms of severe illnesses and deaths. Although these measures have shown to be effective in reducing social contact, their economic costs are expected to be high.

The costs of these measures and the diversity of government responses around the world have provoked political and academic debates on whether these policies can be grounded on economic terms. In this paper I pursue the following three objectives to inform these active debates. First, I quantify the daily demand for specialized healthcare during the COVID-19 epidemic to project the exerted pressure on the limited health infrastructure and resources in Mexico. Second, I quantify the expected deaths over the course of the epidemic and contrast this death toll with the counterfactual scenario where no mitigation measures are implemented. And thirdly, I monetize the benefits of mitigation measures to provide an estimate of the costs of control and how it compares to the large macroeconomic impacts that are likely to occur.

I use the Mexican Health Secretary projections of peak dates and number of cases at the peak for the COVID-19 epidemic to calculate the daily flows of cases under the current scenario of recommended social distance and other mitigation policies, and under a counterfactual uncontrolled scenario in which no action is taken. I estimate the total number of COVID-19 cases to amount 547,000 and 189,000 under the uncontrolled and controlled scenarios, respectively. I use parameters borrowed from the active COVID-19 literature to project the share of cases that would be indicated hospitalization and intensive care units (ICU). I find that mitigation measures reduce healthcare demand by 65%.

I use official sources on the stock of medical equipment in the private and public sectors to quantify the supply of hospital beds and ICUs available for treating COVID-19 patients. Although a rough approximation to the number of beds in the country is the 1.4 beds per thousand inhabitants reported by the OECD (2017), I estimate that only 12,241 hospital beds and 1,070 ICUs are available during the epidemic.

Using estimates of the survival probability for ambulatory cases, and for cases requiring hospitalization and ICU when appropriate care is provided or denied, I estimate the total fatalities due to the COVID-19 disease. I estimate a reduction in the number of deaths of 80% under a mitigation scenario, compared to the counterfactual uncontrolled scenario. I also estimate that around 120,000 deaths can be avoided by delaying and reducing the healthcare system overflow.

I monetize the benefits of mitigation measures using an estimate of the value of a statistical life (VSL) of 2.9 million USD. These benefits amount to 697 billion USD. Assuming a slow economic recovery of 60 months, the accumulated net cost in terms of output represents about 29% of 2019 Mexico's GDP.

Rather than providing exact break-even figures through a sharp cost-benefit analysis, the main objective of this paper is organizing the discussion on the factors that affect the effectiveness of mitigation interventions and informing policy making and public discussion at a stage when uncertainty feeds political confrontation and misinformation.

In Section 1 I briefly describe the mitigation measures followed by the Mexican government to reduce the speed of COVID-19 contagion. In Sections 2 to 6 I present the set of assumptions and calculations in order to project the size of daily flow of cases, excess of demand for beds and ICUs, and deaths. In Section 7 I monetize the benefits of mitigation measures. Section 8 puts these benefits in the context of the expected losses in terms of output projected for the Mexican economy. Section 9 shows the sensitivity of my results to a set of alternative parameters. Finally, Section 10 discusses the implications of my findings and concludes.

1 The COVID-19 disease and non-pharmaceutical public interventions in Mexico

Several research teams around the globe are currently working on developing a treatment for the COVID-19 disease and on finding a vaccine that can be safely applied to humans. In the meantime, national governments have relied on non-pharmaceutical interventions (Ferguson et al., 2020) to reduce the virus transmission by limiting the rates of contact within a population. There are two main strategies that non-pharmaceutical interventions can pursue. The first one, *suppression*, consists in reducing the number of cases each other case generates, that is, reducing the *transmission number* to below 1. The problem with this strategy is that the interventions must be sustained for long periods or implemented periodically until a vaccine is proved to be effective (Anderson et al. 2020). The second one, *mitigation*, does not aim to stop transmission entirely, but making the health impact of the epidemic manageable. This allows delaying the infection peak, buying time for the healthcare system to prepare for weeks of intense demand, and reducing the number of daily patients requiring specialized care. Under the mitigation scenario, still many patients are expected to die, and hospitals and ICUs will very likely be overflown (Ferguson et al., 2020).

The geographical spread of COVID-19 implies that countries have implemented different types of non-pharmaceutical interventions at different stages. The first COVID-19 case in Mexico was confirmed on February 29, 45 days after the first COVID-19 case was confirmed outside China (January 13 in Thailand), and 36 days after the first confirmed case in America (January 20 in the US). In Figure 1 I show the date of the first confirmed cases in selected countries in the Americas, together with the number of cases per million inhabitants confirmed by April 29.

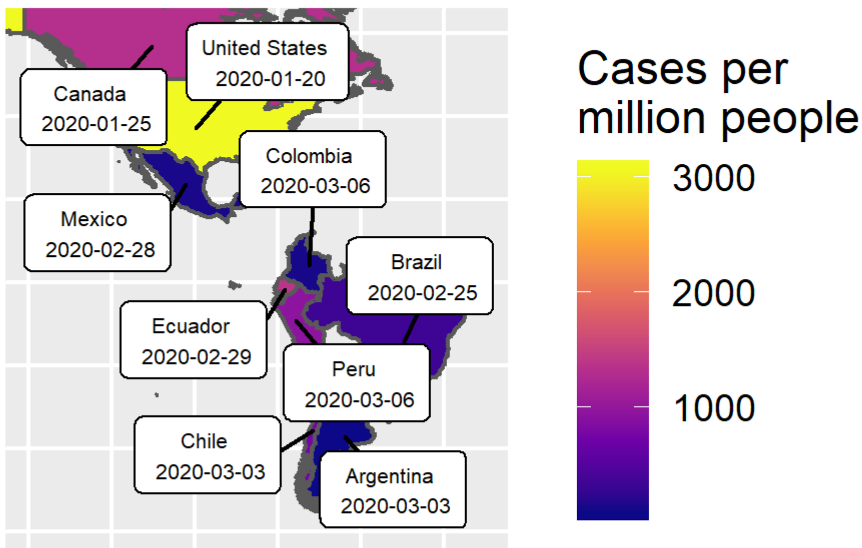


Figure 1: Dates of first confirmed case and number of cases per million inhabitants as of April 29 in selected American countries.

The Mexican government has implemented a series of policies divided into three stages. Stage 1 was defined as from the beginning of the outbreak and while the existing cases in the country could be all traced to patients that had been infected abroad. During this period, the government emphasized public communication on the benefits of hygiene and on reducing social contact. Masks efficacy at the beginning of the epidemic was questioned and not mandated, while security personnel at airports did not perform strict screening as the evidence about its effectiveness was questionable.[1] The school system canceled activities starting March 20. With the beginning of Stage 1, the federal government also began a

[1]See for example: 'Why airport screening won't stop the spread of coronavirus', at https://www.sciencemag.org/news/2020/03/why-airport-screening-wont-stop-spread-coronavirus.

public communication campaign recommending social distance, and scheduled a daily news conference for updates on the latest figures of cases and fatalities in the country.

On March 24, the Health Secretary announced the beginning of community contagion (presence of cases with no travel background) triggering Stage 2. Massive public events were canceled. Starting March 26, an official mandate indicated the cancellation of non-essential activities in all sectors of the economy.[2] Workers above 65 years of age, pregnant women, workers with disabilities, and immunosuppressed individuals where allowed paid leave. On March 30, the Health Council declared the state of *health emergency* and extended the period of cancellation of non-essential activities until April 30. With the beginning of Stage 2, the Health Ministry launched a sentinel surveillance system to track the progression of the epidemic. I briefly describe this surveillance model in Section 2.

On April 23, the Stage 3 of epidemic contagion was declared. During this stage, the daily number of cases, hospitalizations and patients requiring specialized care rise exponentially. Gatherings of more than 50 people are not allowed, while home-office is recommended whenever possible. As of the writing of this manuscript, schools are still closed, while non-essential activities at all sectors of the economy remain paralyzed. In the meantime, the Education Secretary struggles at implementing remote learning in a country where only about a half of households have an internet access and where broadband speed remains the second lowest for an OECD country.[3] On the other hand, while teleworking has been recommended, only about a fifth of workers can work from home (Monroy, 2020).

In brief, mitigation measures in Mexico rely heavily on public communication and non-compulsory social distance. The emphasis has been on restricting social contact by limiting economic activity. At the moment, no mandatory lock-downs have been implemented and those who cannot afford to work from home are still allowed to be outside. Several local governments have made masks mandatory for public spaces and have restricted the supply of public transportation.

All suppression and mitigation measures will have an enormous effect on economic activity around the World. The IMF (2020) estimates a global contraction of 3% during 2020, with a recovery becoming evident only by 2021. More open and integrated economies are expected to perform worst due to the paralysis in the production chains, the collapse of the touristic sector, and the uncertainty on the progression of the epidemic, which has put many investment projects on hold. In the following sections I provide estimates of the benefits of mitigation policies and compare these benefits to the costs of the control in terms of aggregate output.

[2] `https://www.dof.gob.mx/nota_detalle.php?codigo=5590339&fecha=24%2F03%2F2020`.

[3] 7.5 megabites per second (Akami, 2017).

2 Projecting the size of the epidemic in Mexico

Predicting the final size of the epidemic is a difficult task, mainly because of the limited amount and characteristics of available data at the beginning of the event. During the first weeks after the outbreak, data generation efforts were mainly focused on informing the detection of cases to isolate individuals in order to slow the speed of contagion. Thus, most early data suffer of typical problems of selection and censoring (Hauser, et al., 2020) resulting in a lack of representativity. With the beginning of community contagion, the Health Secretary began operating a sentinel surveillance model. This model uses 376 monitoring healthcare units in sites with high probability of seeing COVID-19 cases. These monitoring units must have specialized medical personnel and high-quality laboratories.[4]

The sentinel surveillance allows to identify the early progression of the epidemic without massive testing. Since the majority of cases are asymptomatic, most COVID-19 cases will never reach the healthcare system. Thus, the sentinel model aims to capture most of the symptomatic cases that are those likely to exert pressure on the limited health resources. The model has been criticized for not yielding certainty on the total cases within the population.

Some authors have estimated the size of the epidemic in Mexico and the implied case fatality ratio (CFR). Nevertheless, many of the early estimates rely on a limited amount of data, yielding non-robust predictions.[5] In this paper I circumvent the problem of estimating the size of the epidemic by taking as a starting point the Health Secretary's official predictions made available at a news conference on April 16[6]. I take these predictions as given and assume they are the base for public policy decisions. Thus, I can compare the benefits of mitigation measures with the observed interventions costs in terms of output. Since another of the objectives of this paper is to quantify how mitigation measures reduce the pressure on the health system, I consider that the data from the sentinel model provide a good approximation to the total number of cases that require specialized health care.

The Health Secretary estimates imply that, under an uncontrolled scenario with no mitigation measures taken, the epidemic would have peaked around the first week of April, reaching a maximum of 30,000 new daily cases. On the other hand, the Health Secretary projects that with mitigation measures the peak of the epidemic will happen around the third week of May, reaching over 5,000 new daily cases. Unfortunately, the data and models

[4]`https://www.who.int/immunization/monitoring_surveillance/burden/vpd/surveillance_type/sentinel/en/`.

[5]See for example Luo (2020) for a more optimistic scenario than the one used in this paper as controlled scenario in Mexico.

[6]`https://mexico.quadratin.com.mx/de-mantener-medidas-de-mitigacion-proyectan-25-de-junio-fin-de-epidemia/`.

used to obtain such estimates are not publicly available.[7]

I take the peak dates and the maximum number of daily cases at the peak as given and recover the full distribution of cases under the two scenarios. I assume the uncontrolled and controlled peak dates are April 1 and May 22[8], respectively, and that peak heights are 30,000 and 5,000 cases. I follow Greenstone and Nigam (2020) in assuming a normal distribution for the daily counts of cases (and deaths).

For the uncontrolled scenario, I thus know x and $\phi(x)$ at two points, the peak and the first case date. Then, I solve for the value of the standard deviation (σ_c) that satisfies $\phi(Apr\ 21) = 30,000$ and $\phi(Feb\ 28) = 1$. The implied standard deviation turns out to be $\sigma_c = 7.27$.

For the controlled scenario, I use the actual data of cases from the Health Secretary to solve a non-linear least squares problem for the standard deviation, given the known peak date. I scale up the problem using the value of $\phi(May\ 22) = 30,000$. The estimated standard deviation is $\sigma_c = 15.06$ (s.e 0.2328). In solving the problem I use data from February 27 to May 1st.

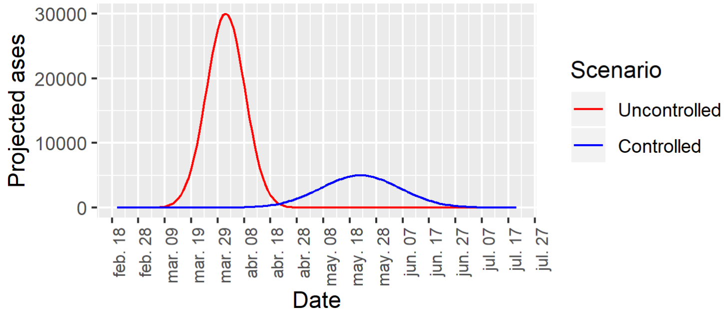
In Figure 2 I show the computed distributions of cases under the uncontrolled and controlled scenarios, together with an image of the Health Secretary projected curves.

Greenstone and Nigam (2020) follow a similar approach to approximate the US' deaths curves from Ferguson et al. (2020) study. Ferguson and colleagues use primary data from China and other countries with early COVID-19 outbreaks, together with the distribution of cases across ages to estimate the expected number of cases and deaths. In their early work, Ferguson and coauthors estimated that the total number of deaths in the US would have been of 2.2 million without social distance measures and 1.1 million under the controlled scenario. Although Greenstone and Nigam (2020) did not have access to Ferguson's data, they recovered almost the same amount of deaths using normal approximations.

My estimates imply a total number of confirmed COVID-19 cases in Mexico of 546,516 (assuming a single wave of contagion) under the uncontrolled scenario and of 188,750 under the controlled scenario of social distance and other mitigation measures. Figure 3 shows the fitted curve in the controlled scenario and the actual observed data of new cases. All my calculations and comparisons consider this is the scenario we are currently experimenting and that no further actions will reshape the parameters that govern the distribution. Of course, this would chang if, for example, mitigation measures are lifted earlier. In Table 1 I summarize these findings.

[7] I analyze the sensitivity of my analysis to changes in the peak dates and sizes of cases peaks.

[8] A BBVA SIR logistic model estimates a similar peak date. See: https://www.bbvaresearch.com/publicaciones/mexico-covid-19-semana-16-proyecciones-sir-bt-arima-y-comparativo-internacional/.



(a)

(b)

Figure 2: (a) Fitted cases distribution, (b) Health Secretary cases projection.

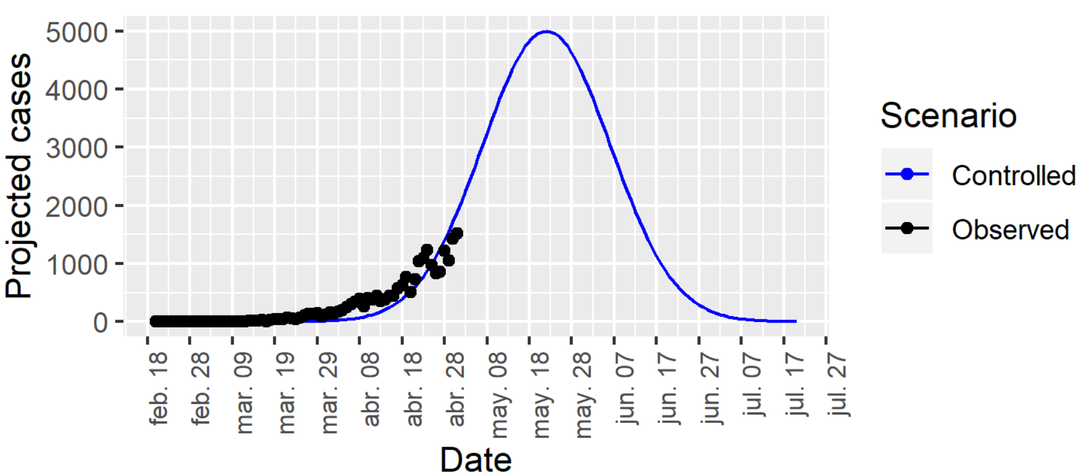


Figure 3: Fitted and observed under the controlled scenario

Table 1: Peak date, cases at peak, and estimated size of the COVID-19 epidemic in Mexico

	Uncontrolled	Controlled
Date of peak cases *	April 1	May 22
Daily new cases at peak *	30,000	5,000
Estimated standard deviation	7.27	15.06
Estimated total cases	546,516	188,750

* Mexico's Health Secretary's projection.

3 Estimating hospital and ICU demand

The Harvard Global Health Institute (HGHI) uses an estimate of 20% of COVID-19 cases requiring hospitalization for modeling the demand for healthcare in the US.[9] This 20% estimate is obtained from Verity et al. (2020), who employ the early data from Wuhan and other countries to estimate the CFR at different ages, accounting for the increased probability of hospitalization for patients over 65 years of age.

On the other hand, Ferguson et al. (2020) estimate the impact of diverse types of interventions on COVID-19 cases number and fatality. According to their read of the relevant literature, about two thirds of cases are not severe and do not require hospitalization.

In order to estimate the demand for a hospital bed in Mexico, I use Ferguson's proportion (0.33) for both the uncontrolled and controlled scenario. Although there is scarce conclusive evidence on this proportion, this figure is not far from the observed share of hospitalized cases reported in Mexico (39% as of May 1st). I will assume the same proportion for the uncontrolled scenario. I thus assume there are not good reasons for the symptoms severity to be different across scenarios.

Similarly, according to the HGHI, up to 5% of COVID-19 cases require ICU, which might include a ventilator. With these two proportions, an estimate of daily and accumulated demands for hospital beds and ICUs can be computed. Table 2 shows the results of these calculations. I estimate over 180,000 patients would have needed a hospital bed and over 27,000 would have required a ICU. These figures decrease to 62,000 and 9,000 with mitigation policies. At the peak date, mitigation measures reduce the demand for healthcare by 83%.

[9] https://www.propublica.org/article/methodology-how-propublica-mapped-hospital-capacity-for-coronavirus

Table 2: Hospital bed and ICU demand

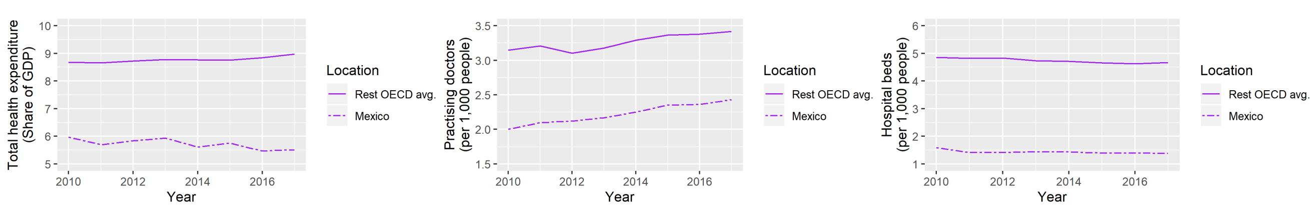
	Uncontrolled	Controlled
Hospital bed accumulated demand	180,350	62,287
ICU accumulated demand	27,326	9,437
Daily hospital bed demand at peak	9,900	1,655
Daily ICU demand at peak	1,500	251

Source: own calculations based on cases projection and parameters from the literature.

These calculations are crucial for estimating the daily fatality since the survival probability depends on whether the indicated healthcare is received or not. In the following section, I calculate the availability of healthcare resources to project the expected daily supply of beds and ICUs.

4 Healthcare supply

The COVID-19 epidemic exhibited structural deficiencies of the Mexican healthcare system. Over the last 10 years, the total expenditure on health in the economy has remained about constant and represents only 60% of the average expenditure in the remaining OECD countries. During the same period, the stock of resources has also remained almost unchanged once accounting for population growth. In Figure 4 I present three indicators that contextualize how unlikely is that the Mexican healthcare can handle a large number of severe COVID-19 cases.



(a) (b) (c)

Figure 4: Comparison of three health indicators for Mexico and the rest of OECD countries: (a) Health expenditure as share of GDP, (b) Number of doctors per 1,000 people, and (c) Number of beds per 1,000 people. Source: World Bank (2020).

For responding to the COVID-19 epidemic, the public and the private sectors have redirected an enormous amount of resources. The availability of resources is extremely important since the survival probability of COVID-19 patients depends mainly on demographic factors, the presence of comorbidities, and, critically, on the provision of adequate specialized care when indicated.

I rely on several sources of data to approximate the total stock of hospital beds and ICU facilities that would be available for COVID-19 patients over the epidemic. According to OECD (2017) figures, there are 1.4 beds per 1,000 inhabitants, the lowest for any OECD member country. Nevertheless, not all of these beds are properly hospitalization beds. Using official data from the Health Secretary's (2020) Catalog of Health Establishments (CLUES) I calculate the stock of hospitalization beds to be 123,214 beds (including both, private and public sectors). For the stock of ICUs, I rely on the same Health Secretary's (2018) Health Resources Open Data. According to this source, there are 3,800 ICU beds in Mexico. Furthermore, the private sector announced it would put at government's disposal up to 3,000 hospital beds and 500 ICUs.[10] This increases notably the capacity of the health sector for handling the epidemic.

In order to convert the stocks of beds and ICUs to daily availability, one must consider that most of the healthcare resources, are always in high demand. Thus, we must take into account the availability of resources given that other non-related COVID-19 cases also push the healthcare demand. Governments have tried to get around this allocation problem by postponing elective treatments in order to free physical and human resources.

Greenstone and Nigam (2020) estimate that up 37% of ICU beds in the US are readily available for treating COVID-19 patients. Moghadas et al. (2020) use a 65% availability to project COVID-19 patients hospital demand in the US. Nevertheless, the health system in Mexico is likely to be under higher demand. According to OECD (2019), the bed occupancy rate in Mexico is 74%, while using internal evaluations, some analyst report[11] that the maximum bed availability is between 10 and 15%. In this paper, I will assume a resources' availability of 15%, for both, hospital beds and ICUs.

Daily bed availability depends also on the severity of the case. Ferguson et al. (2020) and Greenstone and Nigam (2020) assume every ICU patient uses a bed for 12 days, somehow lower than the reported hospitalization duration of 15 days in Hong Kong, Japan, Singapore and South Korea (Gaythorpe, 2020). Guan et al. (2020) estimate that the average hospital stay is 12 days long. In this paper I assume an average length of use of 12 days.

A final piece of information to project the daily supply of hospital beds is that the estimated stock (123,214) is dispersed around all of types of medical specialties, so not every

[10]https://www.eluniversal.com.mx/english/mexican-government-use-private-hospitals-treat-covid-19-patients

[11]See for example: https://medium.com/@datavizero/cu%C3%A1ntas-camas-hay-en-los-hospitales-de-m%C3%A9xico-9fa8ca7eee6a.

bed can be considered as adequate for a COVID-19 patient. Using the most recent Health Secretary's (2018) Health Resources Open Data (with data only available for public health units), I present in Table 3 the share of beds in each medical specialty. I make an assumption that 50% of the available stock of beds can be used or modified to receive COVID-19 patients, mainly considering that even if the physical capacity could be easily converted, it is difficult to think that the highly specialized medical personnel necessary for treating COVID-19 patients can be fastly and properly trained.

Table 3: Share of hospitalization beds by medical speciality, 2018

Speciality	Percentage
Gynecology and obstetrics	18.69%
Internal	17.64%
General and reconstructive	15.88%
Pediatrics	12.58%
Psychiatry	4.82%
Traumatology	4.65%
Isolation	2.31%
General	2.29%
Cardiology	1.44%
Pneumology	0.61%
Others	19.09%

Source: Health Secretary's Health Resources Open Data (2018).

With the estimated stock of beds and ICUs and the share of them that are unoccupied, the amount of resources made available by the private sector, and the average number of hospitalization/ICU days, I can calculate the daily availability of hospital beds and ICUs for treating COVID-19 patients. Table 4 summarizes this information.

As in Greenstone and Nigam (2020), the daily supply of hospital beds and ICUs defines a threshold (*surge capacity*) above which hospitals cannot meet demand and the system becomes overflown.

Table 4: Daily hospitalization beds and ICUs for COVID-19 patients

Parameter	Value
Average bed/ICU use (days)	12
Share of unoccupied resources	0.15
Hospital bed stock	123,214
Share of hospital beds that can be converted	0.5
ICU stock	3,800
Hospital bed availability	9,241
ICU availability	570
Private hospital bed availability added	3,000
Private ICU availability added	500
Total hospital bed availability	12,241
Total ICU availability	1,070
Hospital bed at surge capacity	1,020
ICU at surge capacity	89

Source: own calculations with data from the Health Secretary of Mexico and parameters from the literature.

5 Projecting excess of demand

Using my estimates on the daily supply of hospital beds and ICUs, together with the projected demand for hospitalization and critical care, I estimate the size of the system overflow that would have occurred in the uncontrolled scenario and an approximate the date of that happening. Figure 5 represents this allocation problem. The dashed lines are the amount of resources available at every moment, while the solid curves are the estimated demand derived in Section 3. At the beginning of the epidemic, the system is capable of providing care according to the total hospital bed and ICU availability (12,241 and 1,070 units, respectively). As the infection progresses, demand grows fast exhausting medical resources until they reach the surge capacity. As it is evident from Figure 5, the amount of patients requiring a hospital bed or an ICU would have exceeded the supply as early as by the third week of March. By the time of the projected peak date (April 1st), the system would have required around 9,900 hospital beds and 1,500 ICUs every day.

The area between the supply curve and the projected demand represents the unmet demand and, thus, the amount of patients that face a hike in their survival probability.

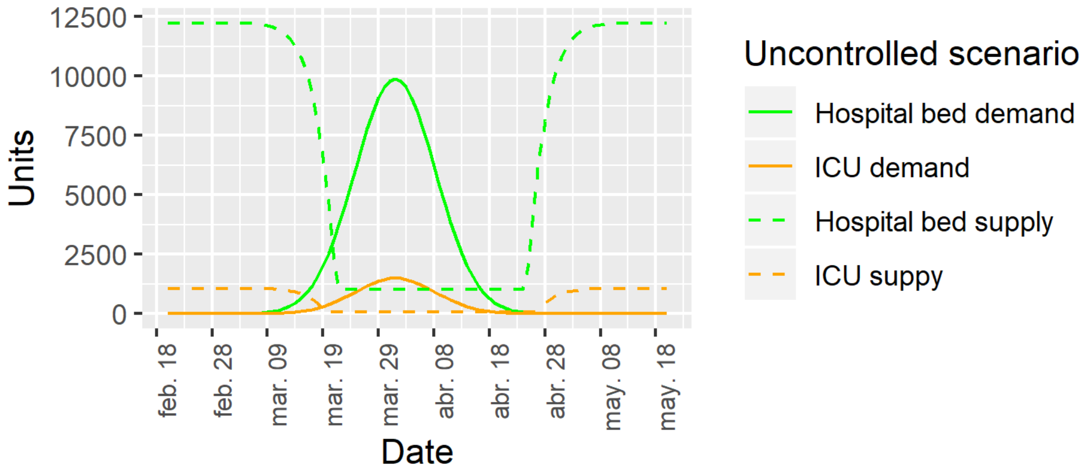


Figure 5: Projected supply and excess of demand, uncontrolled scenario

On the other hand, under the controlled scenario of mitigation measures, Figure 6 depicts a much different situation. One of the main objectives of these paper is to quantify the benefits of social distance and other mitigation policies by reducing the pressure on the healthcare system. Under this situation, the hospital bed and ICU demand will be overflown by the beginning of the second week of May. And, since both curves are flatter than under the controlled scenario, the differences in areas between the supply and demand curves across scenarios provide a measure of one of the most important benefits of *flattening the curve*.

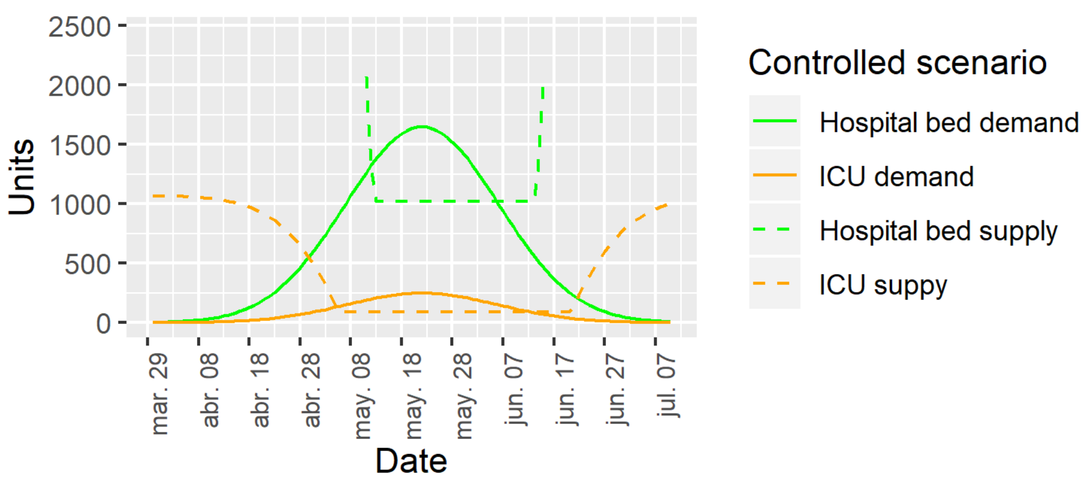


Figure 6: Projected supply and excess of demand, controlled scenario

In Table 5 I summarize these findings. The area between the supply and demand curves is considerably larger under the uncontrolled scenario. Thus, I estimate that the social distance measures reduced hospital bed overflow by 127,611 cases and ICU overflow by 19,319. Still, even under the controlled scenario, about 11,000 patients that are indicated hospitalization are denied it, and over 4,000 patients in urgent need for ICU do not receive the appropriate care. It is important also to note that under the controlled scenario, the number of days the demand for hospital beds is above the supply is decreased from 27 to 24 days. Meanwhile, the period of overflown ICU is 7 days longer. This means that flattening the curve can also translate into some resources being used for longer. Thus, the number of days in which demand exceeds capacity is not in all cases the best indicator for mitigation success.

Table 5: Excess of healthcare demand

	Uncontrolled	Controlled	Flattening the curve benefit
Hospital bed	138,522	10,910	127,611
Date demand exceeds supply	March 21	May 13	
Overflow length	27	24	
ICU	23,362	4,043	19,319
Date demand exceeds supply	March 19	May 6	
Overflow length	31	38	

Source: own calculations.

6 Estimation of daily deaths flow

One of the most important consequence of an overflown system is that fatality increases when appropriate care is not provided. Daily demand for hospitalization beds can be met until hospital bed supply achieves its surge capacity of around 1,020 units. ICUs daily supply at surge capacity is of only 89 new daily cases. I use the projected demand and supply, and the number of cases denied appropriate treatment to project the daily flow of fatalities.

If ICU is indicated and the system is below surge capacity, the survival probability is 50% (Wu and McGoogan, 2020; Greenstone and Nigam, 2020). On the other hand, with the system above surge capacity, patients that require an ICU and do not get appropriate treatment have a 10% survival probability (Ferguson et al., 2020; Greenstone and Nigam, 2020).

Patients that are indicated hospitalization but not ICU have better prospects, but this also depends on the received healthcare. According to the observed data from Mexico 27% of hospitalized patients have died. Thus, I use 73% as an estimate of the survival probability when the system is below surge capacity. For an overflown system, I assume the fatality probability triples for patients who are denied care.[12]

Finally, I will assume that a 99% chance of surviving for COVID-19 ambulatory cases (the observed survival rate in the data is 98.46% of ambulatory cases). In Table 6 I summarize the parameters used to calculate the daily flow of deaths.

Table 6: Survival parameters

$P(\text{survival}\vert \ldots)$	Probability
$P(\cdot\vert$ hospital bed indicated, hospital bed received) *	0.73
$P(\cdot\vert$ hospital bed indicated, hospital bed not received) **	0.19
$P(\cdot\vert$ ICU indicated, ICU received) ***	0.50
$P(\cdot\vert$ ICU indicated, ICU not received) ***	0.10
$P(\cdot\vert$ ambulatory case) *	0.99

Sources: * Observed in actual data; ** Results from assuming a fatality probability twice as large than when a hospital be is indicated and provided; *** Ferguson et al. (2020), Greenstone and Nigam (2020).

Figure 7 presents the results of my estimates of daily flows. Panel (a) shows the daily death toll for both the uncontrolled and controlled scenarios. Under the controlled scenario, the accumulated number of deaths would have exceeded 149,000. On the other hand, under social distance and mitigation measures, the number of deaths is expected to be reduced to about 30,000. Under the uncontrolled scenario, a maximum of 8,969 daily deaths would have been expected versus a maximum of 1,006 daily deaths that are expected under the current controlled scenario. Panel (b) shows together the projected and observed death toll for the controlled scenario. The projection matches available data fairly well. I summarize these findings in Table 7. Flattening the curve lowers the death toll in 80%, not only because less cases occur, but because the system overflow is not as severe as in the uncontrolled scenario, making less likely that patients are denied the indicated healthcare, avoiding a considerable drop in the survival probability.

[12] Since I do not have good estimates on these probabilities, in Section 9 I test how my conclusions change when assuming different magnitudes.

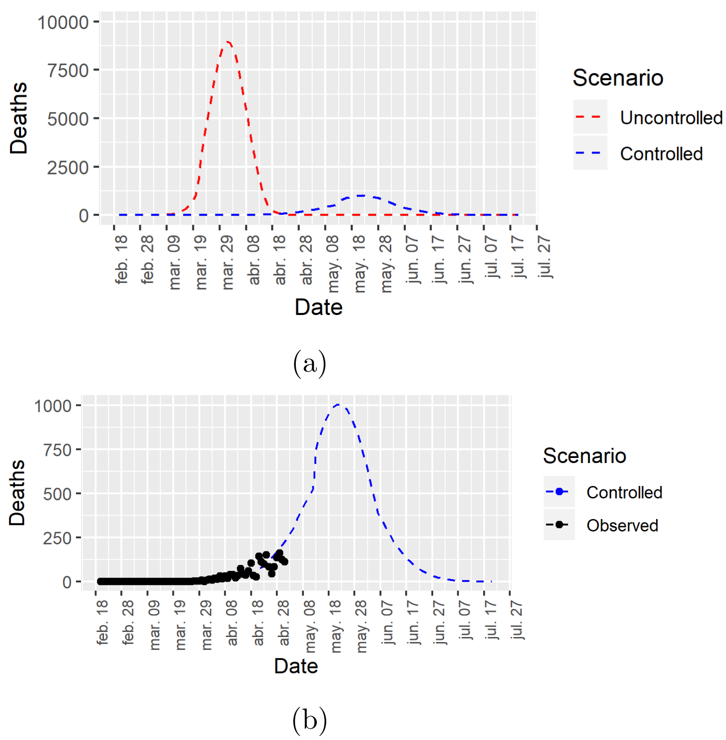


Figure 7: (a) Projected number of deaths, (b) Projected and observed deaths under the controlled scenario

Table 7: Estimated number of deaths

	Uncontrolled	Controlled	Flattening the curve benefit
Total deaths	149,892	30,215	119,677
Maximum daily deaths	8,969	1,006	7,962
Patients denied:			
Hospital bed	138,522	10,910	127,611
ICU	23,362	4,043	19,319
Deaths at overflow:			
Hospital bed	112,202	8,837	103,365
ICU	21,025	3,639	17,387

Source: own calculations.

Put other way, 146,930 more patients face a hike in their probability of dying, from 27 to 83% in the uncontrolled scenario. The benefit of social distance measures in terms of the reduction of overflown deaths amounts to 120,752 more patients who die because overcrowding of hospitals and ICUs.

7 Monetizing the benefits of mitigation measures

Public projects aimed to reduce fatalities or health damages include in their cost-benefit analysis an estimate of the willingness to pay for a reduction of the risk of death. A standard measure of the value of this reduction is the value of a statistical life (VSL), which represents an individual's willingness to pay in dollars for a marginal change in her own risk of dying (typically a 5 in 10,000 change) in a given year (Robinson et al., 2019a). The VSL concept is sometimes wrongly understood as the value that an oneself, the analyst or a government assigns to a human life. Rather, the concept must be interpreted as the rate at which an average person considers a dollar available for spending equivalent to a reduction in her mortality risk (Robinson et al., 2019b). A typically used VSL value for evaluating mortality risk reductions in the US is 10 million USD.[13] Greenston and Nigam (2020) use 10 million USD to value the benefits of social distance.

Direct estimates of the VSL from a population are usually obtained by linking occupational risks and wages or by extracting values from stated valuations surveys. In the absence of recent estimates for Mexico, I rely on an alternative strategy of benefits transfer. The benefits transfer takes a base estimate of the VSL from a country with reliable data (A) to extrapolate the VSL in country B, adjusting by the differences in income between the two countries, according to the following expression:

$$VSL_B = VSL_A \left(\frac{Income_B}{Income_A} \right)^{\delta} \tag{1}$$

where δ is the income elasticity. To obtain an estimate of the VSL for Mexico, I use the 10 million USD benefits from the US as base estimate. I use the per capita GDP (PPP) from the IMF's World Economic Outlook to calculate the income ratio[14] and assume an elasticity of 1.1.[15] Following this procedure I transfer a VSL for Mexico of 2.9 million USD.

Table 8 summarizes the second set of main findings of this paper. The reduction of deaths due to the mitigation policies represents a benefit of 347,000 million USD. In line

[13]Put in other words, suppose an average individual is willing to pay 50,00 USD to avoid a chance of death of 0.05% (5 in 10,000). Then the resulting VSL is $\frac{50,000}{5/10,000} = 10,000,000$ USD per statistical life saved.

[14]The income ratio is 0.33.

[15]A central parameter of the benefits transfer is the assumed elasticity. For very poor countries, Hammitt and Robinson (2011) show that assuming elasticities much larger than 1 is appropriate. For a middle-high income country, I consider assuming a much larger elasticity would be incorrect.

with Greenstone and Nigam (2020), I label this figure as the *direct benefit*. Additionally, social distance and mitigation measures have an indirect effect in reducing hospitals and ICUs overcrowding, generating an additional benefit of 350,000 million USD. The total benefit of mitigation measures amounts to 697,000 million USD.

Table 8: Monetary benefits of mitigation measures

	Averted deaths	VSL (million USD)
Direct deaths	119,677	347,063
Overflow deaths	120,752	350,180
Total benefit	240,429	697,243

Source: own calculations assuming a VSL of 2.9 million USD .

8 A benchmark magnitude of mitigation benefits

The final economic effect of the COVID-19 epidemic in Mexico is as difficult to forecast as the duration of the very same health emergency. New waves of contagion or a too-early lift of restrictions could lead to a new set of mitigation measures that make the cost higher. Moreover, together with the direct effects of the epidemic, the Mexican economy faces an adverse future scenario in which important sources of revenues, such as tourism, remittances, and the oil industry, are expected to perform badly. These factors will influence the depth of the downturn and the speed of recovery.

But, how large are the benefits from mitigation measures estimated above? From an ethical point of view it could be argued that any dollar spent to avoid deaths is worth it. But since mitigation policies involve a high economic costs, we can approximate the implicit value that a government puts on saving lives.[16]

In order to give a magnitude of the estimated benefits, I approximate the drop in aggregate product under the uncontrolled and controlled scenarios. I assume two lengths of recovery and calculate the present value of the product gap with respect to the *business as usual* scenario.

For the business as usual scenario, I follow most projections in that the Mexican economy

[16]Once again, by *value of lives* I do not mean the price of human lives. I follow Thunström et al. (2020) in presenting this section as an approximation of how a government values, for example, avoiding the political cost of an out-of-control crisis, with quickly overflown health systems and social disturbs, among other consequences.

would grow at 1% over the near future. Under the uncontrolled scenario, the economy receives a sever economic shock due to the high number of deaths and temporary freeze of economic activity. On the other hand, under the controlled scenario, the economy receives a more severe impact due to months of social distance measures, the cancellation of economic activity considered as non-essential for several months, and the redistribution of resources to control the epidemic. All my calculations in this section are monthly estimates.

For Mexico, the Finance Secretary projects the GDP growth for 2020 in the range of 0.1 to -3.9%.[17]. Nevertheless, international organizations and the private sector hold in general a more pessimistic view. Specialists consulted by Citibanamex expect a GDP drop of 3%,[18], Credit Suisse forecasts a -4% contraction[19], while the IMF projects the economy to shrink by 6.6%. Worse prospects include a -8 and a -8.4% by Bank of America[20] and Scotiabank[21], respectively.

In what follows, I assume that the economy receives a shock in April 2020 equivalent to a -4% with respect to March 2020 under the uncontrolled scenario, and of -6% under the controlled scenario. This translates into annual growth rates of -2.6 and -4.3%, respectively, at the end of 2020, with respect to the end of 2019. I assume that right after the shock a smooth recovery begins. I follow this strategy to avoid modeling the shape of the downturn.

For the slow (fast) recovery scenario, I assume the GDP achieves the business as usual trajectory 60 (36) months after the initial shock (same recovery times as in Thunström et al., 2020, for allowing comparability). I thus calculate the present value of the stream of monthly gaps between the uncontrolled and controlled trajectories with respect to the business as usual trajectory. To discount future flows I use a discount rate of 8%. The difference between the uncontrolled and controlled present values is a measure of the cost of mitigation policies for a given recovery speed.

Figure 8 shows the intuition of my calculations for the slow recovery case. The solid line represents the business as usual trajectory with no epidemic. Under the controlled scenario, the GDP drop is sharper. The discounted difference between the uncontrolled and controlled curves is the cost of control. Table 9 presents the third set of key results of this paper.

[17] https://www.gob.mx/cms/uploads/attachment/file/544779/Comunicado_034_-_Pre-Criterios_2021.pdf.

[18] https://www.banamex.com/sitios/analisis-financiero/pdf/Economia/NotaEncuestaCitibanamex200320.pdf.

[19] https://www.reuters.com/article/us-mexico-economy-forecast/credit-suisse-sharply-cuts-mexicos-2020-gdp-sees-economy-shrinking-by-4-idUSKBN21448J

[20] https://www.bloomberg.com/news/articles/2020-04-02/bofa-sees-mexican-economy-crashing-8-and-bigger-bears-exist

[21] https://www.bloomberg.com/news/articles/2020-04-18/scotiabank-expects-steeper-drop-for-mexico-gdp-economia-says

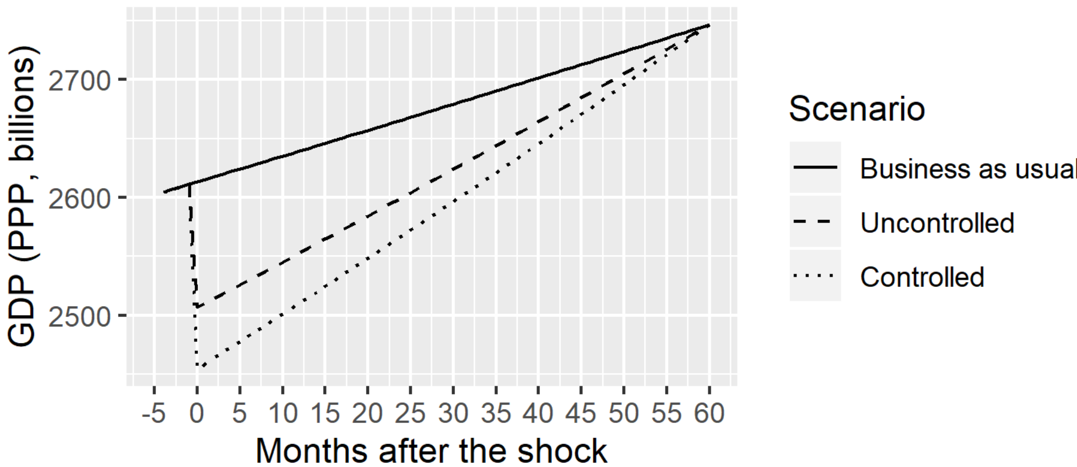


Figure 8: Projected output gap under uncontrolled and controlled scenarios.

Table 9: Cost-benefit analysis of mitigation measures

	Slow recovery (60 months)	Fast recovery (36 months)
Mexico GDP (bn. USD, 2019)	2,605	2,605
Present value of gap, uncontrolled (bn. USD)	2,929	1,857
Present value of gap, controlled (bn. USD)	4378	2,776
Cost of control (bn. USD)	1,449	919
Benefits of control (bn. USD)	697	697
Net cost (bn. USD)	751	222
Break-even averted deaths	499,557	316,823
Break-even VSL (million USD)	6.03	3.82

Source: own calculations.

Under the slow recovery assumption of 60 months to close the gap with respect to the business as usual trajectory, the cost of mitigation represents 1,449 billion USD. A faster recovery of 36 months implies a cost of mitigation of 919 billion USD.

The monetized benefits of mitigation measures is 697 billion USD. This implies that the net cost of mitigation is 751 billion USD under a slow recovery of 60 months. The positive net cost (negative net benefit) does not necessarily mean it would be rational to opt for the uncontrolled scenario. Instead, my interpretation is that this partially reveals the implicit benefit that a government assigns to avoiding the consequences of the uncontrolled scenario (loss of reputation, political instability, and social chaos, among others). Another alternative explanation is that a planner reveals with its mitigation actions that it values the probability risk reduction of a given individual more than the individual's valuation; a typical externalities problem.

Following this reasoning, I calculate two additional indicators. First, I compute the break-even number of averted deaths, which represents the sum of direct and overflow deaths that would need to be averted to compensate the accumulated output gap over the recovery period. That is, if a government only valued the lives saved according to the VSL. Under a slow recovery, about 500,000 lives would need to be saved. This number is about the same as the total cases I expected under the uncontrolled scenario. That is, the break-even number of deaths could only be achieved under a much more sever epidemic, with many more cases and deaths.

Second, I compute the break-even VSL, interpreted as the VSL that compensates the accumulated output gap over the recovery period given the 240,429 averted deaths under the controlled scenario estimated in Section 7. Under a slow recovery, the break-even VSL is more than twice as large than the one used in Section 7 (6.03 versus 2.9 million USD). Under a fast recovery assumption, the VSL necessary to make the net cost equal to zero is 3.82 million USD.

9 Sensitivity analysis

One disadvantage on the previous analysis is that it is mostly deterministic once . I borrow most key parameters from an emerging literature and complement some of the missing information with the early data from Mexico. Thus, in order to analyze the sensitivity of my results and to emphasize the channels through which key parameters operate I performed the same analysis described in this paper, under different parameter values.

I present in Table 10 a summary of the consequences of deviating from the parameters assumed in the earlier sections of this paper for the controlled scenario (the uncontrolled scenario remains the same) in terms of cases, deaths, healthcare system overflown, net control costs, and break-even death toll and VSL. For each alternative parameter specification, I compare what the controlled scenario achieves with respect to the uncontrolled one. The first line of this table summarizes the findings described earlier in this paper. The mitigation strategies reduce the number of cases by 65% and the number of deaths by 80%. There are less days of overflown hospitals and more days of overflown ICUs (-11% and 23% respectively). The mitigation policies reduce deaths in 91%. The benefits of flattening the curve are monetized as 647 billion USD.

If we assume a flatter curve, with the peak happening as early as May 8 (as in Luo, 2020) and with a peak number of daily cases of only 2,500, the number of total cases would be much smaller (80% reduction).[22] Under these alternative assumption, the healthcare system would be under considerably less pressure: there would never be overflown hospitals and the number of days with overflown ICUs would be reduced in 20%. Still, the net cost of control would be 669 billion USD if the recovery takes 60 months, but only 139 billion USD under a fast 36 months recovery.

On the other hand, if the peak of the epidemic is much larger than the 5,000 daily cases assumed in Section 2 (for example, if the size of the cases is underestimated, as some claim to be the case), the control measures would be less but still effective, reducing the number of cases in only 46% and the number of deaths in 56%. In this case, the healthcare system would be overflown under a considerably longer period. The net cost would increase to 953 billion USD. Still, mitigation measures would reduce the number of deaths in 56%.

The assumption on the percentage of total beds that can be converted for treating COVID-19 patients is an important one and the consequences of different probabilities deserve to be discussed. A larger probability of conversion can also represent an scenario where the initial bed and ICU availability was higher than at the beginning of the epidemic. As I report in Section 4, the overall expenditure in the health sector and the amount of healthcare resources in Mexico have remained considerably below than the average OECD country. Thus, an increase to a probability of conversion of 75% also represents a situation in which the initial available stock of hospital beds for providing adequate care to COVID-19 patients was 16,862 rather than 12,241. Also, the surge capacity would be increased to 1,405 beds under this alternative assumption. The results show the following: since more beds are available at the beginning of the epidemic, it is more likely that even under the uncontrolled scenario more people receive appropriate healthcare. Under the controlled scenario, with more beds available, the number of days the hospitalization capacity is overflown would be reduced in 48%. As the uncontrolled scenario is not as bad now in terms of fatalities, the net cost of control is even higher than in my base estimates. That is, a higher probability of conversion (or not having invested enough in health resources in the past) translates into a more costly controlled scenario today, compared to the corresponding uncontrolled counterfactual. Put in other words, had the initial resources been sufficient for better handling the

[22] Under this new assumption, instead of using the observed data to estimate the standard deviation under the controlled scenario, I use the same procedure to solve for σ_c given the peak date and height and the date of the first case, as described in Section 2.

epidemic, a controlled scenario as costly as the one is expected nowadays could have been avoided. The intuition of switching the conversion probability to 25% is just the opposite.

If we now assume a larger fractions of cases indicated ICU (10%, twice as large as most estimates), the number of days the ICU capacity is overflown increases 45%. In such a case, the benefits of control are more evident and the net cost of control under a slow recovery decreases to 656 billion USD. If we assume a bed is used for 18 days, the control is less effective in terms of deaths avoided, while the healthcare system would be overflown for many more days, increasing the net cost of control to 759 billion USD, assuming a slow recovert.

Assuming an income elasticity of 1 in the transfer of benefits (which results in a VSL of 3.3 million USD) yields qualitatively similar results to the main results in this paper. Similarly, assuming a larger discount rate in the valuation of the future output gap in Section 8 does not alter dramatically the calculated net cost.

Finally, as it is the case for the epidemic duration, the time when measures can be lifted, and the size of the economic impact that the pandemic will cause remain uncertain. In the meantime, most national governments around the globe have implemented fiscal programs to mitigate the economic consequences of the pandemic. In the last alternative scenario, the economy receives a 5% negative shock in the aftermath of the outbreak (rather than a 6% negative shock, as in Section 8). Under this scenario, the economy would suffer a -3.5% decrease during 2020. The main implication is that the net cost of control becomes much lower (726 billion USD, about a half of the cost I estimated in Section 8). Thus, the net cost of control is about 28 billion dollars (1% of GDP), under the slow recovery scenario. Furthermore, under a fast recovery of 36 months, mitigation measures yield a positive benefit of 237 billion USD. This finding adds to the rationale of using active fiscal policies to mitigate the economic effects of the epidemic.

Table 10: Sensitivity of results to changes in parameters

Parameters:	Cases (%)	Deaths (%)	Days hospital overflown (%)	Days ICU overflown (%)	Overflow deaths (%)	Control benefit (bn USD)	Control cost (slow recovery) (bn USD)	Control cost (fast recovery) (bn USD)	Net cost (slow recovery) (bn USD)	Net cost (slow recovery) (bn USD)	Break-even death toll (slow recovery) (number)	Break-even VSL (slow recovery) (m USD)
As in main results in the paper:	-65.46	-79.84	-11.11	22.58	-90.64	697	1,449	919	751	222	499.6	6.03
Sensitivity to:												
Flatter curve: 2,500 cases, May 8	-79.71	-90.93	-100.00	-19.35	-99.57	780	1,449	919	669	139	499.6	5.39
Higher control peak: 10,000 cases	-45.39	-56.44	18.52	29.03	-64.69	495	1,449	919	953	423	499.6	8.48
Higher conversion probability: 75%	-65.46	-82.13	-48.00	22.58	-95.56	680	1,449	919	769	239	499.6	6.18
Lower conversion probability: 25%	-65.46	-76.09	19.35	22.58	-83.68	697	1,449	919	751	222	499.6	6.03
Higher probability of ICU: 10%	-65.46	-78.03	-11.11	45.71	-87.22	792	1,449	919	656	126	499.6	5.30
Longer bed use: 18 days	-65.46	-76.50	17.86	37.50	-84.27	690	1,449	919	759	229	499.6	6.09
Higher elasticity of income: 1.1	-65.46	-79.84	-11.11	22.58	-90.64	793	1,449	919	655	125	439.0	6.03
Higher discount rate: 10%	-65.46	-79.84	-11.11	22.58	-90.64	697	1,405	902	708	205	484.5	5.84
Lower initial GDP contraction: 5%	-65.46	-79.84	-11.11	22.58	-90.64	697	726	460	28	-237	250.2	3.02

Source: own calculations.

10 Conclusion and agenda

In this paper I calculate the daily flows of cases under the current scenario of recommended social distance and restricted economic activity, and under a counterfactual uncontrolled scenario with no mitigation measures. I quantify the supply of hospital beds and ICUs to project the fatality of cases under both scenarios. I estimate that social distance will reduce the number of COVID-19 cases in 65%. The benefits of mitigation measures amount to a direct reduction of 120,000 direct fatalities and of 121,000 deaths avoided by reducing the exerted pressure on the healthcare system. The benefits of these measures are monetized as 697 billion USD.

In the absence of treatments and vaccines, mitigation measures to control the COVID-19 pandemic are likely to produce vast economic impacts. Assuming a slow recovery of 60 months, the accumulatethe mitigation scenario d cost in terms of output of the mitigation measures in Mexico represents about 29% of 2019 Mexico's GDP. This cost would be reduced under more favorable scenarios (for example, if the mitigation measures lower the number of cases more than what is projected, or if more resources become available to avoid the health system). Also, a lower cost can be obtained if a faster recovery occurs or if the government stimulates the economy enough to reduce output gap between and the scenario with no mitigation policies, making a case for an active role for fiscal policies.

Some limitations of my analysis deserve to be discussed for future research. In this paper, I assume that the differences in fatality rates for patients that receive appropriate healthcare versus those who are denied it are independent of the age profile. Verity et al. (2020) have shown that fatality rates differ across age groups. A recent debate on the ethical dimension of assigning medical resources questions whether younger patients should be allocated for treatment first. In my calculations I have implicitly assumed random assignment of patients to healthcare in case of overflow. If one assumes some form of sorting in the assignment, the net cost of the control is likely change. Can a lower cost justify discrimination in care assignment?

In this paper, as in other analysis at an aggregate level of healthcare resources, an implicit assumption is that patients from all over the country can be allocated to a hospital bed or ICUs if required. A more detailed analysis would utilize state specific projections of the epidemic and regional supply of resources, together with transaction costs. Unfortunately, there is scarce data as of today that allow for reliable local predictions on the epidemic progression an the local availability of health resources.

Finally, my calculations imply that the net cost of the control in terms of aggregate output is twice as large as the estimated benefits. If this is the case, we need to understand the factors that make a planner to still incur the cost of control. For example, a planner may be willing to pay more than what an individual is for reducing a mortality risk if each individual generates positive externalities for the society. Alternatively, the planner is likely to assign a very large cost to the political consequences of an uncontrolled epidemic. Consequently, if other costs and benefits are considered in the analysis, the cost-benefit conclusion will be different.

My results are likely to be sensitive to assumptions I cannot directly test (for example, the sizes and dates of epidemic peaks) and to changes in the policy mix that alter the course of the pandemic and the behavior of economic agents. With the release of more data, it will be possible to study several other problems that arise from the interaction of the epidemiological event with the economic systems.

As the pandemic progresses, the results in this paper must be frequently updated to incorporate the most recent changes in policies and induced economic behavior. More evidence is needed to quantify the benefits and costs of mitigation measures and to inform decision making in a context where policies have important consequences for lives and societies welfare.

References

Akamai (2017). State of the Internet: Q1 2016 Report. https://www.akamai.com/fr/fr/multimedia/documents/state-of-the-internet/q1-2017-state-of-the-internet-connectivity-report.pdf.

Anderson, R. M., Heesterbeek, H., Klinkenberg, D., & Hollingsworth, T. D. (2020). How will country-based mitigation measures influence the course of the COVID-19 epidemic?. *The Lancet*, 395(10228), 931-934.

Ferguson, N. et al. (2020). Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand. Imperial College COVID-19 Response Team.

Gaythorpe, K. et al. (2020) Report 8: Symptom progression of COVID-19. Imperial College COVID-19 Response Team.

Greenstone, M., & Nigam, V. (2020). Does Social Distancing Matter?. University of Chicago, Becker Friedman Institute for Economics Working Paper.

Guan, W. J. et al. (2020). Clinical characteristics of coronavirus disease 2019 in China. *New England Journal of Medicine*.

Hammitt, J. K., & Robinson, L. A. (2011). The income elasticity of the value per statistical life: transferring estimates between high and low income populations. *Journal of Benefit-Cost Analysis*, 2(1), 1-29.

Harvard Global Health Institute (2020). How ProPublica Mapped Hospital Capacity for Coronavirus. https://www.propublica.org/article/methodology-how-propublica-mapped-hospital-capacity-for-coronavirus.

Hauser, A. et al. (2020). Estimation of SARS-CoV-2 mortality during the early stages of an epidemic: a modelling study in Hubei, China and northern Italy. medRxiv.

IMF (2020). World Economic Outlook. Chapter 1: The Great Lockdown. https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020.

Luo, J. (2020). When Will COVID-19 End? Data-Driven Prediction. Working paper. https://ddi.sutd.edu.sg/.

OECD (2019). Hospital beds and discharge rates. https://www.oecd-ilibrary.org/sites/0d67e02a-en/index.html?itemId=/content/component/0d67e02a-en.

Moghadas, S. M. et al. (2020). Projecting hospital utilization during the COVID-19 outbreaks in the United States. *Proceedings of the National Academy of Sciences*, 117(16), 9122-9126.

Monroy-Gomez-Franco, L.A. (2020). Who Can Work From Home? Evidence from Mexico. Working paper.

Robinson, L.A. et al. (2019a). Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development. Boston, MA: Center for Health Decision Science, Harvard TH Chan School of Public Health.

Robinson, L. A., Hammitt, J. K.,& O'Keeffe, L. (2019b). Valuing mortality risk reductions in global benefit-cost analysis. *Journal of Benefit-Cost Analysis*, 10(S1), 15-50.

Secretaria de Salud (2020), Catálogo de Clave Única de Establecimientos de Salud-CLUES, http://www.dgis.salud.gob.mx/contenidos/sinais/s_clues.html.

Thunstrom, L. et al. (2020). The benefits and costs of flattening the curve for COVID-19. Available at SSRN 3561934.

Verity, R. et al. (2020). Estimates of the severity of COVID-19 disease. MedRxiv.

Wu, Z., & McGoogan, J. M. (2020). Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. Jama, 323(13), 1239-1242.

World Bank. (2020). World Bank Open Data. https://data.worldbank.org/.