Three perspectives on the impact of the COVID-19 pandemic in Portugal

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A dissertation

Submitted in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

University of Washington

2023

Reading Committee:

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Program Authorized to Offer Degree:

Global Health

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Abstract

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The COVID-19 pandemic was the most profound health crisis of the 21st century, leading to over 6 million fatalities globally. It tested health systems worldwide, revealing their weaknesses and resilience. Health systems' ability to maintain essential operations, quickly regain optimal performance and undergo structural and functional transformations to improve their overall strength is essential to improve the response to future external health shocks. However, the full impact of the COVID-19 pandemic still needs to be better understood in economic and health system terms. We applied time series analysis methods to the case of Portugal, a high-income European country, to assess three different aspects of the impact of COVID-19.

In Chapter two, we present evidence of the economic impact of the two government COVID-19 mitigation lockdowns. The first lockdown had a more significant impact, resulting in a 21% decrease in spending, whereas the second lockdown resulted in a 16% decrease in spending. Our findings also reveal a rise in spending in the pharmaceutical sector during the first lockdown, which could put pressure on supply chains and result in disruptions within and across countries. In contrast, the health services sector did not see a decrease in spending during the second lockdown, likely indicating adaptations during the period between lockdowns (the inter-lockdown period). Lastly, our research adds to the growing body of literature demonstrating lockdowns' effectiveness in reducing SARS-CoV-2 cases and COVID-19 deaths.

In Chapter three we illustrate the effects of the governmental lockdowns on routine health service utilization. We found that the lockdowns resulted in moderate to severe disruptions in health services across different sectors of the health system (including outpatient care, surgical care, and emergency department visits). A more significant decrease was observed during the first lockdown compared to the second. An increase in telemedicine consultations partially offset this decrease. While hospitals were able to return to pre-pandemic levels of operation quickly after the second lockdown, they did not increase their production to make up for the lost visits. On the other hand, the impact on primary care was even more severe, and even a year after the end of the second lockdown, primary care had not yet recovered to pre-pandemic levels. The pandemic resulted in millions of missed hospital and primary care visits, increasing unmet need on a population level.

In Chapter four, we observed a general decrease in inpatient care for non-COVID related conditions, followed by an increase in case fatality rates. During the first lockdown, there was an immediate 17% increase in case fatality rates, while the second lockdown saw a 62% increase. The rise in case fatality rates was not uniform across age groups, with higher increases being observed in older age groups, particularly in conditions related to the circulatory and digestive systems. Despite the increase in case fatality rates, our analysis showed that the expected number of deaths did not rise during the pandemic period, suggesting that the frailest patients may have been selectively admitted during this time.

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ACKNOWLEDGMENTS

The opportunity to do a Ph.D. at the University of Washington was utterly transformative at a professional and personal level. This endeavor would not have been possible without the support of the dissertation committee. To Kenny for his patience and invaluable guidance, for making me believe that this was possible even after more than one year away due to my COVID-19 work duties in Portugal. To Steve, who guided me through the first two years and taught me everything I know about health equity and global health. To Joe for the great intellectual insights on my ideas and for giving me room to experiment. To David, who always provided a fresh interpretation of my problems and findings. Thank you for guiding me through these years.

I could not have undertaken this journey without the support of the Fulbright Portugal program; their financial and personal development support was life-changing. I have the deepest gratitude to Otília and all the Fulbrighters who walked with me on this journey.

Thanks should also go to my cohort-mates, the Ph.D. students in Global Health - Metrics and Implementation Sciences; special thanks to my classmates Stephanie, Claire, Joey, Adrien, Beatrice, Barbara, Rima, Becky, Meredith, Deanna, Kristen, Elizabeth, Quinhas, Yoshi, Nami and Sarah. I have to mention the Portuguese community in Seattle for their emotional support.

To my colleagues at Nova University of Lisbon, Julien, Susana, Bruno, Joana, João, and Pedro, for helping me find the right data to support my ideas. To everyone at Direção Geral da Saúde for encouraging me and supporting me in finishing the Ph.D.

Lastly, I would be remiss in not mentioning my family, parents, and brother for supporting me in all my endeavors. To my wife Sara for her love and support.

GLOSSARY

ATM - Automated Teller Machine

CFR - case fatality rates

DALY - Disability-Adjusted Life Years

EDI-PT - Portuguese European Deprivation Index

EU - European Union

GDP- Gross Domestic Product

ICD-10 - International Classification of Diseases 10th revision

IMF - International Monetary Fund

NHS - National Health Service

NPI - Non-pharmacological interventions

PCR - Polymerase Chain Reaction

POS - point of Sales

OECD - Organization for Economic Cooperation and Development

RAT - Rapid Antigen Test

SIBS - Sociedade Interbancária de Serviços

SINAVE - Portuguese Epidemiological Surveillance System

WHO - World Health Organization

Chapter 1. Specific aims

Background

The COVID-19 pandemic was an unprecedented challenge to societies and health systems, resulting in more than 6 million deaths worldwide. Non-pharmacological interventions (NPI) were widely used to control SARS-CoV-2 transmission and protect health services from operating beyond capacity before vaccination was available. Nevertheless, many direct and indirect effects of NPI still need to be clarified, especially on how resilient health systems were to the COVID-19 shock.

Setting

Portugal is a Southern European country with a population of 10 million people. It has had a democratic regime since 1974 and has been part of the European Union (EU) since 1989. According to the World Bank, Portugal is a high-income country with a Gross Domestic Product (GDP) of 24.2 thousand dollars (2021), below the EU GDP per capita of 38.2 thousand dollars (2021). During the international economic crisis of 2008, Portugal experienced a significant economic downturn, which led to a period of financial assistance from international institutions. From 2012 until 2020, the economy grew, and unemployment was low, supported by a thriving tourism sector.

The average life expectancy is still higher than the EU average; in 2019, it was 81.9 years in Portugal and 81.3 years in the EU. However, higher life expectancy than average hides high rates of income and health inequalities and a rapidly aging society. Portugal has one of the highest Gini coefficients in the European Union, and the percentage of the population at risk of poverty increased from 21.1% in 2019 to 22.4% in 2021, and is now above the EU average (21.7%).

The health system has three co-existing and overlapping systems: the National Health Service (NHS), employer-provided and private voluntary health insurance (1). The NHS is funded through general taxation, and all residents are eligible for the benefits package. Private health insurance has a mainly supplementary role. Total health expenditure amounted to 9.6% of the GDP in 2020, in line with the EU average (9.9%). However, the out-of-pocket contribution in Portugal represented 30% of health expenditures, whereas it accounts for only 15.4% in the EU. The NHS health information system is fully digital, with hospital and primary care centers having a dedicated and unique electronic health records system.

Dissertation aims

In this dissertation we explore the effect of governmental lockdowns on the economy and health system. Thought the thesis, we used a quasi-experimental study design (interrupted time series) to explore the effect of governmental lockdowns on the outcomes studied. This method allows comparing the outcomes had the COVID-19 pandemic not happened.

Aim 1: The effect of COVID-19 lockdowns on epidemic control and economic activity, in Portugal.

Aim 2: Impact of the COVID-19 pandemic on outpatient hospital and primary care services, telemedicine and surgical procedures.

Aim 3: The impact of lockdowns on non-COVID-19 hospital inpatient episodes and case fatality rates (CFR), in Portugal.

Chapter 2. The effect of COVID-19 lockdowns on epidemic control and economic activity in Portugal

Abstract

Introduction: The effects of lockdowns on the economy and COVID-19 control in Portugal still need to be better understood, especially for the second lockdown.

Methods: We used an interrupted time series to explore the effect of lockdowns on economic activity measured as the transaction value in million Euros spent on the point of sales terminals, and automated teller machine payments and withdrawals, in Portugal, at the municipality level. To explore the effect on COVID-19 control, we used the number of SARS-CoV-2 cases and deaths by 10-year age groups, sex, and municipality. We used a negative binomial model with the month and municipality as fixed effects, with the following periods: The baseline (January 2018-February 2020), the first lockdown (March-May 2020), the inter-lockdown period (June-December 2020), the second lockdown (January-April 2021), and the recovery period (May-August 2021).

Results: The value of transactions decreased by 21% (RR=0.79; 95%CI: 0.78-0.80) during the first lockdown, and by 16% (RR=0.84; 95%CI: 0.83-0.86) during the second lockdown. However, the pharmaceutical sector had a 28% increase during the first lockdown (RR=1.28; 95%CI: 1.25-1.31). The January 2021 lockdown was associated with a reduction of 80% in SARS-CoV-2 cases and 88% in COVID-19 deaths.

Conclusions: Our analysis found that lockdowns were effective at reducing the spread and mortality due to COVID-19. In addition, we found adaptive economic responses to lockdowns including increases in pharmaceutical sector spending, which can stress supply chains, meriting efforts to reinforce this health system building blocks.

Keywords: COVID-19, lockdowns, economic impact, COVID-19 deaths, SARS-COV-2, time-series, Portugal

Introduction

The COVID-19 pandemic has been the most significant health challenge of this century, putting immense pressure on health systems (1), governments (2), the economy (3), and the scientific community (4). By the beginning of 2023, more than 350 million cases and 6 million deaths had been attributed to the pandemic (5). However, disease burden has not been equally on a global scale, where European countries have been disproportionately affected (6).

In early 2020, most European countries implemented general lockdowns to minimize the effect of the pandemic on health systems and population health (7,8). Portugal declared a national lockdown on March 13, 2020, two days after the first COVID-19 death, that ended on May 18, 2020. Later in 2020, facing a second wave of COVID-19 infections, many governments adopted “tier measures” (bundles of non-pharmacological interventions adapted according to the intensity of SARS-CoV-2 transmission in each municipality or region). In the UK, the “3-tier lockdown” instituted in October 2020 emphasized the need to keep schools open and minimize the economic impact of generalized lockdowns (9).

After a surge of cases following holiday activities in late December 2021 and early January 2022, Portugal entered a complete lockdown on January 14, 2021, ending on April 30, 2022. Earlier modeling studies demonstrated that non-pharmaceutical interventions (NPI), and lockdowns in particular, significantly reduced transmission (7). Other evidence suggests that, other than lockdowns, other NPIs (such as canceling gatherings) are effective in limiting the spread of SARS-CoV-2 (10) (11). However, not all

NPIs are equal in terms of their unintended consequences, such that the most effective NPIs are likely to have greater economic impacts (12).

While lifting NPIs is associated with an increase in infections and higher economic activity, (13) the extent of these effects is not known (especially for the 2021 lockdowns). Combining two novel datasets from Portugal can shed light on the effect of lockdowns on disease control and the consequent economic impact; exploring the intended and unintended consequences of lockdowns can inform policymakers about the expected impacts of future interventions to address external shocks.

Methods

Design

We used a controlled interrupted time series to assess the effect of lockdowns on economic activity measured as money spent on point of sales (POS) terminals as well as automated teller machine (ATM) payments and withdrawals in Portugal. Furthermore, we evaluated the effect of the second lockdown on SARS-CoV-2 cases and COVID-19 deaths.

Data sources

We used three data sources for our analysis. First, financial expenditure data were accessed through SIBS (the Portuguese abbreviation for *Sociedade Interbancária de Serviços*), which manages the integrated banking network in Portugal, including ATM and POS terminals. SIBS Analytics provides aggregate data on all payments with bank cards in Portugal, including with national and foreign bank-issued cards. Data are reported as the value in million euros aggregated by municipality where the transaction was completed. Second, data on SARS-CoV-2 infections were sourced from the Portuguese Epidemiological Surveillance System (SINAVE), a surveillance system that registers all SARS-CoV-2 cases. Third, information on deaths was recorded in the Death Certificate Information System (SICO), a national mandatory information system that records all deaths, from which we were able to abstract data on COVID-19 deaths. Information about hospitalization was not available. These data sources were aggregated by municipality, age group, sex and month of diagnosis using the academia dataset provided by the Directorate General of Health. Finally, we used the Portuguese Institute of Statistics data to account for the resident population by age group, sex and municipality, and the European Deprivation Index for Portuguese small-areas (EDI-PT) (14) as a measure of social deprivation by municipality.

COVID-19 data sources have a high quality for basic information (residence, sex, age, date of diagnosis), with approximately 3% missing values. Those without a unique national health identifier (including undocumented migrants and tourists) will not be represented in these datasets.

Setting and participants

Portugal is divided into 308 municipalities; only 278 from Portugal's mainland were included in our analysis, excluding the Portuguese islands (Madeira and Azores) because they had different e governmental measures hence are not comparable with Portugal's mainland. Our study period assessing the economic impact of lockdowns spanned from January 1, 2018 through August 2021 (the latest available economic data), and from January 1, 2018 through June 2021 (the latest available data on COVID-19 cases and deaths).

Outcomes

Economic impact: Electronic payments

We measured economic impact as the value of electronic payments and transactions (in millions of euros), using the same methodology as Carvalho et al. (15). We estimated the economic impact as the monthly value of transactions at the municipality level. We also evaluated the economic impact of pharmaceutical products (spending on pharmacies) and private healthcare services (spending on private hospitals, dentists, and private outpatient care).

SARS-CoV-2 cases and COVID-19 deaths

A SARS-CoV-2 case corresponds to a laboratory-confirmed SARS-CoV-2 infection (either polymerase chain reaction (PCR) and rapid antigen test (RAT) are reported in SINAVE). We allocated SARS-CoV-2 cases to the municipally of the case current address, and when missing, the address of residence of the case registered in the national patient's database. A COVID-19 death was defined as any record of death on the national Death Certificate Information System (SICO) with COVID-19 as the primary cause of death (International Classification of Diseases 10th revision (ICD-10) code U.071) according to the World Health Organization (WHO) classification (16). We calculated the monthly number of SARS-CoV-2 cases, and COVID-19 deaths per 100,000 inhabitants, by age group and sex.

Exposure and other explanatory factors

To model the effects of lockdowns, we added an interaction term between period of interest (the March-May 2020 lockdown, June-December 2020 inter-lockdown period, January-April 2021 lockdown, and May 2021-August 2021 recovery period) and the time variable, following the model specification for multiple periods described by Xiao (17). We added the month of the year and municipality as fixed effects to account for each municipality's seasonality and unique characteristics. We also explored the effect of social deprivation on the lockdown's economic impact using the social deprivation index at the municipality level. The model assessing the effects of the second lockdown on SARS-

CoV-2 cases and COVID-19 deaths was adjusted for 10-year age groups, sex and municipality.

Statistical Analysis

We used a generalized linear model (GLM) with a negative binomial distribution and fixed effects at the municipality level and month of the year (Equation 1). We used the sandwich estimator for variance calculation to account for clustered errors.

$$Y_{it} - NB(\mu_{it}, \alpha)$$

$$\mu_{it} = exp\big(\beta_0 + \beta_1 V_i + \beta_2 X_{1-3|it} + \beta_3 T_i + \beta_4 XT_{it} + \beta_5 \gamma_{it} + offset(\ln{(p_{it})} + \varepsilon_{it}\big)$$

In Equation 1, where: Y is the outcome of interest for each time t and municipality i, with a mean μ_{it} and a variance α. V_i (period) is the time since the beginning of the study and represents the frequency of the recorded outcome in months. X_{1-3} is a dummy variable (0 and 1) for each of the lockdown, inter-lockdown and recovery periods. T_i (period) is the time after the start of the lockdown, inter-lockdown or recovery, and assumes the value zero in all the other months. γ_{it} are vectors of fixed effects in the model (SARS-CoV-2 cases and COVID-19 deaths, or age group and sex in the model with COVID-19 outcome), p_{it} is the population by municipality and ε_{it} is an error term.

The β_1 estimator represents the outcome trend before the first lockdown. The β_2 estimator represents the immediate effects of the lockdown or inter-lockdown period. The β_4 estimator represents trends during the lockdown or inter-lockdown period. We calculated the model's predicted outcome using the marginal effects package (18) for the average municipality.

For the COVID-19 outcomes we used a slightly different approach as we could not apply the model to the first lockdown since we did not have a pre-COVID-19 reference period, and March 2020 was both the month of the first case and the first month of the lockdown period. Therefore we present the model only for the second lockdown, using the interlock-down period as the reference period. Moreover, we used deaths as the outcome to account for changes in testing strategies, as testing was more systematic during the study period. We adjusted the model with fixed effects for age group, sex and municipality, and used the population as the model's offset. We present the rate ratios of the outcome and the 95% confidence intervals.

Robustness checks

COVID-19 transmission could generate a high percentage of sick workers who are absent from work, affecting labor supply and reducing spending. The dynamics of reduced work supply and demand could cause decreases in aggregate spending, even in the absence of lockdowns (19). To test this theory we adjusted our model for all services and sectors for the monthly incidence of SARS-CoV-2 cases and COVID-19 deaths, and calculated the predicted spending for a mean municipality in a scenario with no SARS-CoV-2 cases and COVID-19 deaths and compared it with the predicted spending for a mean municipality with SARS-CoV-2 cases and COVID-19 deaths. Finally, we tested the effect of Social Deprivation on the transaction values by stratifying the municipalities by EDI-PT quintiles.

Results

Economic impact

We included data from 278 municipalities and 44 months, from January 2018 to May 2022, corresponding to 7,832 observations (Table 1). During the first lockdown the average municipality spending in all sectors decreased from a mean of 29.40 (SD=3.01) million euros per month in the pre-lockdown period to 21.14 (SD=2.98) million euros per month during the first lockdown. Spending decreased slightly less during the second lockdown to a mean of 23.67 (SD=2.16) million euros per month. The value of healthcare services transactions followed a similar pattern, with decreases in the first and second lockdowns. However, for pharmaceutical products, the value of transactions increased during the first lockdown, with a mean 0.47 (SD=0.08) million euros per month, compared with 0.41 (SD=0.03) million euros per month in the pre-COVID-19 period.

Table 1. Mean financial transactions at the municipal level (in millions of Euros) | *Portugal*

Sector	**Metric**	**Pre COVID-19**	**First lockdown**	**Inter-lockdown**	**Second lockdown**	**Recovery**
Pharmaceutical products	Mean (SD) € Million	0.41 (0.03)	0.47 (0.08)	0.46 (0.02)	0.55 (0.04)	0.62 (0.04)
Healthcare services	Mean (SD) € Million	0.52 (0.05)	0.30 (0.11)	0.61 (0.05)	0.75 (0.09)	0.81 (0.07)
All sectors and services	Mean (SD) € Million	29.40 (3.01)	21.14 (2.98)	29.35 (2.54)	23.67 (2.16)	33.26 (2.54)

All sectors

Across all sectors, the first lockdown was associated with an immediate 21% reduction in the value of the transactions (RR=0.79; 95%CI: 0.78-0.80) in the first month compared with the pre-pandemic period, and a non-significant trend during the rest of the lockdown (Table 2). The second lockdown had a smaller immediate effect, with a 16% reduction in the value of the transactions in January 2021 (RR=0.84; 95%CI: 0.83-0.86).

Table 2. Effect of COVID-19 pandemic lockdowns on transactions value (million euros), Portugal January 2018 - August 2021

Term[a]	**Rate ratio (95% CI)**	**p value**
Pre COVID-19 trend	1.01 (1.01-1.01)	0.000
First lockdown	0.79 (0.78-0.80)	0.000
Inter-lockdown	0.91 (0.89-0.92)	0.000
Second lockdown	0.84 (0.83-0.86)	0.000
Recovery	0.98 (0.96-1.00)	0.108
Trend first lockdown	0.99 (0.97-1.00)	0.251
Trend inter-lockdown	1.01 (1.01-1.02)	0.000
Trend second lockdown	1.03 (1.03-1.04)	0.000
Trend recovery	1.01 (1.00-1.01)	1.000

[a]Negative binomial model with month, municipality fixed effects

Examining the predicted transaction value of the average municipality demonstrates the immediate decrease in spending at the onset of lockdowns, and subsequent increases at the end of each lockdown (Figure 1). Notably, economic expenditures began to recover during the second lockdown period, with a return to pre-Covid-19 values by the end of this lockdown.

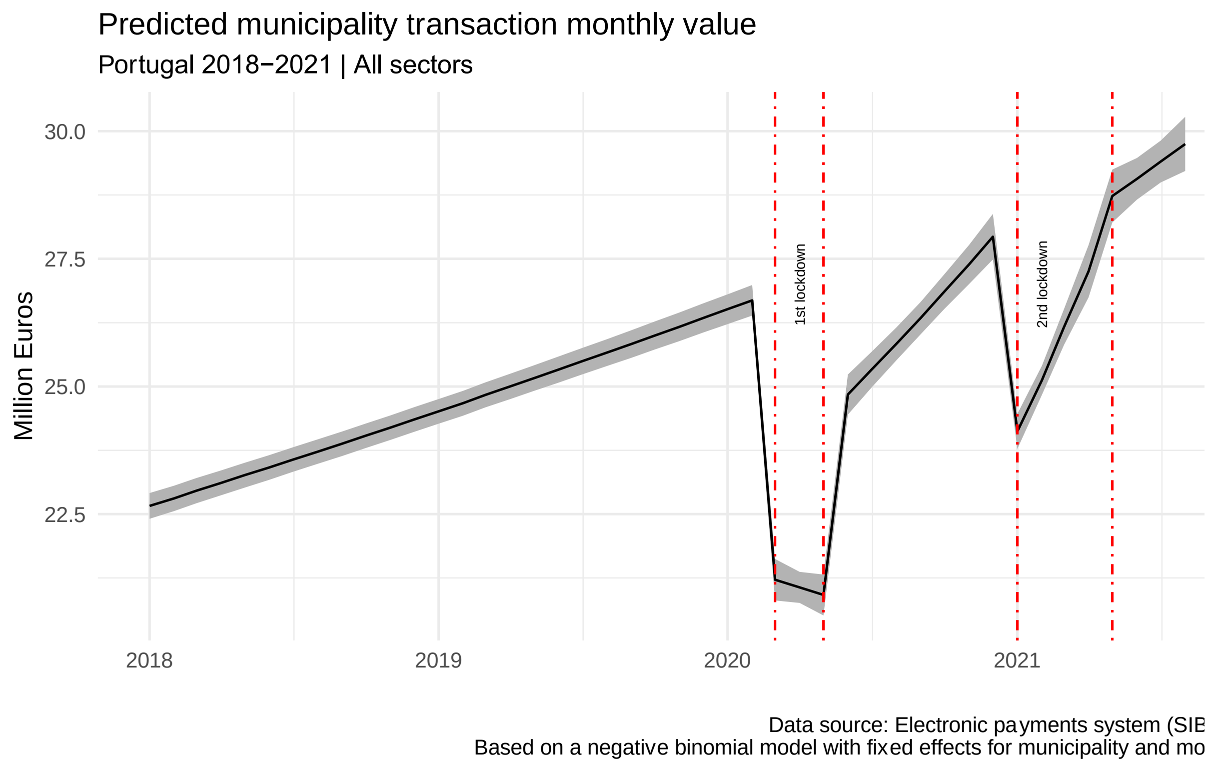


Figure 1. Transaction monthly value (million Euros) for all sectors in Portugal, January 2018 - August 2021

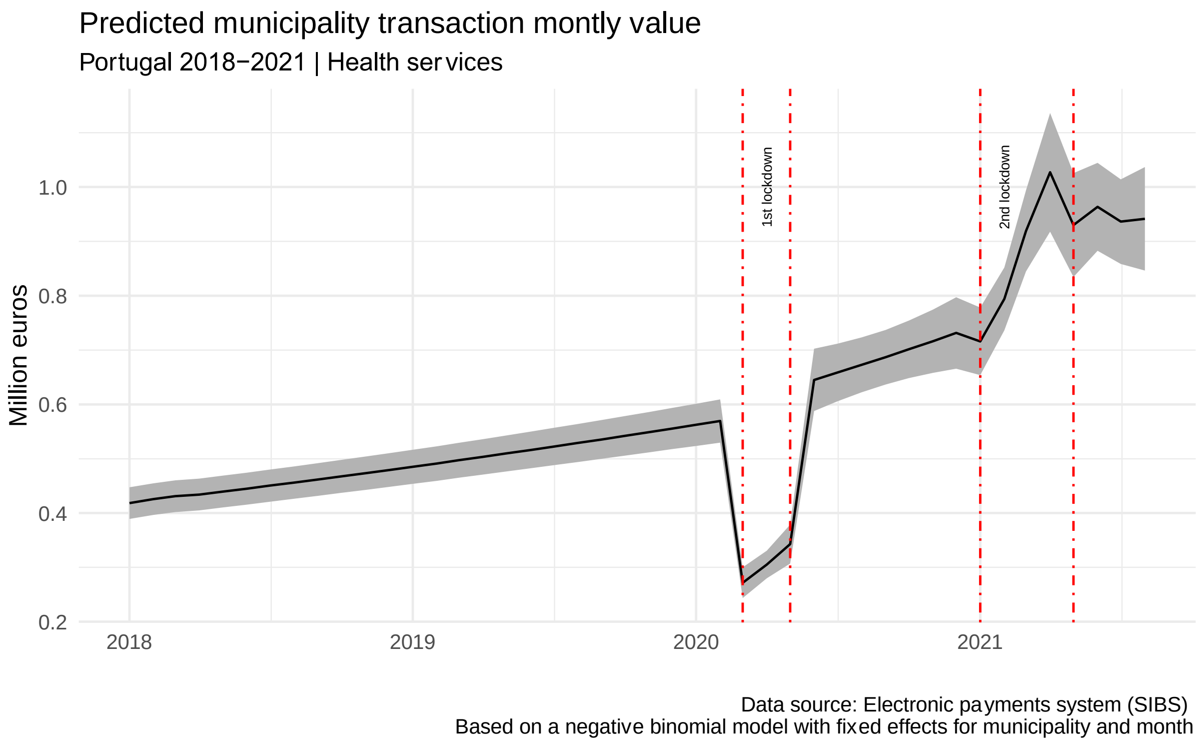
Health and pharmaceutical sectors

Spending on health services decreased in the value of financial transactions during first lockdown, with an immediate 53% decrease (RR=0.47; 95%CI: 0.43-0.52) (Table 3; Figure 2). However, there was no immediate change in spending during the second lockdown (RR=0.97; 95%CI: 0.88-1.06), and spending on health services increased on average 11% per month after the first month of the second lockdown (RR=1.11; 95%CI: 1.07-1.16). Spending on the pharmaceutical sector increased by 28% immediately after the first lockdown in March 2020 (RR=1.28; 95%CI: 1.25-1.31), though decreased over the remainder of the first lockdown. There was a 3% (RR=1.03; 95%CI: 1.01-1.04) monthly increase during the second lockdown.

Table 3. Effect of COVID-19 pandemic lockdowns on value of transactions (million euros) for health services and the pharmaceutical sector

Study Outcome[a]	Term	Rate ratio (95% CI)	p value
Healthcare services	Pre COVID-19 trend	1.01 (1.01-1.01)	0.000
	First lockdown	0.47 (0.43-0.52)	0.000
	Inter-lockdown	1.08 (1.00-1.16)	0.291
	Second lockdown	0.97 (0.88-1.06)	1.000
	Recovery	1.20 (1.08-1.32)	0.003
	Trend first lockdown	1.11 (1.04-1.18)	0.009
	Trend inter-lockdown	1.01 (0.99-1.03)	1.000
	Trend second lockdown	1.11 (1.07-1.16)	0.000
	Trend recovery	1.00 (0.96-1.04)	1.000
Pharmaceutical products	Pre COVID-19 trend	1.01 (1.01-1.01)	0.000
	First lockdown	1.28 (1.25-1.31)	0.000
	Inter-lockdown	1.03 (1.01-1.05)	0.022
	Second lockdown	0.89 (0.87-0.92)	0.000
	Recovery	0.94 (0.91-0.97)	0.000
	Trend first lockdown	0.85 (0.84-0.87)	0.000
	Trend inter-lockdown	0.99 (0.98-0.99)	0.000
	Trend second lockdown	1.03 (1.01-1.04)	0.001
	Trend recovery	1.02 (1.00-1.03)	0.097

[a]Negative binomial model with month, municipality fixed effects



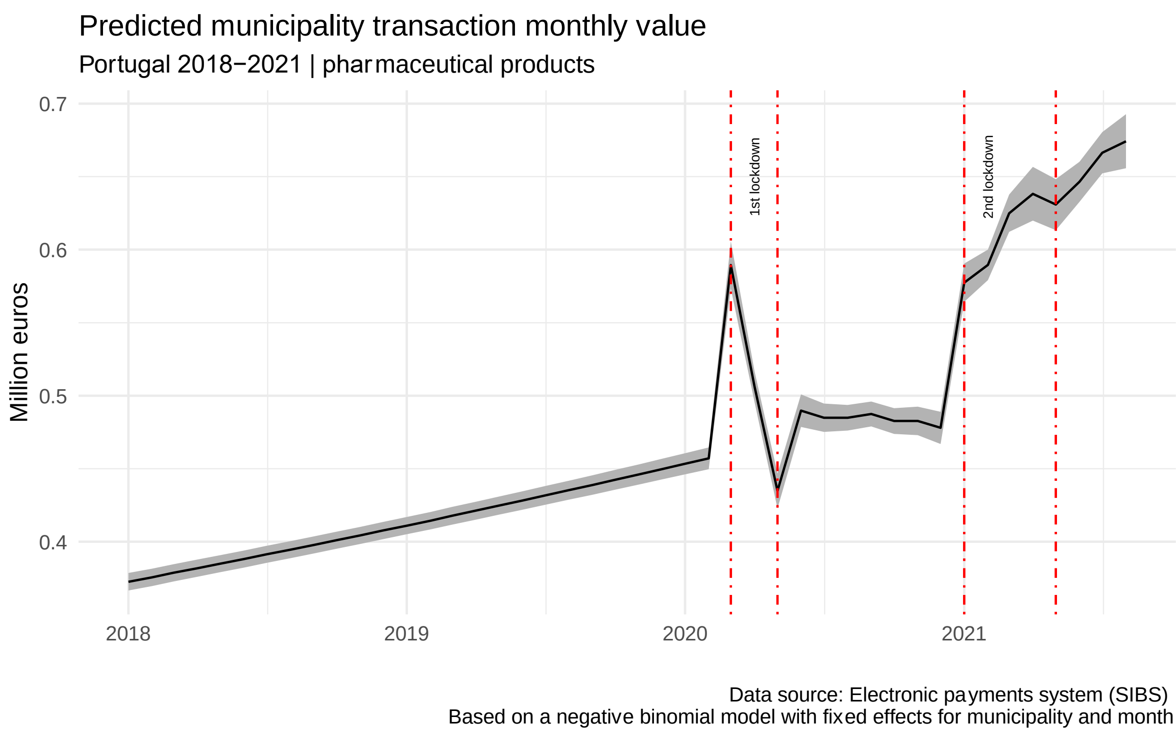


Figure 2. Monthly transaction value (million Euros) on private health services (top) and pharmaceutical products (bottom) in Portugal, January 2018 - August 2021

Robustness checks

Adjusting for SARS-CoV-2 cases and COVID-19 deaths had a minimal effect on aggregate spending in all sectors, with less than a 5% relative difference. Moreover, we found no differences in the effect of lockdowns after stratifying the municipalities by social deprivation quintiles (see Appendix: Chapter 2).

COVID-19 control

The mean monthly incidence of SARS-CoV-2 and COVID-19 deaths per 100,000 inhabitants at the municipality level was highest during the second lockdown (January 2021) (Table 4). The incidence of both cases and deaths decreased in the early recovery period compared with the second lockdown period. During the periods under study, SARS-CoV-2 infections were more common among young adults in the working age range (20-30 and 30-40 years old) and older individuals (aged 80 years or above). However, COVID-19 deaths were predominantly observed among the elderly aged 70 years and older (Table 4).

Table 4. Mean monthly incidence of SARS-CoV-2 cases and SARS-CoV-2-associated deaths per 100,000 inhabitants at the municipality level, by lockdown period and age group in Portugal

Study outcome	Age group	First lockdown	Inter-lockdown	Second lockdown	Recovery
SARS-CoV-2 Cases	**All**	**79 (37)**	**478 (544)**	**924 (1251)**	**195 (131)**
	[0,10]	20 (12)	312 (373)	604 (768)	184 (140)
	[10,20]	26 (12)	460 (563)	889 (1229)	271 (196)
	[20,30]	87 (37)	665 (714)	1108 (1497)	384 (279)
	[30,40]	96 (34)	592 (647)	1062 (1440)	284 (193)
	[40,50]	83 (37)	525 (602)	1007 (1386)	225 (155)
	[50,60]	90 (45)	487 (568)	960 (1317)	154 (88)
	[60,70]	71 (31)	365 (416)	786 (1051)	89 (39)
	[70,80]	71 (39)	311 (358)	667 (880)	60 (31)
	[80,120]	186 (142)	550 (632)	1215 (1661)	48 (30)
COVID-19 Deaths	**All**	**4 (3)**	**8 (9)**	**20 (29)**	**1 (0)**
	[0,10]	0 (0)	0 (0)	0 (0)	0 (0)
	[10,20]	0 (0)	0 (0)	0 (0)	0 (0)
	[20,30]	0 (0)	0 (0)	0 (0)	0 (0)
	[30,40]	0 (0)	0 (0)	0 (1)	0 (0)
	[40,50]	0 (0)	0 (1)	1 (1)	0 (0)
	[50,60]	1 (0)	1 (2)	3 (5)	0 (0)
	[60,70]	2 (1)	5 (6)	14 (20)	0 (0)
	[70,80]	8 (5)	17 (20)	42 (62)	2 (1)
	[80,120]	39 (30)	81 (96)	198 (296)	4 (4)

There was an immediate 6% increase in the number of SARS-CoV-2 cases after the second lockdown in January 2021 (RR=1.06; 95%CI: 0.96-1.12), and a 28% increase in deaths (RR=1.28; 95%CI: 1.12-1.45) compared with the inter-lockdown period (Table 5).

However, during the subsequent months of the second lockdown there was a significant decrease in the trend of both outcomes, with an 80% decrease in cases and 88% decrease in deaths. At the start of the recovery period SARS-COV-2 trend increased; however, COVID-19 deaths remained stable.

Table 5. Effect of January 2021 lockdown on SARS-CoV-2 cases, COVID-19 deaths, in Portugal

Study Outcome[a]	**Term**	**Rate ratio (95% CI)**	**p value**
SARS-CoV-2 Cases	Interlockdown trend	1.70 (1.66-1.75)	0.000
	Second lockdown	1.06 (0.96-1.16)	0.246
	Recovery	0.01 (0.01-0.01)	0.000
	Trend second lockdown	0.20 (0.19-0.21)	0.000
	Trend recovery	1.27 (1.12-1.44)	0.000
COVID-19 Death	Interlockdown trend	1.75 (1.67-1.84)	0.000
	Second lockdown	1.28 (1.12-1.45)	0.000
	Recovery	0.00 (0.00-0.00)	0.000
	Trend second lockdown	0.12 (0.11-0.13)	0.000
	Trend recovery	0.93 (0.61-1.43)	0.756

[a]Negative binomial model with month, municipality, age group and sex fixed effects

Discussion

Our analysis on the effects of lockdowns to mitigate the COVID-19 pandemic in Portugal highlight that – while these non-pharmaceutical interventions reduce cases and deaths – they have a marked impact on financial expenditures. The first lockdown was associated with the most significant economic impact, with a 21% decrease in transaction values, compared with a 16% decrease during the second lockdown. These results suggest an adaptation of the population to the economic effects of lockdowns, (20) though our data is not disaggregated to enable us to test this hypothesis. An alternative explanation for the decreased economic impact of the second lockdown could be pandemic fatigue, with less strict compliance with stay-at-home orders (and increased spending) during the January 2021 lockdown compared with the March 2020 lockdown (21). Studies from other countries found similar decreases in spending during the first lockdown, with a 30% decrease in Denmark (22), a 35% in the United States (23), and a 37% decrease in China (24).

Assessing health and pharmaceutical sector expenditures separately indicates increased transactions in the pharmaceutical sector early in the first lockdown, which decreases over time, which is likely due to anticipatory purchases in preparation for the impending lockdown. Other authors have reported increases in pharmaceutical spending during the first lockdown (25) (26) (22) with similar magnitude (Elek et al reports a 30% increase (27), while we report a 28% increase). In some middle and low-income countries similar spending patterns disrupted the supply chains, increasing inequities in access to essential medical supplies (28).

The precipitously implemented first lockdown was associated with a significant decrease in transaction values, likely due to the closure of the private healthcare sector (such as dental offices, outpatient care, and laboratories) (29). During the second lockdown, private healthcare providers had more than six months to prepare and reorganize services in a way that would allow them to remain open, which could explain why there was no decrease in health sector transaction values during this period.

Our robustness checks demonstrated that adjusting for SARS-CoV-2 cases and COVID-19 deaths had little effect on the economic impact of lockdowns. This has several possible explanations. First, the number of SARS-CoV-2 cases and COVID-19 deaths may be insufficient to decrease the workforce and lead to a noticeable impact on spending. A study comparing Sweden (no lockdowns) and Denmark (lockdowns) found that, despite not having had lockdowns, Sweden had a similar decrease in aggregate spending during the first lockdown, hinting that it is changes in behavior driven by COVID-19 and not lockdowns that contribute to the decrease in spending (30). Our results suggest that, given that lockdowns were implemented, the number of SARS-CoV-2 cases and COVID-19 deaths had only a marginal effect on decreased spending. We did not find any heterogeneity in results by deprivation quintile at the municipal level, which could be due to active policies by the government to protect lower-income communities, or the municipality unit of analysis does not allow to study the unequal effect effects by income. Studies in Denmark (22) and the United States (31) found that panic buying before the first lockdown was similar across income quintiles, which could explain why we did not find differences by level of deprivation.

Our findings indicate that the second lockdown led to a reduction in the number of SARS-CoV-2 cases and COVID-19 deaths, while causing less economic damage. Despite the smaller economic impact, the effectiveness of the lockdown in controlling the spread of COVID-19 was not significantly affected. These results highlight the importance of adapting to the economic consequences of lockdowns while still achieving the goal of controlling the disease's spread. The decision to implement a lockdown is a complex one that requires balancing the economic and social costs against the potential benefits for public health. During the second lockdown, despite the possibility of pandemic fatigue, the Non-Pharmaceutical Intervention (NPI) measures remained effective. However, our study was unable to determine the relative contribution of each NPI in achieving this effectiveness.

Our study has some notable limitations. The datasets are reported monthly, which limits our ability to study lockdowns implemented in mid-March mid-January 14. The effects of this lack of granularity likely underestimate the immediate effect of the lockdowns on our model. Additionally, we attempted to study the heterogeneity of the effect of lockdowns on social deprivation, given that previous research found that lockdowns led to higher income losses amongst poorer populations (32) (33). The use of municipality-level data may pose challenges in identifying relevant associations, as income populations within municipalities can vary significantly. To address this issue, it may be necessary to consider more granular data that was unavailable.

Our study also has notable strengths. We were able to combine data from multiple sources to estimate the effects of two lockdowns on economic activity, which demonstrated likely societal adaptation to lockdowns over time. This is especially important in the health services sector, which was less affected during the second lockdown. We also highlight the need for governments to anticipate hoarding of pharmaceutical goods and promote resilient supply chains.

Conclusion

This study demonstrates that the COVID-19 lockdowns decreased economic activity, which was more dramatic in the March 2020 lockdown than the January 2021 lockdown. Moreover, the second lockdown effectively decreased SARS-CoV-2 cases and COVID-19 deaths. We did not find differences in impact by level of social deprivation. For the pharmaceutical sector, the March 2020 lockdown resulted in anticipatory purchases, which should be accounted for in future external shocks to ensure a resilient medical products supply chain.

Chapter 3. Impact of the COVID-19 pandemic on outpatient hospital and primary care services, telemedicine and surgical procedures

Abstract

Introduction: The COVID-19 pandemic affected the capacity of health systems to maintain essential health services. We aim to estimate the pandemic's impact on outpatient hospital, telemedine, primary care, and hospital surgical procedures in Portugal, as well as to quantify the magnitude of lost visits for elective care through 12 months after the end of the last lockdown.

Methods: We used an interrupted time-series analysis to explore the effects of the March-May 2020 (lockdown one), June-December 2020 (the inter-lockdown period), January-April 2021 (lockdown two), and May 2021-May2022 (the recovery period). We used a negative binomial model with fixed effects for calendar month and health facility, and adjusted for the number of doctors and nurses at the facility-level, and the population over 65 years of age at the regional level. We explored first and follow-up outpatient hospital visits and elective and urgent surgeries; we evaluated in-person outpatient visits, telemedicine or home visits for primary care. For emergency care, we evaluated the number of visits. We present the Rate Ratios (RR) for the outcomes and the 95% confidence intervals.

Results: The first lockdown had the most significant impact on services, with a 40% decrease (RR 0.60 95%CI 0.57-0.62) in hospital outpatient first visits, a 21% decrease (RR 0.79 95%CI 0.76-0.81) in hospital outpatient follow-up visits, 58% decrease (RR 0.42 95%CI 0.39-0.46) in elective surgeries, and 16% decrease (RR 0.84 95%CI 0.79-0.89) in urgent surgeries, compared with a pre-pandemic period. Telemedicine follow-up visits increased eightfold in the first lockdown (RR 7.97 95%CI 3.29-19.33) and continued to increase during the study period. The second lockdown had a lesser impact on activity than the first lockdown. Primary in-person care had a nearly 50% decrease during the lockdowns. One year after the end of the last lockdown, there are still significant lost visits in elective care for all the outcomes.

Conclusions: The COVID-19 pandemic resulted in moderate disruption of all outcomes studied, with some mitigation mechanisms like telemedicine. Hospitals resumed pre-pandemic levels faster than primary care; however, many lost visits remain unaddressed, which could increase unmet needs.

Keywords: COVID-19, lockdowns, access to healthcare, telemedicine, time-series

Introduction

The COVID-19 pandemic disrupted health service delivery globally (34) (35). However, as the World Health Organization (WHO) highlights, service disruptions were heterogeneous in effect, ranging from moderate (change of 5-50% in service provision or use), to severe (over 50% change in service provision or use).

Healthcare access can be defined as “the timely use of personal health services to achieve the best health outcomes” (36). Access is multi-dimensional, and includes coverage (proportion of the population with physical and financial access), service comprehensiveness, timeliness, and workforce quality (37). Other definitions of access incorporate dimensions of affordability (financial protection), cultural appropriateness, and digital availability (synchronous and asynchronous communication with providers) (38). Pragmatically, the observable aspect of access that can be measured using routine data systems is healthcare utilization, defined as the number of healthcare services encounters and procedures used (39).

COVID-19 was an external shock that impacted healthcare access due to delayed diagnoses; canceled, and delayed care; and a surge of patients with moderate to severe COVID-19 disease. The Organization for Economic Cooperation and Development (OECD) highlighted the need for resilient healthcare systems capable of anticipating, absorbing, recovering, and adapting to future shocks (40). During the pandemic governments were faced with balancing the direct effects of policies aimed at controlling COVID-19 transmission and preventing health system overload with the indirect effects of restrictions on mobility, school closures, and healthcare reorganization (with its associated effects on healthcare access and services provided) (41). During the peak COVID-19 waves in Portugal (April 2020, January 2021), non-urgent care was delayed to prioritize professionals and available hospital beds for COVID-19 patients. Nurses were allocated to the mass vaccination campaign from January to September 2021. Additionally, the fear of being infected in a healthcare setting has been linked to reduced healthcare utilization early in the pandemic (42). Finally, a shortage of healthcare professionals due to sickness and essential medicines and supplies due to supply chain disruptions contributed to decreases in healthcare access.

People with chronic conditions are vulnerable to adverse COVID-19 outcomes and to the indirect effects of decreased healthcare access. A systematic review found a median 37.2% (IQR −50.5% to −19.8%) reduction in healthcare utilization from pre-pandemic levels (43). Several European countries documented reductions in primary care visits (8), cancer screening programs (44), and emergency department visits (45). Estimating the extent of the direct and indirect effects of COVID-19 control efforts on access to healthcare is fundamental to developing policies aimed at mitigating the impact of foregone or delayed care.

Our paper aims to assess the direct and impact of the COVID-19 pandemic on outpatient hospital and primary care services, telemedicine, emergency care visits and hospital surgical procedures.

Methods

Design

We implemented an interrupted time series analysis to explore the effect of the COVID-19 pandemic on healthcare access in Portuguese from prior to March 2020 (the control period) through May 2022.

Data source

Outcomes data were sourced from the routine health information system of the National Health Service in Portugal (NHS-PT) that covers monthly outpatient care and surgical visits, as well as staffing (number of workers), at public sector hospitals and primary care clinics (designated as trusts in the Portuguese health system). Data are reported monthly, aggregated to the hospital or primary care trust level. Data for our analyses covered the January 2018 to May 2022 period. Data on the size of the population over 65 years of age were provided by the Portuguese National Institute of Statistics for the study period.

Setting and participants

Portugal is a high-income country with a network of public hospitals and primary care trusts that form the NHS-PT (46). The NHS-PT provides free services for all legal residents in Portugal. The National Institute of Statistics estimates that the NHS-PT provides 70% of all surgeries and 60% of all medical visits in Portugal, with the rest being provided through private sector providers. We only included data from mainland Portugal, as island health system is separately managed, and no data were available.

Outcomes

Our analysis explored healthcare utilization, measuring several aspects of outpatient care. Outpatient hospital visit refers to any professional encounter between a non-hospitalized individual and a Medical Doctor. We divided outpatient hospital visits into two categories: 1) the first consultation after a referral (usually from a primary care facility), or 2) a follow-up hospital-based consultation. Hospital telemedicine was defined as a real-time consultation using interactive, audiovisual and data communications in the patient's presence at a distance. Surgical care was divided into 1) urgent and 2) elective surgeries according to the OCDE definition (47). Emergency department visits were unscheduled outpatient care visits at hospital-based emergency departments that are staffed 24 hours a day, seven days a week. Primary care outpatient visits were divided into 1) in-person visits, and 2) home visits.

Exposure and other explanatory factors

To model the effects of COVID-19 lockdown strategies, we added an interaction term for the time variable and the following periods of interest: 1) March-May 2020 (the first government lockdown), 2) June-December 2020 (the period between the first and second lockdowns), 3) January-April 2021 (the second government lockdown), and 4) May2021-May2022 (the post-lockdown recovery period) using the model specification approach for multiple periods described by Xiao (14). To account for seasonality and unique hospital or primary care practices, we added the month of the year and hospital or primary care trust as fixed effects. The model accounted for determinants of supply and demand by including the number of medical doctors and nurses working full-time at each facility by month, and the population over 65 years of age (at the regional level). We used the sandwich method at the facility level to adjust for clustered standard errors (48).

Statistical Analysis

We used a negative binomial generalized linear model with the monthly outcome (Equation 2):

$$Y_{it} - NB(\mu_{it}, \alpha)$$

$$\mu_{it} = exp\left(\beta_0 + \beta_1 V_i + \beta_2 X_{1-3|it} + \beta_3 T_i + \beta_4 XT_{it} + \beta_5 \gamma_{it} + \varepsilon_{it}\right)$$

In the Equation 2, where: Y is the outcome of interest for each time t and hospital i, with a mean μ_{it} and a variance α, V_i is the time since the beginning of the study, and represents the frequency of the recorded outcome in months, X_{1-3} is the dummy variable (0, 1) indicating each of the periods of interest, including the two lockdown periods, the inter-lockdown period, and the recovery period. T_i is the time after the start of the lockdown, inter lockdown or recovery, and assumes the value zero in all the other months. γ_{it} are vectors of fixed effects in the model (number of medical doctors, nurses and population over 65 years old). ε_{it} is an error term.

The β_1 estimator represents the outcome trend before the first lockdown. The β_2 estimator represents the immediate effects of the lockdown or inter-lockdown period. The β_4 represents the trends during the lockdown or inter-lockdown period. We present the outcome's rate ratio (RR) and the 95% confidence intervals (95% CI).

We calculated the number of potential lost visits by predicting the number of monthly visits for each outcome of interest based on the pre-pandemic utilization levels. We used the model’s predicted outcome using the marginal effects package (18) for the average facility.

We also calculated the potentially lost visits by predicting the number of care indicators monthly episodes. However, we used the model described above only for the pre-pandemic period. We calculated the difference between the observed and expected values had the pandemic not happened. We present the sum of the potentially lost visits through May 2022 compared with the annual sum of visits for the year prior to the pandemic for each outcome measure.

Robustness checks

We replicated the models with no adjustment for the number of medical doctors and nurses working full-time at the facility level by month and the population over 65 years old at the regional level.

Results

Our study included 46 hospitals and 55 primary care trusts. The monthly mean number of outpatient and surgical visits decreased from the pre COVID-19 period through the March 2020 lockdown period, with the exception of outpatient telemedicine visits at the primary care level, which increased in all periods after the pandemic (Table 6). Notably, the average number of monthly consultations observed during the recovery period surpassed the number of monthly consultations observed prior to the pandemic for some outcomes, including 1) first outpatient visit at the hospital level, 2) follow-up outpatient visits at the hospital level , and 3) elective surgeries .

Table 6. Monthly average number of outpatient hospital, telemedicine, outpatient primary-level, and surgical visits by COVID-19 lockdown period, in Portugal January 2028 – May 2022

Study Outcome	Pre COVID-19	Mar20 Lockdown	Inter-lockdown	Jan21 Lockdown	Recovery
Outpatient follow-up | Hospital	728.6 (75.4)	588.8 (55.3)	685.3 (79.9)	738.9 (74)	758 (70.9)
Elective surgeries | Hospital	48.6 (6.1)	21.8 (10.4)	44.4 (6.1)	46.3 (12)	54.2 (5.6)
Urgent surgeries | Hospital	8.4 (0.5)	6.9 (0.6)	7.7 (0.3)	7.5 (0.8)	8 (0.4)
Outpatient 1st visit | Hospital	292.7 (27.9)	177.9 (44.9)	260.3 (31.9)	281.6 (39.9)	303.6 (26.7)
Telemedicine 1st visit | Hospital	1.1 (0.3)	1.6 (0.3)	1.5 (0.2)	6.6 (0.4)	6.6 (2.7)
Telemedicine follow-up | Hospital	1.2 (0.1)	3 (0.1)	2.3 (0.5)	28 (2.6)	17 (14)
Emergency department | Hospital	533.3 (23.1)	295.8 (45.9)	367.4 (27)	321.4 (56.2)	499.5 (42.8)
Outpatient home | PC	16.1 (2.2)	10.4 (5.9)	9.2 (1.1)	11.6 (2.8)	13.9 (3.2)
Outpatient onsite | PC	1725.4 (165.7)	760.6 (370.5)	975.2 (137)	1083.3 (149)	1343.9 (153.2)

Hospital outpatient visits

There was a 40% (RR 0.60 95%CI 0.57-0.62) immediate reduction in first outpatient hospital visits in March 2022 compared with the pre-pandemic period, which decreased 8% per month (RR 0.92 95%CI 0.90-0.95) during the first lockdown (Table 7). The immediate effect of the inter-lockdown was more modest, with an 18% decrease (RR 0.83 95%CI 0.79-0.85) and a slight increase of 2% by month (RR 1.02 95%CI 1.01-1.03) in the following months. The second lockdown resulted in a 28% decrease (RR 0.72 95%CI 0.69-0.75). However, followed by a 15% monthly increase during the lockdown months (RR 1.15 95%CI 1.13-1.17).

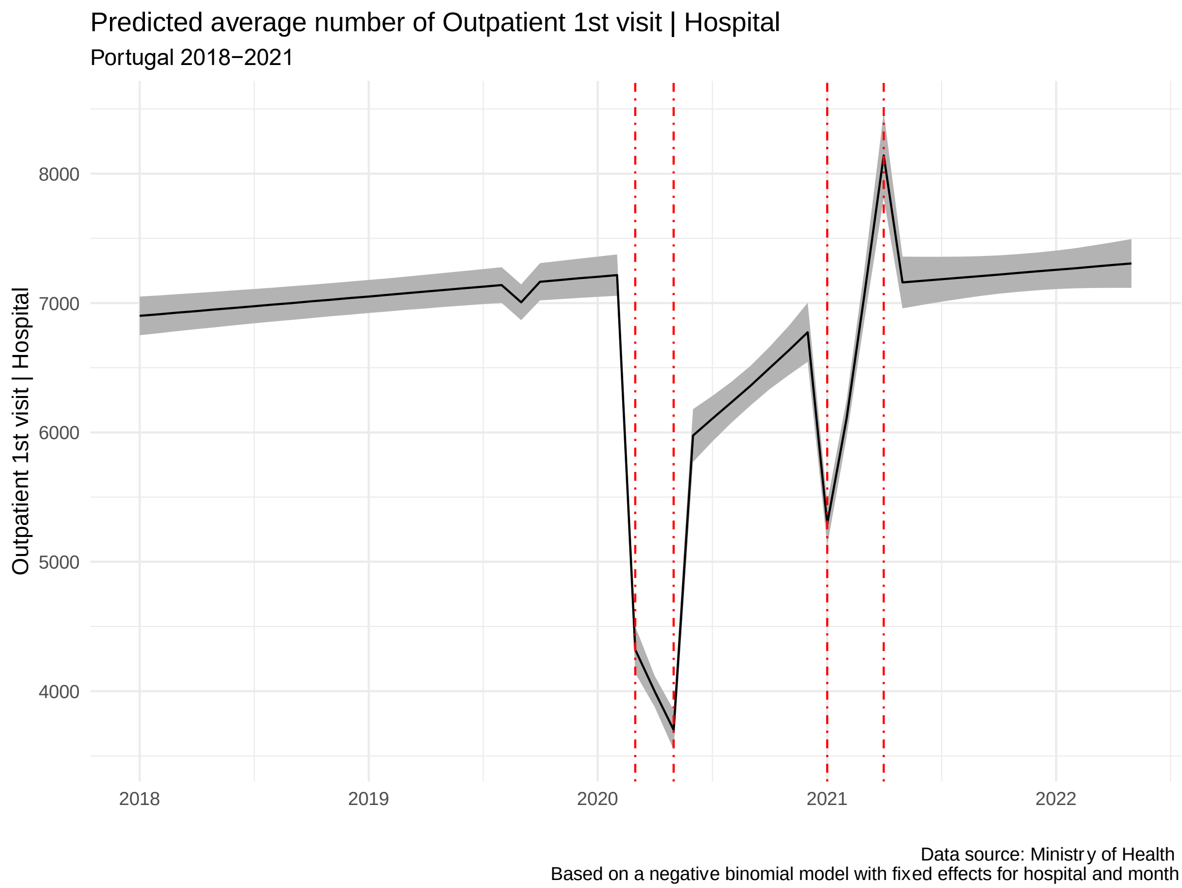


Figure 3. Outpatient predicted outpatients visits in Portugal, January 2018 - May 2022

The outpatient follow-up consultations had a more modest impact than the outpatient first visit. The first lockdown had an immediate effect of a 21% decrease (RR 0.79 95%CI 0.76-0.81) compared with the pre-pandemic period. The inter-lockdown period had a 3% decrease (RR 0.97 95%CI 0.95-0.99), with no increase during the following months. The second lockdown had an 18% decrease (RR 0.84 95%CI 0.81-0.87), with a slight increase in the following lockdown months. The recovery trend did not differ from the pre-pandemic period for outpatient first visits and follow-ups. That is also clear in figure 3, where the mean hospital was very fast to recover to pre-pandemic levels. However, it did not increase the number of outpatient visits to account for lost visits.

Telemedicine visits increased immediately after the March 20 lockdown with an 97% increase (RR 1.97 95%CI 0.97-3.98) for first visits. However, it was only significant for follow-up. The increase in telemedicine first and follow-up visits was consistent across the interlock down, January 2021 lockdown and recovery period. That significant expansion in telemedicine care balanced the outpatient care decrease; see table 7.

Elective surgeries had a decrease of 58% (RR 0.42 95%CI 0.39-0.46) immediately after the March 20 lockdown, followed by less severe decreases in the following periods, 21% decrease in the inter-lockdown (0.79 95%CI 0.74-0.84), and 47% decrease in the second lockdown (RR 0.53 95%CI 0.49-0.58), the following month during the second lockdown had an increase of 28% (RR1.28 95%CI 1.23-1.32). As expected, the effect of lockdowns was less pronounced in urgent surgeries, 16% (RR 0.84 95%CI 0.79-0.89) immediately after the first lockdown, 9% (RR 0.91 95%CI 0.87-0.96) in inter-lockdown and 17% (RR 0.83 95%CI 0.78-0.89) in the second lockdown.

Regarding emergency care visits, March 2020 resulted in a 44% decrease in visits (RR 0.56 95%CI 0.54-0.58), and it was even more pronounced in the second lockdown 49% decrease (RR 0.51 95%CI 0.50-0.53). However, emergency care visits were the only indicator where the recovery trend increased by 1% monthly.

Table 7. Trends in hospital outpatient visits, telemedicine and surgical procedures by COVID-19 lockdown period

Study outcome[a]	Term	Rate ratio (95% CI)	p value
Outpatient 1st visits	First lockdown	0.60 (0.57-0.62)	0.000
	Inter-lockdown	0.82 (0.79-0.85)	0.000
	Second lockdown	0.72 (0.69-0.75)	0.000
	Recovery	0.97 (0.93-1.00)	0.440
	Trend first Lockdown	0.92 (0.90-0.95)	0.000
	Trend inter-lockdown	1.02 (1.01-1.03)	0.000
	Trend second Lockdown	1.15 (1.13-1.17)	0.000
	Trend recovery	1.00 (1.00-1.00)	1.000
Outpatient follow-up visits	First lockdown	0.79 (0.76-0.81)	0.000
	Inter-lockdown	0.93 (0.91-0.96)	0.000
	Second lockdown	0.84 (0.81-0.87)	0.000
	Recovery	1.00 (0.97-1.02)	1.000
	Trend first Lockdown	0.97 (0.95-0.99)	0.032
	Trend inter-lockdown	1.00 (1.00-1.01)	1.000
	Trend second Lockdown	1.09 (1.07-1.10)	0.000
	Trend recovery	1.00 (1.00-1.00)	1.000
Telemedicine 1st visits	First lockdown	1.97 (0.97-3.98)	0.560
	Inter-lockdown	1.83 (1.03-3.25)	0.385
	Second lockdown	11.03 (5.56-21.87)	0.000
	Recovery	11.81 (6.61-21.08)	0.000
	Trend first Lockdown	0.94 (0.58-1.53)	1.000
	Trend inter-lockdown	1.05 (0.91-1.19)	1.000
	Trend second Lockdown	1.04 (0.77-1.40)	1.000
	Trend recovery	1.09 (1.04-1.15)	0.010
Telemedicine follow-up visits	First lockdown	7.97 (3.29-19.33)	0.000
	Inter-lockdown	9.66 (4.66-20.03)	0.000
	Second lockdown	236.25 (99.18-562.79)	0.000
	Recovery	74.26 (35.03-157.40)	0.000

Study outcome[a]	Term	Rate ratio (95% CI)	p value
	Trend first Lockdown	1.02 (0.56-1.87)	1.000
	Trend inter-lockdown	0.95 (0.80-1.12)	1.000
	Trend second Lockdown	0.76 (0.52-1.10)	1.000
	Trend recovery	1.26 (1.18-1.34)	0.000
Elective surgeries	First lockdown	0.42 (0.39-0.46)	0.000
	Inter-lockdown	0.80 (0.75-0.86)	0.000
	Second lockdown	0.53 (0.49-0.58)	0.000
	Recovery	0.96 (0.90-1.03)	1.000
	Trend first Lockdown	0.87 (0.82-0.92)	0.000
	Trend inter-lockdown	1.02 (1.00-1.03)	0.430
	Trend second Lockdown	1.28 (1.23-1.32)	0.000
	Trend recovery	1.00 (0.99-1.00)	1.000
Urgent surgeries	First lockdown	0.84 (0.79-0.89)	0.000
	Inter-lockdown	0.91 (0.87-0.96)	0.002
	Second lockdown	0.83 (0.78-0.89)	0.000
	Recovery	0.96 (0.91-1.01)	0.860
	Trend first Lockdown	0.99 (0.95-1.04)	1.000
	Trend inter-lockdown	0.99 (0.98-1.00)	1.000
	Trend second Lockdown	1.07 (1.05-1.10)	0.000
	Trend recovery	1.00 (0.99-1.00)	1.000
Emergency department visits	First lockdown	0.56 (0.54-0.58)	0.000
	Inter-lockdown	0.69 (0.67-0.71)	0.000
	Second lockdown	0.51 (0.50-0.53)	0.000
	Recovery	0.85 (0.83-0.88)	0.000
	Trend first Lockdown	0.96 (0.94-0.99)	0.022
	Trend inter-lockdown	0.99 (0.99-1.00)	0.093
	Trend second Lockdown	1.10 (1.09-1.12)	0.000
	Trend recovery	1.01 (1.01-1.01)	0.000

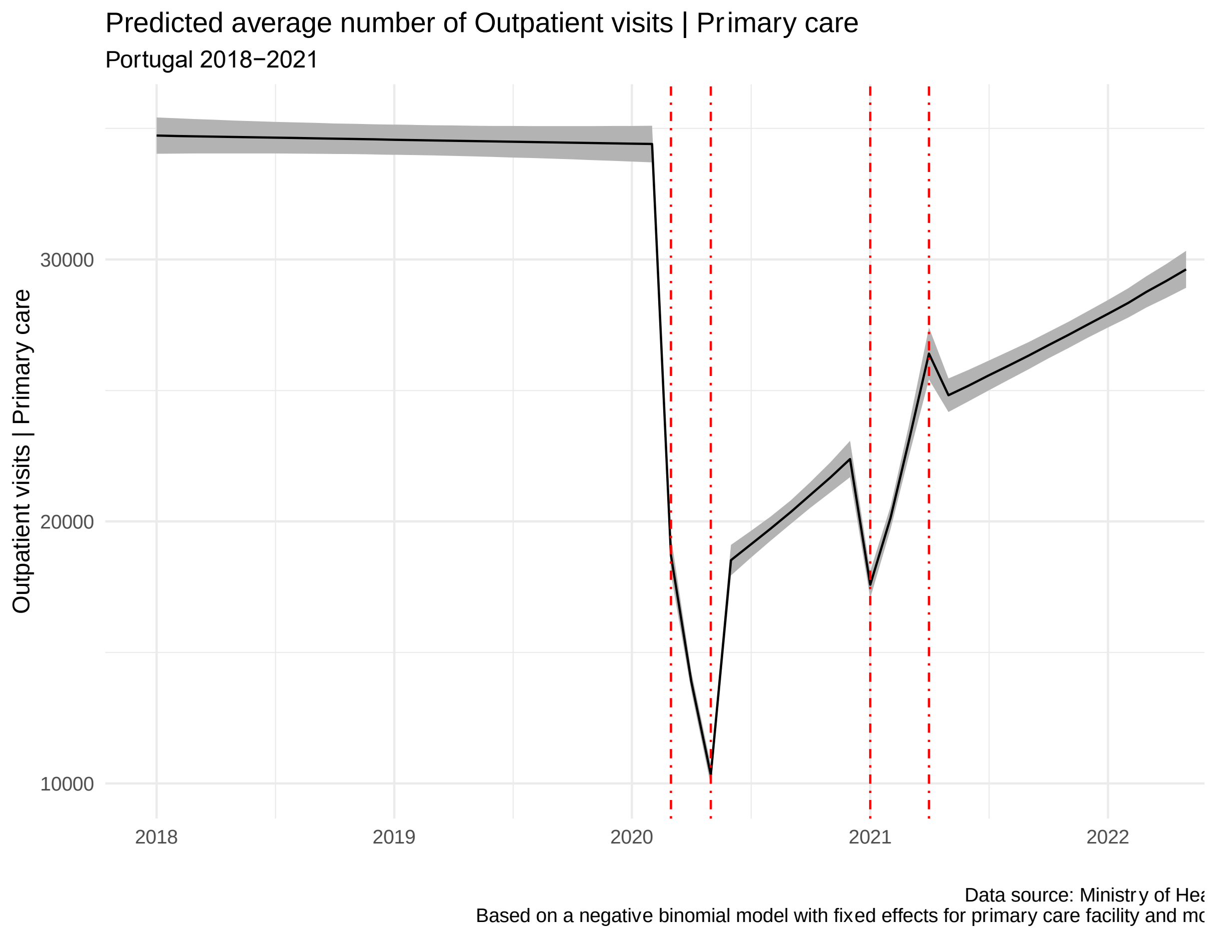
Study outcome[a]	Term	Rate ratio (95% CI)	p value

[a]Negative binomial model with month, hospitals, number of medical doctors, number of nurses and population over 65 years of age as fixed effects

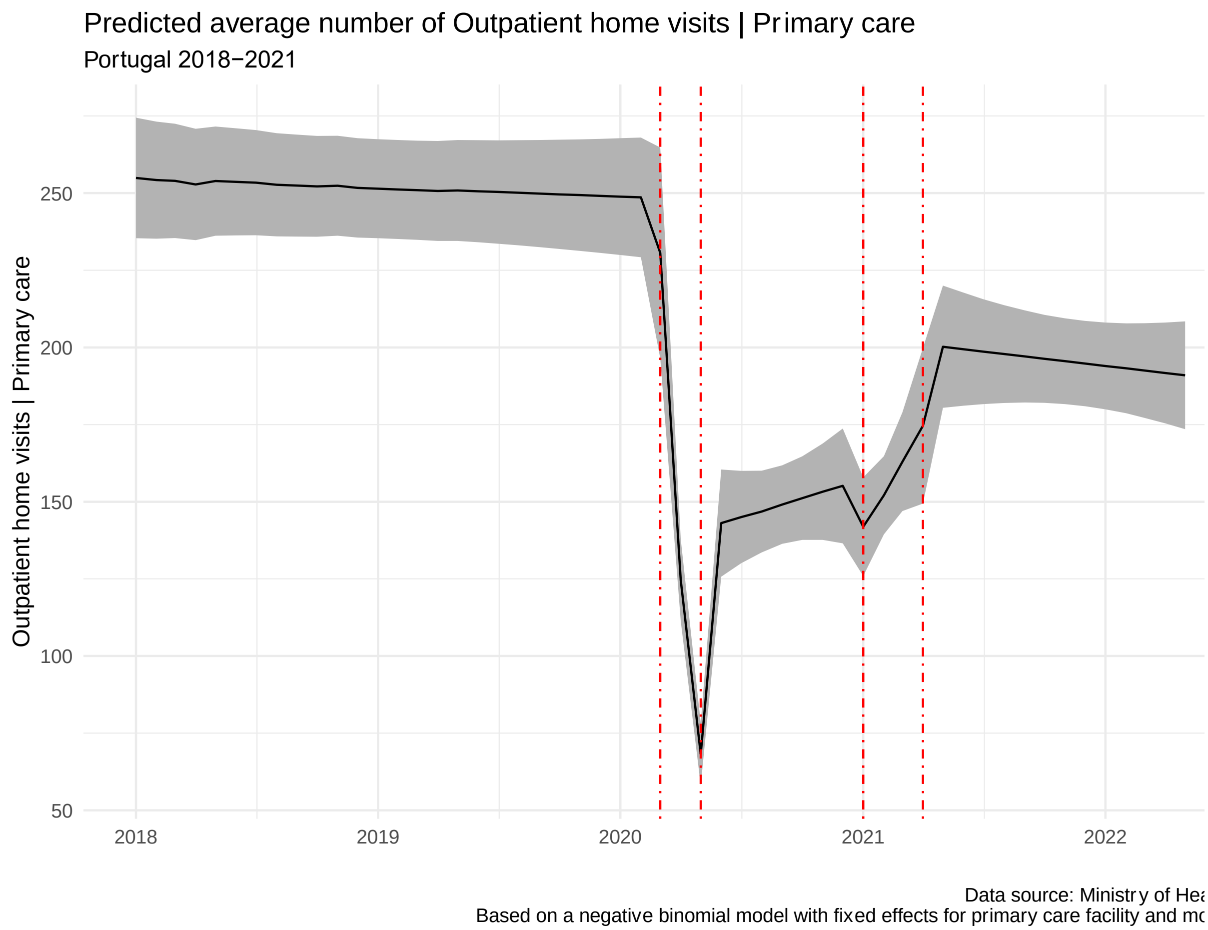
Primary care outpatient visits

Primary care utilization followed similar patterns as outpatient hospital visits, though with greater activity decreases (Table 8). There was an immediate 47% decrease (RR 0.57 95%CI 0.54-0.59) in March 2020 compared with the pre-pandemic period. The second lockdown resulted in a 48% decrease (RR 0.52 95%CI 0.50-0.54), followed by a 16% monthly increase during the lockdown months (RR 1.16 95%CI 1.14-1.18). The outpatient home visit had a similar lockdown impact as the in-person care visits, see table 8. One year after the second lockdown, the primary care had not recovered to pre-pandemic levels, figure 4.

The models without adjustment for the number of medical doctors and nurses working full-time at the facility level by month and the population over 65 years old at the regional level remained similar.



(a) Outpatient visits in primary care



(b) Home visits in primary care

Figure 4. Predicted outpatient and home visits in primary care in Portugal, January 2018 – May 2022

Table 8. Effect of COVID-19 pandemic on primary care outpatient care. in Portugal January 2018 - May 2022

Study Outcome[a]	Term	Rate ratio (95% CI)	p value
Outpatient onsite	First lockdown	0.57 (0.54-0.59)	0.000
	Inter-lockdown	0.55 (0.54-0.57)	0.000
	Second lockdown	0.52 (0.50-0.54)	0.000
	Recovery	0.77 (0.75-0.80)	0.000
	Trend first Lockdown	0.74 (0.72-0.76)	0.000
	Trend inter-lockdown	1.03 (1.02-1.04)	0.000
	Trend second Lockdown	1.16 (1.14-1.18)	0.000
	Trend recovery	1.00 (1.00-1.01)	1.000
Outpatient home visit	First lockdown	0.92 (0.79-1.07)	1.000
	Inter-lockdown	0.57 (0.51-0.65)	0.000
	Second lockdown	0.52 (0.45-0.61)	0.000
	Recovery	0.76 (0.66-0.87)	0.001
	Trend first Lockdown	0.55 (0.49-0.61)	0.000
	Trend inter-lockdown	1.00 (0.97-1.03)	1.000
	Trend second Lockdown	1.07 (1.00-1.15)	0.386
	Trend recovery	0.98 (0.96-1.00)	0.339

[a]Negative binomial model with month, primary care clinic, number of medical doctors, number of nurses and population over 65 years of age as fixed effects

Lost healthcare visits

All healthcare visit outcomes - except telemedicine visits - were estimated to have decreased from March 2020 through May 2022. This includes over 874 thousand hospital outpatient visits (95%CI -527.4 thousand to -1.2 million), representing 25% of the annual outpatient hospital visits for the 2019 year. The Outpatient follow-up lost visits represented 1.14 million episodes (95%CI -548.5 thousand to -1.7 million) or 13% of the

2019 total. There was an excess of 94.3 thousand visits for telemedicine first visits, and 307.8 thousand second visits. That represented an increase of 6.2 and 21.4 fold, respectively, compared with 2019. Despite the increased telemedicine, that was insufficient to offset the decrease in outpatient visits. The lost procedures sum for elective surgeries was -287.1 thousand (95%CI -152.3 to -435.8 thousand) and represented 48% of the annual elective surgeries for 2019.

The estimated lost visits of in-person outpatients in primary care were 8.8 million (95%CI -7.0 to -10.8 million) until May 2022. That represented 42% of the total number of in-person outpatient visits for 2019. Finally, the outpatient home visits had lost 111.0 thousand visits (95%CI -37.9 to -199.1 thousand), representing 56% of the total visits in 2019.

Table 9. Estimated effect of the pandemic on visits for elective care at hospital and primary care levels from March 2020 through May 2022

Study outcome[a]	**2019 sum[b]**	**Visits sum[c]**	**95% CI[d]**
Outpatient 1st visit | Hospital	3,529.9	-874.2	(-527.4 ; -1237)
Outpatient follow-up | Hospital	8,767.5	-1,140.2	(-548.5 ; -1750.6)
Telemedicine 1st visits	14.9	94.3	(; 126.3)
Telemedicine follow-up visits	14.4	307.8	(; 325)
Elective surgeries | Hospital	592.4	-287.1	(-152.3 ; -435.8)
Outpatient onsite | PC	20,691.0	-8,864.7	(-7017.3 ; -10802.8)
Outpatient home | PC	196.5	-111.0	(-37.9 ; -199.1)

[a]Outpatient and surgical elective care, PC - Primary Care; [b]Sum of episodes by indicator, for the year 2019; [c]Sum of the diference between the observed and estimated episodes by a negative binomial model; [d]95% confidence intervals

Discussion

Our study described lost outpatient and surgical care visits in 46 hospitals and 55 primary care trusts in Portugal between January 2018 and May 2022 associated with the COVID-19 pandemic and associated government mitigation policies.

The most significant impact on service utilization was observed during the March 2020 lockdown, with a 40% decrease in hospital outpatient first visits, a 21% decrease in hospital outpatient follow-up, a 58% decrease in elective surgeries, 19% decrease in urgent surgeries. However, that was followed by an eight-fold increase in telemedicine follow up visits. The months during the interlock-down period were followed by modest recoveries (outpatient first visit) in activity or stable trends.

The January 2021 lockdown was associated with more modest utilization decreases compared with the March 2020 lockdown. First outpatient hospital visits declined by 28% decrease, follow-up hospital outpatient visits decreased by a 17%, and a 50% decrease in elective surgeries. Hospitals recovered to pre-pandemic levels very early after the end of the second lockdown. However, they still need to increase procedures to address the lost visits. At the primary care level, in-person outpatient care visits markedly declined compared with pre-pandemic utilization – by 43% in the first lockdown and 48% in the second lockdown. Primary care has not recovered yet to pre-pandemic levels one year after the end of the second lockdown.

Finally, there was a considerable number of lost visits had the pandemic not happened, representing 25% of the annual outpatient hospital visits for 2019, 13% for outpatient follow-up, and 42% for in-person outpatient visits for primary care.

Understanding the Portuguese context can help to situate our results. During both lockdowns, the Ministry of Health ordered NHS-PT health facilities to suspend non-urgent care activities that, due to their nature or clinical priority, do not pose a risk to the lives of users, limit their prognosis or limit access to periodic treatments or surveillance. After the lockdowns, NHS-PT providers were instructed to ensure the identification and rescheduling of all scheduled assistance activities not carried out due to the COVID-19 pandemic. These policy directives help to explain the significant losses in most in-person consult outcomes, as well as the recovery patterns described in our analysis.

First outpatient visits decreased more substantially than follow-up visits, which is likely due to medical doctors prioritizing care continuity for patients referred by emergency departments instead of new patient visits. We observed a modest recovery during the interlock-down period, which may mean that hospitals were continuing to adapt to new standards of care, were at capacity and could not further increase their patient load (despite Ministry of Health recovery mandates), or that patients missed rescheduled care visits. Telemedicine had a vast expansion, which was higher during the second lockdown, which could indicate the time needed to have the hardware and software needed for telemedicine. However, telemedicine expansion was insufficient to offset the decrease in outpatient visits (49). Only some outpatient visits might be suitable for telemedicine; also, the number of telemedicine procedures is limited availability of human and other resources.

At the primary care level, the Ministry of Health ordered that physicians should provide clinical consults to COVID-19 patients via phone, which partially explains the decrease in in-person outpatient visits due to the repurposing of the workforce.

The NHS experienced moderate to severe essential services disruptions associated with the COVID-19 pandemic, resulting in millions of lost visits or procedures. However, the impact of these finding should be interpreted in context. Some of these reasons for seeking care that was delayed or cancelled may have been solved by the time of rescheduling (such as episodic low back pain). Patients may have sought care with private providers, with associated increases in out-of-pocket expenditures. Notably, the effects of delayed care is not expected to have equal impact on future health across conditions (for example, delayed cancer diagnosis or staging can lead to dire health consequences) (50). A limitation to our study is the lack of ICD-10 codes to stratify our results by diagnosis, which is necessary to understand the potential impact of lost visits.

Other research has found similar results to ours. A publication by the WHO found that 92% of surveyed countries in the WHO European Region experienced service disruptions between February and August 2020, and while disruptions attenuated between October 2020 and February 2021, these losses were considerable (and continued to a lesser degree until November 2021) (51).

A large study in the United States on the impact of state lockdowns enacted in March 2020 found a 40% decline in outpatient hospital care, followed by a rebound in the summer months (though below pre-pandemic levels) (52). Outpatient hospital care in England decreased by 38% in some specialties during the first lockdown compared with the pre-pandemic period (53). In contrast, telemedicine increased by 35.3% during the second trimester of 2020 (54). A study in Brazil found a 46% reduction in elective surgeries, even after a considerable effort to address the backlog (55). In the Netherlands, emergency care visits for children were reduced by 59% (56). In European Union states COVID-19 mitigation restrictions translated into unmet needs; a survey from April 2021 found that 21% of the population had missed a medical examination, and 18% reported continued unmet needs (though results varied across countries) (57). In the United States, in-person primary care visits decreased by 50.2% during the first lockdown compared with the pre-pandemic period. Service disruption also affected low-income countries, like TB care in Mozambique (58). The existing body of literature in high-income countries, as well as, low and middle income countries (59) (60) points to significant disruptions caused by the lockdowns, with subsequent lockdowns having a smaller impact.

This study has several strengths. To the best of our knowledge, it is the first to comprehensively study the effects of two major lockdown to address the COVID-19 pandemic on outpatient hospital care (including telemedicine), surgical procedures, and primary care outpatient (including telemedicine) visits. The results provide unique insights into the impact of the two lockdowns, and the differences between primary care and hospital care visits. We also provide new information about the magnitude of lost visits one year after the end of the second lockdown, which demonstrates that – although activity resumed to pre-pandemic levels or even slightly exceeded these levels – there were still considerably lost visits and potential increases in unmet needs. We provide novel evidence of the expansion of telemedicine during the pandemic. We leverage routinely collected data at national level to provide a nationwide assessment of the impact of the lockdowns.

There are several limitations to this study. Given the available data, we were unable to explore if observed decreases in outpatient care, surgeries and primary care affected more vulnerable populations with greater health needs and limited resources. Including variables such as diagnoses, age, sex and other data that could be used to understand the profiles of who utilized which services across the study period would have provided valuable insights into the impact of diminished service utilization. Moreover, given available data and our analytic approach, we are limited in our ability to tease apart the drivers of observed visit patterns, such as to what extent reduced visits are due to changes in supply (human resources and available commodities) and demand (fear of using health services or increased utilization of private sector health facilities). The decline in emergency care visits and urgent surgeries may partially be explained by declines in work accidents and road traffic injuries associated with the mobility restrictions and shift to remote work. Our analytic approach was designed to minimize the effects of changes in supply and demand across time, including in the model the population over 65 years of age at the regional level, and the number of physicians and nurses at the facility level.

Further research is warranted to explore the characteristics of patients with canceled or delayed elective care for two main reasons. First is to identify the long-term effects of delayed elective care. Second is to develop better approaches that prioritize patients who would benefit the most from elective care for use in future instances of supply restrictions (for example pandemics and natural catastrophes). Nevertheless, our study has immediate utility to policymakers and health system stakeholders who can adjust public policies to account for lost outpatient care visits and support the development of telemedicine and other approaches to foster health system resilience when facing extreme shocks.

Conclusion

The March 2020 and January 2021 COVID-19 government lockdowns in Portugal were associated with moderate to severe disruptions in outpatient hospital care (17% and 40%, respectively), elective surgeries (50% and 58%, respectively), and in-person outpatient primary care visits (43% and 48%, respectively). However, followed by an increase in hospital telemedicine activity. Overall, the first lockdown caused more significant service disruption of services than the second. By one year after the end of the second lockdown, we estimated substantial visit losses associated with the pandemic and associated government mitigation strategies.

Chapter 4. The impact of lockdowns on non-COVID-19 hospital inpatient episodes and case fatality rates (CFR), in Portugal

Abstract

Introduction: The effect of the COVID-19 lockdowns on non-COVID-19 hospital case fatality rates (CFR) is still unclear. We conducted an interrupted time series to explore the effect of lockdowns on non-COVID-19 hospital inpatient episodes and CFRs at Portuguese National Health System hospitals from January 2018 to April 2021.

Methods: We developed a negative binomial model using: 1) the number of monthly inpatient visits to assess the changes in hospital admissions, and 2) the number of deaths (with the number of inpatient visits as the offset), adjusted for age group, sex, hospital and ICD-10 code. The two general lockdowns (March-May 2020 and January-April 2021) were the exposures of interest, and June-December 2020 was considered an inter-lockdown period. We present the rate ratios and 95% confidence intervals for effect on the outcomes.

Results: Our study included 41 hospitals, resulting in 2,514,138 inpatient care episodes and 161,473 deaths. The number of non-COVID-19 inpatient episodes decreased after the pandemic started, ranging from a decrease of 22% immediately after the first lockdown (RR=0.78; 95%CI: 0.76-0.81) to a 35% decrease immediately after the second lockdown (RR=0.65; 95%CI: 0.62-0.68), compared to the pre-COVID-19 period. The decrease in inpatient episodes was followed by an increase in CFR, with an immediate increase of 17% (RR=1.17; 95%CI: 1.12-1.23) for the first lockdown and a 62% increase (RR=1.62; 95%CI: 1.52-1.72) in the second lockdown. The population over 25 years old drove the increase in CFR, as did the population with some specific ICD-10 diagnosis like diseases of the circulatory, respiratory, digestive, genitourinary, musculoskeletal systems and other infectious diseases. We did several robustness checks that support our findings; however, in a model with only the number of deaths as the outcome, we found no significant increases in the expected deaths for non-COVID-19 conditions after the pandemic. That finding, together with decreased inpatient care and increased CFR, points to a possible selection of the frailest patients for inpatient care.

Conclusions: This study found that lockdowns decreased inpatient care for usual care conditions and was associated with an increase in CFR. However, the increase in CFR is likely due to prioritization of inpatient care for sicker patients.

Keywords: COVID-19, lockdowns, inpatient care, case fatality rates, mortality, Portugal

Introduction

Globally, there were an estimated 14.83 million excess deaths through 2022 associated with the COVID-19 pandemic; however, only a third of these were attributable to COVID-19 infection, with the other two-thirds resulting from indirect causes. (61) The COVID-19 pandemic caused immense disruptions in health system capacity due to changes in health-seeking behaviors (risk perception), physical access to healthcare (mobility restrictions during lockdowns), clinical behaviors (admission criteria), physical healthcare space (hospital capacity), and workforce. (62) Assessing COVID-19's effects on health care systems – including hospital capacity to provide non-COVID-19 care – assists in untangling the complex routes through which COVID-19 contributed to excess mortality.

How health services, in particular hospitals, respond to exogenous and unexpected shocks affects the quality of care and health outcomes. (63) Determinants of the resilience of hospitals to exogenous shocks include the ability to maintain a qualified workforce (reduce absenteeism), presence of sufficient physical space and materials to meet increased demand, and presence of a skilled workforce (as is the case with university hospitals). These determinants of resilience can be thought of as the “4S”: staff, stuff, space, and systems. (64)

A community-based COVID-19 survey in Portugal found that the perception of risk for severe COVID-19 disease was higher among older people with comorbidities, and that people in poorer health reported avoiding emergency department visits during the first COVID-19 lockdown compared with healthier individuals (43% of those with self-assessed poor health reported avoiding emergency room visits compared with 30% of those in reasonable health). (65) However, this pattern decreased during the second lockdown. (6) Furthermore, patients who trusted the response of the national health system were less likely to avoid emergency department visits (66), and, overall, 50% of the population reported that the healthcare system was well prepared to address the COVID-19 pandemic. (67) These findings suggest underutilization of health services, especially among those in poor health and those who did not believe in the preparedness of the Portuguese National Health Service.

Changes in healthcare supply and demand for inpatient services may influence case fatality rates. A comprehensive Danish study (68) found a 30% decrease in hospital inpatient care during the first lockdown, a gradual return to baseline levels, and a 22% decrease in the second lockdown. Furthermore, there was a 28% increase in 30-day mortality rates across major diagnostic groups during the COVID-19 lockdowns. (68) A study in Italy during the first lockdown in 2020 described a 7.5% increase in all-cause hospital mortality (IRR 1.074, 95%CI 1.007-1.145). (69) However, a systematic review found that reduced inpatient care for patients with myocardial infarction was not associated with a significant increase in in-hospital mortality rates. (70) Similarly, a study from a hospital population in Qatar showed no significant change in in-hospital mortality associated with the first COVID-19 lockdown.

The effect of the COVID-19 pandemic on non-COVID-19 hospital case fatality rates (CFR) remains unclear, (1) as an increase in non-COVID-19 CFR may be the result of reduced or constrained demand (due to hospital avoidance among patients with less severe conditions or changes in admission criteria), (2) or differential effects on specific sub-populations (such as age, sex, and co-morbidities).

In this manuscript we aim to explore the effect of the COVID-19 lockdowns on hospital CFR for non-COVID conditions in Portuguese public hospitals.

Methods

Design

We conducted an interrupted time series analysis to explore the effect of two COVID-19 lockdowns (March 2020 and April 2021) on patterns of monthly inpatient admissions and CFR in public sector hospitals on mainland Portugal.

Data source

We used the hospital morbidity and mortality dataset for hospitals in the Portuguese National Health System (NHS). This dataset records all inpatient hospital visits and deaths at NHS hospitals, aggregated by month, hospital, age group, sex, and ICD-10 group of primary admission diagnoses. Our analysis relied on data from January 2018 to April 2021, and was truncated in April 2021 (when only 8% had the two doses scheme completed) to focus on the pre-vaccination period and include the entirety of the last lockdown period. All NHS hospitals included fulfilled the OECD definition of a hospital as “licensed establishments primarily engaged in providing medical, diagnostic and treatment services that include physician, nursing, and other health services to inpatients and the specialized accommodation services required by inpatients” (71).

Setting and participants

Portugal is a high-income country with a network of public hospitals that form the NHS. NHS hospitals provide 70% of the total number of hospital admissions in Portugal and cover all municipalities on mainland Portugal. Our analysis included 41 hospitals, excluding three long-term care hospitals and three specialized cancer hospitals. None of the excluded hospitals had COVID-19 patients and were minimally impacted by the pandemic, and accounted for 4.0% of admissions and 4.4% of deaths in our dataset. We excluded all the patients with COVID-19 as the primary cause of admission (ICD-10 codes U00-U99).

Outcomes

We tested for two primary outcomes, including 1) the monthly number of inpatient care episodes and 2) the CFR measured as the proportion of deaths during inpatient care episodes. A patient was considered admitted to inpatient care if transferred from the emergency department to another department and with a length of stay longer than one day. The inpatient care and CFR definitions align with those used by the OECD (71).

Exposures and other explanatory factors

We used the periods of the two general lockdowns (March-May 2020 and January-April 2021) as the exposures of interest; June to December 2020 was considered an inter-lockdown period. Our analysis included additional explanatory factors that may affect the probability of dying during inpatient care, including those at the individual level (e.g. patient age and comorbidities), and others related to the quality of care. In our analysis, we control for age groups, sex, hospital, and ICD-10 condition. However, we could not control for comorbidities as these data were unavailable.

Statistical Analysis

We used a negative binomial generalized linear model with two monthly outcomes: 1) the number of inpatient episodes and 2) the CFR, with the reference population as the number of patients admitted. Both outcomes were desegregated by month, ICD-10 diagnosis, hospital, age group, and sex. We used the R package MASS (72) to implement our model.

To model the effects of lockdowns, we added an interaction term between events of interest (March-May 2020 lockdown, Jun-December 2020 inter-lockdown, and January-April 2021) and the time variable; we followed the model specification for multiple periods described by Xiao (73). We added the month of the year and hospital fixed effects to account for seasonality and unique hospital practices. In the fully adjusted model, we added age groups, sex, and ICD-10 conditions as fixed effects. At the hospital level, we used the sandwich method to deal with clustered standard errors (74).

$$Y_{it} - NB(\mu_{it}, \alpha)$$

$$\mu_{it} = exp\left(\beta_0 + \beta_1 V_i + \beta_2 X_{1-3|it} + \beta_3 T_i + \beta_4 XT_{it} + \beta_5 \gamma_{it} + \varepsilon_{it}\right)$$

In the equation 3, where: Y is the outcome of interest for each time t and hospital i, with a mean μ_{it} and a variance α. V_i (period) is the time since the beginning of the study and represents the frequency of the recorded outcome in months. X_{1-3} is a dummy variable (0 and 1) for each of the lockdown periods and inter-lockdown. T_i (period) is the time after the start of the lockdown or inter-lockdown, and assumes the value zero in all the other months. γ_{it} are vectors of fixed effects in the model (age group, Sex, ICD-10 condition, and hospital), and ε_{it} is an error term. The β_1 estimator represents the outcome trend before the first lockdown. The β_2 estimator represents the imediate effects of the lockdown or inter-lockdown period. β_4 represents the trends during the the lockdown or inter-lockdown period. We tested for interactions between the outcome of interest and the exposure by age group and ICD-10 diagnosis. We found no interaction for sex. The p-value for the stratified analysis are adjusted for multiple testing using the Benjamini-Yekutieli correction (75).

Robustness checks

We did several robustness checks in our analysis. First, we replicated adjusted model using hospitals as random effects. We did this to account for the possibility of type II errors using hospitals as fixed effects. Second, we replicated the CFR analysis using all hospital inpatient care, including COVID-19; this would account for the patients that would have died during the same period by other causes had the pandemic not happened but instead died because of COVID-19. Third, we replicated the analysis using the number of non COVID-19 deaths as the outcome. The pandemic caused a substantial decrease in admission. Hence the increase in CFR could be due to only admitting the fraction of the population that has the most severe disease forms (selection bias). Fourth, we tested our model excluding ICD-10 codes of respiratory infections and other infectious diseases to account for the potential miss classification of COVID-19 diagnosis. Finally, we included the excluded hospitals to prove that the exclusion did not influence the results.

Results

Our study population included 41 hospitals, resulting in 2,514,138 inpatient care episodes and 161,473 deaths from January 2018 until April 2021 (Figure 5).

Overall the mean number of inpatient episodes by month decreased during the March-May 2020 lockdown, which was consistent across age groups, sex and ICD-10 conditions. During the inter-lockdown period there was a slight increase in the mean of monthly inpatient episodes. However, this period was followed by a decrease in inpatient episodes during the Jan-April 2021 lockdown.

The CFR increased more generically across the three periods of analysis after the COVID-19 pandemic (Table 10).

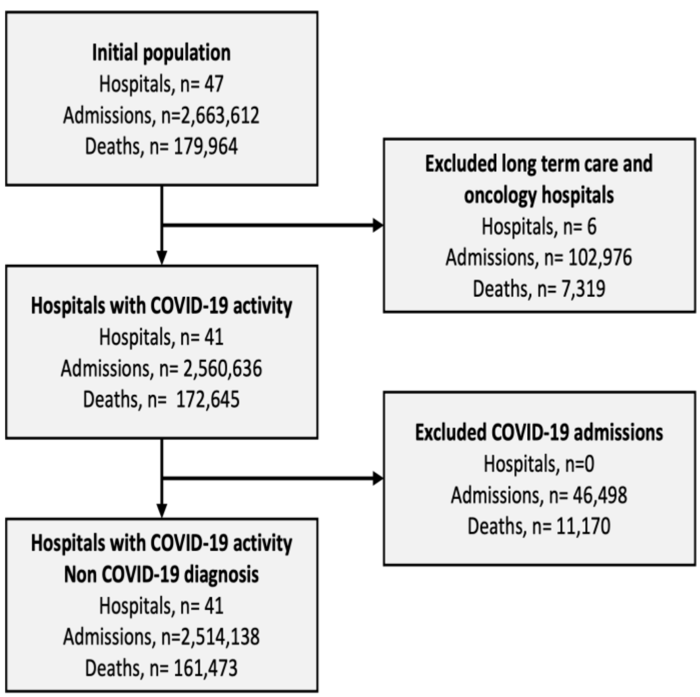


Figure 5. Flowchart of the study population, Portugal January 2018 - April 2022

Table 10. Inpatient care and case fatality rate of non COVID-19 condition, January 2018-April 2021

		Pre COVID-19		First lockdown		Interlockdown		Second lockdown	
Group	**Term**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**
Age group	[0-1[	7005 (392)	0.27	6204 (419)	0.24	6108 (352)	0.20	5067 (275)	0.24
	[1-5[	1074 (138)	0.28	501 (278)	0.40	549 (72)	0.18	470 (89)	0.43
	[15-25[	2762 (159)	0.29	1890 (333)	0.32	2266 (154)	0.35	1949 (299)	0.26
	[25-45[	10931 (487)	0.59	8460 (1183)	0.72	9404 (720)	0.61	7978 (1124)	0.56
	[45-65[	13260 (713)	3.92	8645 (2272)	5.17	10808 (932)	4.34	9818 (2086)	4.26
	[5-15[	1410 (91)	0.21	684 (232)	0.15	986 (108)	0.20	874 (214)	0.23
	[65-120[	30301 (2149)	11.54	22082 (4423)	14.62	24204 (1311)	12.77	22714 (3703)	13.89
Sex	Female	36250 (1662)	5.30	26624 (4691)	6.65	29582 (1905)	5.77	26556 (4052)	6.36
	Male	30493 (1437)	7.20	21841 (4377)	9.11	24743 (1520)	7.82	22315 (3673)	8.75
ICD-10	A00–B99	1829 (106)	21.16	1409 (181)	27.68	1471 (129)	26.24	1207 (157)	30.49
	C00–D48	5597 (293)	12.76	4327 (801)	13.84	4696 (355)	13.05	4323 (704)	12.03
	D50–D89	537 (37)	5.77	382 (54)	7.07	427 (26)	7.03	419 (120)	6.68
	E00–E90	1563 (84)	5.44	953 (272)	8.18	1322 (194)	6.51	1264 (354)	7.91
	F00–F99	1166 (84)	0.94	818 (212)	0.86	934 (74)	1.39	893 (153)	1.46
	G00–G99	1182 (68)	5.58	728 (172)	8.52	909 (54)	6.27	863 (174)	6.72
	H00–H59	482 (53)	0.21	204 (72)	0.00	310 (54)	0.32	263 (85)	0.00
	H60–H95	405 (38)	0.25	159 (87)	0.63	282 (45)	0.35	218 (94)	0.00
	I00–I99	9538 (670)	8.61	7165 (1115)	10.93	7915 (287)	9.05	8072 (1004)	10.22
	J00–J99	8178 (2508)	13.28	5379 (2425)	17.33	4145 (363)	19.16	3693 (379)	21.80

		Pre COVID-19		First lockdown		Interlockdown		Second lockdown	
Group	**Term**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**	**Inpatent n(SD)**	**CFR**
	K00–K93	6840 (388)	4.37	4240 (992)	6.46	5723 (522)	4.84	5042 (1298)	5.73
	L00–L99	723 (77)	4.01	402 (130)	5.47	550 (69)	4.00	448 (126)	5.36
	M00–M99	2578 (329)	0.89	1081 (744)	2.22	2140 (442)	1.07	2029 (1034)	1.08
	N00–N99	4744 (280)	4.87	2991 (707)	7.32	4044 (459)	6.45	3537 (891)	7.18
	O00–O99	6519 (422)	0.02	6050 (275)	0.00	6097 (355)	0.02	5074 (313)	0.00
	P00–P96	203 (19)	1.48	132 (12)	0.76	141 (15)	1.42	116 (9)	2.59
	Q00–Q99	389 (45)	0.77	197 (97)	1.02	328 (34)	1.22	324 (76)	0.62
	R00–R99	1392 (79)	5.46	1009 (137)	8.33	1090 (65)	6.70	1031 (163)	7.37
	S00–T98	5944 (328)	3.35	4515 (906)	4.30	5307 (264)	4.01	4591 (567)	4.25
	Z00–Z99	6935 (430)	0.74	6323 (330)	0.95	6493 (376)	1.06	5461 (381)	1.03

Figure 6 demonstrates that the lockdowns had a greater impact on reducing inpatient care than the interlockdown period did when compared to the same time period in 2018 2019. Even with the additional burden of COVID-19 patients, there was an overall decrease in inpatient care. Meanwhile, in figure 7, we observe a decline in inpatient deaths among non-COVID-19 patients when compared to the 2018-2019 period.

However, when taking into account all deaths including those related to COVID-19, we see an increase after mid-2020.

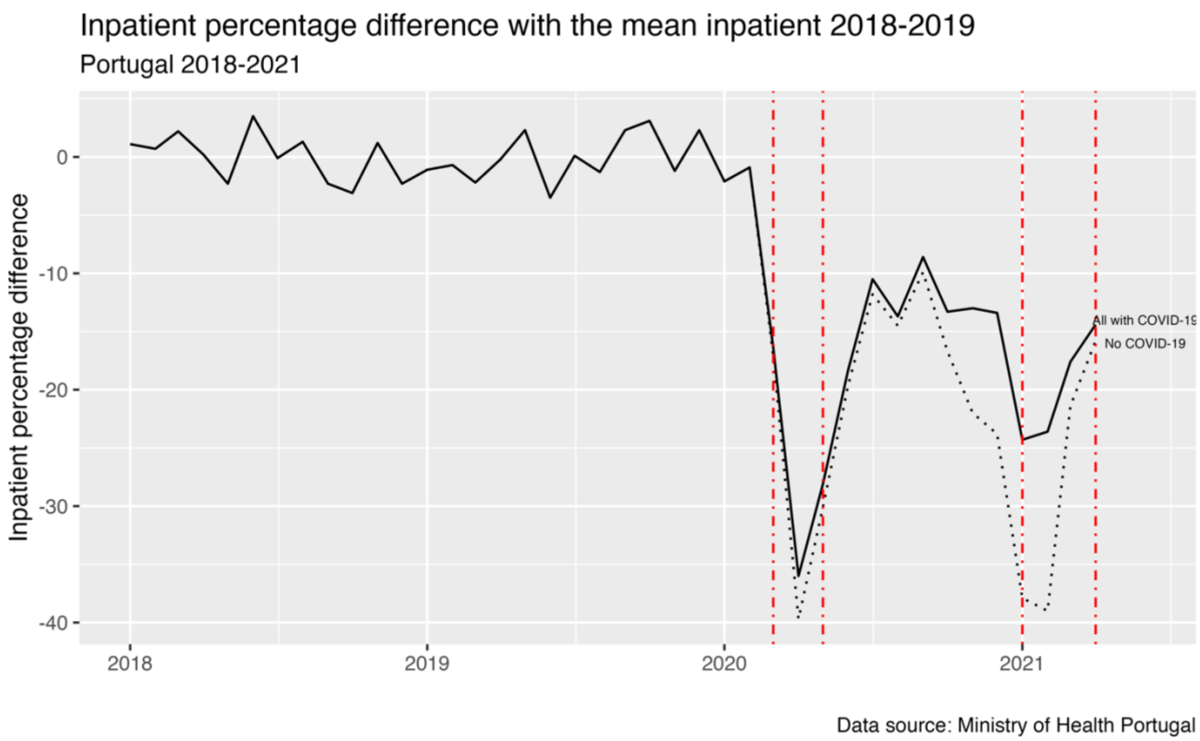


Figure 6. Inpatient percentage difference with the mean monthly inpatient 2018-2019

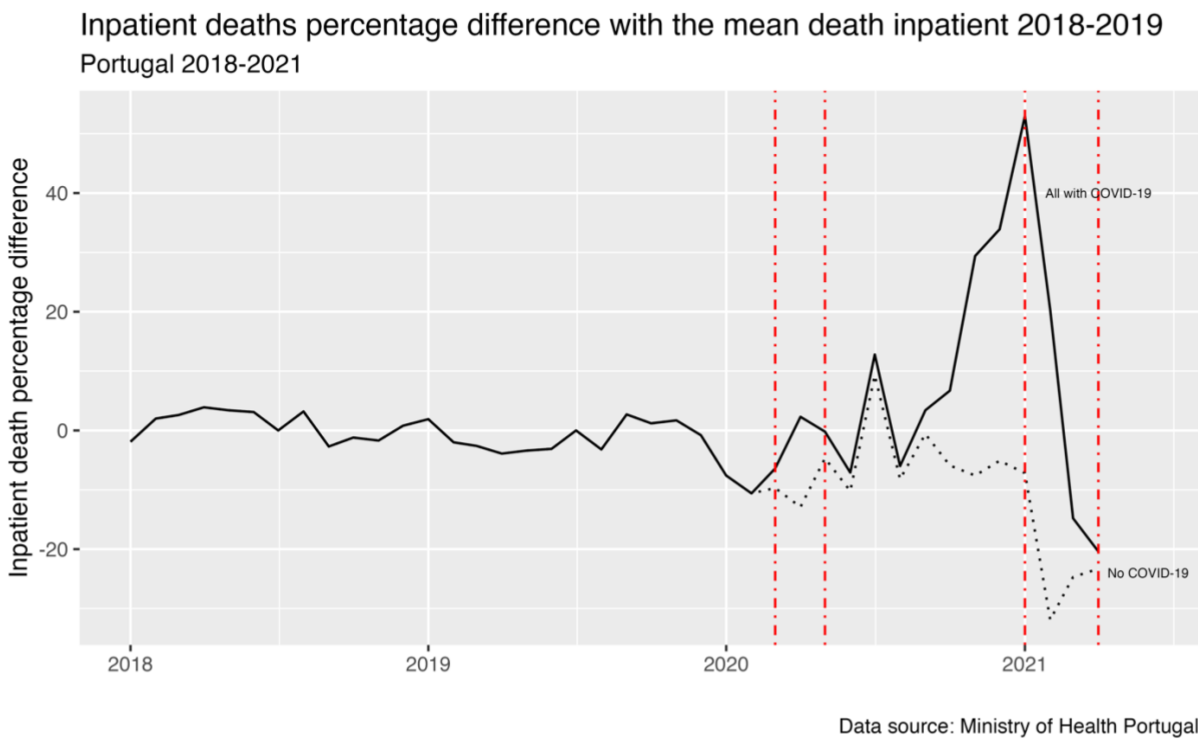


Figure 7. Inpatient deaths percentage difference with the mean monthly death inpatient 2018-2019

Unadjusted Results

The unadjusted model found a 12% decrease in inpatient care episodes (RR=0.89; 95%CI: 0.87-0.92) as an immediate effect of the first lockdown, and a 2% decrease per month during the lockdown, compared with the pre-COVID-19 trend. The immediate decrease in inpatient episodes was followed by a 30% increase in CFR (RR=1.30; 95%CI: 1.23-1.37), which increased 15% per month in the months following the lockdown.

During the inter-lockdown period, inpatient episodes were not different from the pre-COVID-19 period (RR=0.97; 95%CI: 0.95-1.00); however, there was still a 22% increase in CFR during this period (RR=1.22; 95%CI: 1.16-1.28). During the Jan-April 2021 lockdown there was a 23% reduction in inpatient care episodes (RR=0.77; 95%CI: 0.73-0.80), and a 79% increase in CFR (RR=1.79; 95% CI: 1.65-1.94). However, during the following months (February-April 2021) there was a 7% monthly increase in inpatient care episodes and an 18% decrease in CFR.

Table 11. Effect COVID-19 of lockdowns on inpatient and hospital case fatality rates for non COVID-19 diagnosis

Term[a]	Inpatient RR (95% CI)	p value*	CFR RR (95% CI)[b]	p value
Pre COVID-19 trend	1.00 (1.00-1.00)	0.726	1.00 (1.00-1.00)	0.096
Lockdown March 2020	0.89 (0.87-0.92)	0.000	1.30 (1.23-1.37)	0.000
Interlockdown Jun-Dec 2020	0.97 (0.95-1.00)	0.077	1.22 (1.16-1.28)	0.000
Lockdown Jan 2021	0.77 (0.73-0.80)	0.000	1.79 (1.65-1.94)	0.000
Trend Lockdown March 2020	0.98 (0.96-0.99)	0.010	1.15 (1.11-1.19)	0.000
Trend Interlockdown Jun-Dec 2020	0.99 (0.98-0.99)	0.000	1.01 (1.00-1.02)	0.116
Trend Lockdown Jan 2021	1.07 (1.06-1.08)	0.000	0.82 (0.80-0.84)	0.000

[a]Negative binomial model with month and hospitals fixed effects; [b]Case fatality rate ratio

Adjusted results

Adjusting the analysis for age group, sex, ICD-10 diagnosis increased the effect of the reduction in inpatient care after the pandemic and attenuated the effect on CFR. Inpatient care decreased by 22% (RR=0.78; 95%CI: 0.76-0.81) due to the immediate effect of the first lockdown and by 35% (RR=0.65; 95%CI: 0.62-0.68) during the second lockdown. The effects of the lockdowns and inter-lockdown period on CFR were smaller. The first lockdown was associated with a 17% immediate increase in the CFR (RR=1.17; 95%CI: 1.12-1.23), a 15% increase during the inter-lockdown period (RR=1.15; 95%CI: 1.10-

1.20), and a 62% increase during the second lockdown (RR=1.62; 95%CI: 1.52-1.72). The CFR trends were similar compared with the unadjusted model (Table 12).

Table 12. Adjusted effects of lockdowns on inpatient and hospital case fatality rates for non COVID-19 diagnosis

Term[a]	Inpatient RR (95% CI)	p value	CFR RR (95% CI)[b]	p value*
Pre COVID-19 trend	1.00 (1.00-1.00)	0.869	1.00 (1.00-1.00)	0.037
First lockdown	0.78 (0.76-0.81)	0.000	1.17 (1.12-1.23)	0.000
Interlockdown	0.89 (0.86-0.92)	0.000	1.15 (1.10-1.20)	0.000
Second lockdown	0.65 (0.62-0.68)	0.000	1.62 (1.52-1.72)	0.000
Trend first lockdown	0.94 (0.92-0.95)	0.000	1.11 (1.08-1.15)	0.000
Trend Interlockdown	0.99 (0.98-0.99)	0.001	1.01 (1.00-1.02)	0.012
Trend second lockdown	1.12 (1.11-1.14)	0.000	0.84 (0.82-0.85)	0.000

[a]Negative binomial model with month, hospitals, age group, sex and ICD-10 group fixed effects; [b]Case fatality rate ratio

Stratified Analyses

Age stratification

When stratifying by age, the adult population over 25 (25-44, 45-64, 65 plus) drove the effects on decreases in inpatient care episodes, followed by increases in the CFR (Table 4). The reduction in inpatient care episodes for the first lockdown ranged from 22% (in the 65-120 age group) to 28% (in the 45-65 age group). The reduction was more pronounced in the second lockdown.

Increases in CFR were only significant in the 25-45 and 45-65 age groups during the Jan-April 2021 lockdown; however, the 65-120 age group experienced increased CFR in all periods after the COVID-19 pandemic, except for a nonsignificant trend during the inter-lockdown period.

Table 13. Adjusted effect of lockdowns on inpatient and hospital case fatality rates for non COVID-19 diagnosis

Age group[a]	Term	Inpatient RR (95% CI)	p value*[b]	CFR RR (95% CI)	p value*.1
[25-45[	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	0.99 (0.99-1.00)	0.946
	First lockdown	0.74 (0.71-0.78)	0.000	1.35 (1.01-1.82)	0.933
	Inter lockdown	0.85 (0.82-0.88)	0.000	1.35 (1.06-1.72)	0.377
	Second lockdown	0.61 (0.58-0.64)	0.000	1.80 (1.34-2.42)	0.003
	Trend first lockdown	0.92 (0.89-0.96)	0.000	1.20 (0.97-1.47)	1.000
	Trend Inter lockdown	0.99 (0.98-1.00)	0.077	0.99 (0.94-1.05)	1.000
	Trend second lockdown	1.13 (1.11-1.16)	0.000	0.75 (0.64-0.86)	0.003
[45-65[	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	1.00 (1.00-1.00)	1.000
	First lockdown	0.72 (0.70-0.75)	0.000	1.13 (1.02-1.27)	0.521
	Inter lockdown	0.87 (0.85-0.90)	0.000	1.07 (0.97-1.17)	1.000
	Second lockdown	0.58 (0.56-0.61)	0.000	1.56 (1.40-1.73)	0.000
	Trend first lockdown	0.91 (0.89-0.94)	0.000	1.13 (1.04-1.22)	0.088
	Trend Inter lockdown	0.99 (0.98-0.99)	0.001	1.02 (1.00-1.04)	1.000
	Trend second lockdown	1.17 (1.15-1.19)	0.000	0.80 (0.76-0.84)	0.000
[65-120[	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	1.00 (1.00-1.00)	0.241
	First lockdown	0.78 (0.76-0.81)	0.000	1.17 (1.12-1.22)	0.000
	Inter lockdown	0.90 (0.88-0.93)	0.000	1.16 (1.12-1.20)	0.000
	Second lockdown	0.63 (0.61-0.65)	0.000	1.61 (1.55-1.68)	0.000
	Trend first lockdown	0.91 (0.89-0.94)	0.000	1.11 (1.08-1.14)	0.000
	Trend Inter lockdown	0.98 (0.98-0.99)	0.000	1.01 (1.00-1.02)	0.171
	Trend second lockdown	1.14 (1.13-1.16)	0.000	0.84 (0.83-0.86)	0.000

[a]Negative binomial model with month, hospitals, age group, sex and ICD-10 group fixed effects; [b]Case fatality rate ratio

ICD-10 diagnosis stratification

In stratified analysis by ICD-10 diagnosis, only a few conditions were associated with simultaneous changes in the inpatient care ratio and CFR, specifically diseases of the circulatory, respiratory, digestive, genitourinary, musculoskeletal systems, as well as other infectious diseases (Table 5). During the first lockdown, the increase in CFR was highest among patients admitted with digestive system conditions (a 55% increase (RR=1.55; 95%CI: 1.36-1.78)) and diseases of the circulatory system (a 21% increase (RR=1.21; 95%CI: 1.11-1.31)). The increase in CFR was more noticeable during the second lockdown, with a 48% increase in CFR for patients with circulatory diseases, a 97% increase for patients admitted with respiratory conditions, a 99% increase for patients admitted with digestive conditions, a 77% increase for patients admitted with genitourinary conditions, a 252% increase for patients admitted with musculoskeletal systems, and a 50% increase for patients admitted with other infectious diseases. Overall the trend of small increases in inpatient care and decreases in CFR was maintained during Feb-April 2021 lockdown.

Table 14. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

ICD-10[a]	Term	Inpatient RR (95% CI)	p value[b]	CFR RR (95% CI)	p value*
Diseases of the circulatory system	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	1.00 (1.00-1.00)	0.149
	First lockdown	0.77 (0.73-0.82)	0.000	1.21 (1.11-1.31)	0.000
	Inter lockdown	0.89 (0.85-0.93)	0.000	1.08 (1.01-1.16)	0.668
	Second lockdown	0.75 (0.72-0.80)	0.000	1.48 (1.37-1.60)	0.000
	Trend first lockdown	0.96 (0.92-0.99)	0.278	1.10 (1.04-1.17)	0.034
	Trend Inter lockdown	1.00 (0.99-1.01)	1.000	1.02 (1.01-1.04)	0.169
	Trend second lockdown	1.09 (1.06-1.11)	0.000	0.85 (0.82-0.88)	0.000
Respiratory system diseases	Pre COVID-19 trend	1.00 (1.00-1.00)	0.008	1.00 (1.00-1.00)	1.000
	First lockdown	0.80 (0.76-0.84)	0.000	1.08 (1.00-1.16)	0.882
	Inter lockdown	0.86 (0.82-0.90)	0.000	1.25 (1.18-1.34)	0.000
	Second lockdown	0.32 (0.30-0.34)	0.000	1.97 (1.84-2.11)	0.000
	Trend first lockdown	0.80 (0.77-0.84)	0.000	1.22 (1.15-1.28)	0.000
	Trend Inter lockdown	0.94 (0.93-0.95)	0.000	1.02 (1.00-1.03)	0.660
	Trend second lockdown	1.22 (1.18-1.25)	0.000	0.85 (0.83-0.88)	0.000
Some infectious diseases	Pre COVID-19 trend	1.00 (1.00-1.00)	0.407	1.00 (0.99-1.00)	0.017
	First lockdown	0.83 (0.77-0.89)	0.000	1.13 (1.00-1.27)	0.875
	Inter lockdown	0.86 (0.82-0.92)	0.000	1.26 (1.15-1.39)	0.000
	Second lockdown	0.68 (0.63-0.73)	0.000	1.50 (1.34-1.67)	0.000

ICD-10[a]	Term	Inpatient RR (95% CI)	p value[b]	CFR RR (95% CI)	p value*
	Trend first lockdown	0.96 (0.92-1.02)	1.000	1.10 (1.01-1.20)	0.542
	Trend Inter lockdown	0.99 (0.98-1.00)	1.000	1.00 (0.98-1.03)	1.000
	Trend second lockdown	1.04 (1.00-1.08)	0.299	0.90 (0.85-0.95)	0.004
Diseases of the Digestive System	Pre COVID-19 trend	1.00 (1.00-1.00)	0.188	1.00 (0.99-1.00)	0.358
	First lockdown	0.65 (0.62-0.68)	0.000	1.55 (1.36-1.78)	0.000
	Inter lockdown	0.87 (0.84-0.91)	0.000	1.12 (0.99-1.25)	1.000
	Second lockdown	0.55 (0.53-0.58)	0.000	1.99 (1.75-2.27)	0.000
	Trend first lockdown	0.93 (0.90-0.96)	0.000	1.05 (0.95-1.15)	1.000
	Trend Inter lockdown	0.98 (0.97-0.99)	0.000	1.03 (1.00-1.05)	1.000
	Trend second lockdown	1.19 (1.16-1.21)	0.000	0.79 (0.75-0.84)	0.000
Diseases of the genitourinary system	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	1.00 (1.00-1.01)	1.000
	First lockdown	0.65 (0.61-0.69)	0.000	1.24 (1.06-1.45)	0.203
	Inter lockdown	0.91 (0.86-0.95)	0.001	1.25 (1.11-1.42)	0.013
	Second lockdown	0.60 (0.57-0.64)	0.000	1.77 (1.54-2.04)	0.000
	Trend first lockdown	0.98 (0.94-1.02)	1.000	1.07 (0.96-1.19)	1.000
	Trend Inter lockdown	0.98 (0.97-0.99)	0.001	1.01 (0.98-1.04)	1.000
	Trend second lockdown	1.18 (1.15-1.21)	0.000	0.78 (0.73-0.84)	0.000
	Pre COVID-19 trend	1.00 (1.00-1.00)	0.025	1.00 (0.99-1.01)	1.000

ICD-10[a]	Term	Inpatient RR (95% CI)	p value[b]	CFR RR (95% CI)	p value*
Diseases of the musculoskeletal system	First lockdown	0.54 (0.50-0.59)	0.000	1.76 (1.08-2.86)	0.508
	Inter lockdown	0.82 (0.77-0.87)	0.000	1.31 (0.87-1.97)	1.000
	Second lockdown	0.42 (0.38-0.45)	0.000	3.52 (2.26-5.47)	0.000
	Trend first lockdown	0.80 (0.75-0.85)	0.000	1.74 (1.22-2.47)	0.060
	Trend Inter lockdown	1.00 (0.99-1.02)	1.000	0.99 (0.90-1.09)	1.000
	Trend second lockdown	1.40 (1.35-1.45)	0.000	0.52 (0.43-0.64)	0.000
Symptoms not elsewhere classified	Pre COVID-19 trend	1.00 (1.00-1.00)	1.000	1.00 (0.99-1.00)	1.000
	First lockdown	0.81 (0.75-0.88)	0.000	1.44 (1.10-1.87)	0.185
	Inter lockdown	0.82 (0.77-0.87)	0.000	1.23 (0.99-1.53)	1.000
	Second lockdown	0.75 (0.70-0.81)	0.000	1.77 (1.38-2.26)	0.000
	Trend first lockdown	0.95 (0.89-1.00)	0.454	1.12 (0.93-1.35)	1.000
	Pre COVID-19 trend	1.00 (0.98-1.01)	1.000	1.02 (0.97-1.07)	1.000
	First lockdown	1.05 (1.01-1.09)	0.075	0.76 (0.68-0.86)	0.001

[a]Negative binomial model with month, hospitals, age group, sex and ICD-10 group fixed effects; [b]Case fatality rate ratio

Robustness checks

The model that included hospitals as random effects generated comparable results, with a 16% increase in CFR for the immediate effect of the March-May 2020 lockdown

(RR=1.16; 95%CI: 1.11-1.21) and a 56% increase in CFR for the immediate effect of the Jan-April 2021 lockdown (RR=1.56; 95%CI: 1.50-1.63) (see supplementary materials). The model that incorporated all hospital admissions, including COVID-19, produced similar results as the adjusted model with non-COVID-19 conditions in terms of size and direction of effect (see Appendix: Chapter4).

The effect of lockdowns on the expected number of deaths is no longer significant after assessing only non-COVID-19 deaths as the outcome in the adjusted model, which may have two potential explanations: 1) only the most severe non-COVID-19 patients were admitted to hospitals; 2) there was a place of death displacement from the hospital to long-term care facilities and the household.

When we tested our model excluding ICD-10 codes for respiratory infections and other infectious diseases and included those hospitals that were excluded, the effects of the lockdowns and trends did not change substantially (see Appendix: Chapter4).

Discussion

Our analysis of inpatient episodes and CFR for non-COVID-19 patients in Portuguese public sector hospitals found a general decrease in inpatient care episodes after the COVID-19 pandemic, only increasing during the February-April 2021 period. Inpatient care for non-COVID-19 patients decreased by 22% due to the immediate effect of the first lockdown and 35% due to the immediate effect of the second lockdown. We also found an increase in hospital CFRs, with an immediate 17% increase for the first lockdown and a 62% increase during the second lockdown. We also found that the increase in CFR during the first lockdown was mainly driven by the 65-plus age group, which experienced a 17% increase in CFR. However, during the second lockdown, the increases in CFR were significant in the 25-45, 45-65, and 65-plus age groups. Finally, we found that the increase in the CFR was concentrated in patients with circulatory, respiratory, digestive, genitourinary, and musculoskeletal systems and other infectious diseases conditions at hospital admission. Our robustness checks found that the expected number of inpatient non-COVID-19 deaths did not change during the pandemic period.

Other studies have found similar results. *Bodilsen et al* in Denmark (68) described a 30% (0.66-0.74) decrease in inpatient care for non-COVID-19 conditions and a 28% (1.23-1.32) increase in CFR during the first lockdown, and 22% decrease (0.73-0.82) in inpatient care and a 20% increase in CFR (1.16-1.24) during the second lockdown. The increase was particularly salient for diseases of the endocrine, nutritional and metabolic diseases and circulatory system. Portugal experienced a more marked effect for the second lockdown compared with Denmark, likely explained by Denmark having implemented the second lockdown earlier (December 2020), and with a lower 14-day cumulative incidence of COVID-19 at the time of lockdown (318 cases per 100,000 population for Denmark, compared with 1,124 cases per 100,000 population in Portugal). These factors likely influenced health-seeking behaviors and hospital admissions practices that can then influenced the effect of the second lockdown on inpatient care and CFR. We cannot exclude the impact of differences in design between our studies that could also explain differences in effect magnitudes. A study in New York found that hospitalizations due to exacerbation of chronic conditions and acute medical events decreased after lockdowns (76).

Our results should be interpreted within the context of the pandemic response in Portugal, as well as population characteristics. During the first and second lockdowns, the government imposed severe mobility restrictions, and the NHS reduced routine primary care activities and focused on COVID-19 surveillance, which reduced hospital referrals from primary care. Moreover, elective hospital activities were curtailed during lockdowns. The combination of these factors could result in patients with less severe conditions being kept out of the hospital. That is consistent with our results and robustness checks, which ameliorated the decreases in inpatient care and increases in CFR. However, the expected number of deaths had the pandemic not happened did not increase.

We cannot discount alternative explanations for our study findings, including selection of the frailest patients for inpatient admission and decreases in the quality of care that increase CFR. In this case we would expect to observe a displacement of the place of death from hospitals to long-term care facilities and patients' homes. We do have some indication that some patients with severe disease might have avoided seeking healthcare during the first lockdown. (66). If the same phenomena happened in the second lockdown a displacement of the local of death from the hospital to home or long-term care facilities is more likely, and the increase in CFR in our study could be due to lower quality of care.

Our study has several strengths. We present information on the effect of the COVID-19 lockdowns and inter-lockdown period for non-COVID-19 conditions in a novel context. We use a design and analytic approach that creates a counterfactual scenario as if the lockdowns had not happened, strengthening our findings' causal interpretation. We also used a conservative approach in the modeling options, using fixed effects at the hospital, month, ICD-10 conditions, age group and sex. We accounted for the possible changes in hospital practices and the case mix of conditions before and after the lockdowns.

However, our study has some limitations. Our use of aggregate data at the hospital level hinders adjusting for individual-level factors that can be time-varying confounders. We attempted to minimize this confounding by adjusting for other factors associated with individual disease burden, including age group and sex. A second limitation is the potential for selection bias to explain changes in health-seeking behaviors, which may affect the CFR estimates. We attempted to address this by assessing changes in the expected number of deaths, and found no changes due to the lockdowns, which could be due to the reasons previously mentioned (less severe patients not being admitted to hospitals). We can not exclude the effect of ascertainment bias, where the testing probability is not the same for all the study populations or changed during our study. However, the NHS testing protocol in place in all hospitals (testing all patients for SARS-CoV-2 before admission) minimizes this bias. In addition, we excluded patients with an inpatient diagnosis that could be due to COVID-19, including respiratory and other infectious diseases, and found similar results as the adjusted model.

Conclusion

Within Portuguese public sector hospitals, inpatient episodes for non-COVID-19 conditions decreased by 22% after the first lockdown and by 35% after the second lockdown, and the CFR increased by 17% after the first lockdown and 62% after the second lockdown. However, we did not find increases in the expected number deaths during these periods. Our results suggest that the frailest patients were admitted during lockdowns, resulting in increases in CFR. The magnitude of our findings may be specific to the context of the Portuguese Health System; however, these results still provide generalizable insights into other health systems that lockdowns likely decrease inpatient care and increase CFR for non-COVID-19 conditions.

Chapter 5. Conclusions

Summary of findings

The COVID-19 pandemic was the most significant health challenge of the century, resulting in more than 6 million deaths worldwide. For health systems worldwide, the pandemic was a test of resilience, testing how health systems could sustain critical operations, resume optimal performance as quickly as possible, and transform its structure and functions to strengthen the system.

The overall goal of this dissertation was to study the effects of the two government lockdowns on several aspects of the COVID-19 response. In aim one, we assessed the economic impact of government lockdowns, with a focus on spending in the pharmaceutical health sector and the COVID-19 control. In aim two, we assessed the impact of COVID-19 mitigation strategies on outpatient, telemedicine and primary care services. In aim three, we assessed the impact of lockdowns on inpatient utilization and case fatality rates for non-COVID-19 conditions.

This work generated a number of significant findings. In chapter 2 we describe that the first governmental lockdown had a more significant economic impact (21% decrease) than the second lockdown (16% decrease). Moreover, we found evidence of increases in pharmaceutical sector spending in the first lockdown that could strain supply chains and cause disruptions across and within countries. The health services sector did not experience a decrease in spending during the second lockdown, highlighting the capacity to adapt over the inter lockdowns period. Finally, we added to the existing literature showing that lockdowns effectively reduced SARS-CoV-2 cases and COVID-19 deaths.

In chapter three, we demonstrate that the governmental lockdowns were associated with moderate to severe disruptions in utilization of routine health services. In hospitals, the decrease in outpatient visits was more significant in the first lockdown than the second, though was partially compensated by an increase in telemedicine consultations. Hospitals had an early recovery to pre-pandemic utilization levels; however, utilization did not increase sufficiently to account for lost visits. At the primary care level, decreased utilization associated with lockdowns was more severe, and not recovered to pre-pandemic levels by 12 months after the second lockdown. Overall, there were millions of lost visits at the hospital and primary care levels associated with the pandemic.

In chapter four we found a generalized decrease in inpatient care for non-COVID conditions followed by an increase in CFR (17% immediately after the first lockdown and a 62% increase immediately after the second lockdown). The increase in CFR was heterogeneous across age groups (with higher increases in the older age groups), and among patients admitted with circulatory and digestive system conditions. However, the expected number of deaths did not increase during the pandemic, pointing to a possible selection of the frailest patients being prioritized for inpatient services.

Future work

This dissertation contributes to the growing body of literature on the effects of the COVID-19 pandemic on health systems. In aim one, we would benefit from having more information about the characteristics of individuals affected by the lockdowns, such as income levels. We did not find differences in economic impact at the municipal level when comparing municipalities by social deprivation index. Southern European countries, like Portugal, share some characteristics that make their populations more vulnerable to the impact of lockdowns. An economy based on tourism and composed of low-skilled or temporary workers (77) was especially vulnerable to the effects of lockdowns. Therefore, with individual-level data, we would expect to find heterogeneous effects of lockdowns on vulnerable populations. We did not address the cumulative COVID-19 mortality by social deprivation at the municipality level; that would be a logical next step to provide evidence of heterogeneous impact on the most vulnerable populations and areas.

In aim two we are unable to characterize who are the patients affected by canceled or delayed care. That characterization would help create a patient profile based on clinical needs that should be prioritized when rescheduling care. In addition, a longer-term follow-up of these patients would estimate the long-term effects of delayed care. We did not explore the heterogeneity of recovery strategies employed by different public providers; though in a centralized healthcare system like Portugal, these strategies are likely more limited than in other countries with decentralized health systems. Nevertheless, exploring which recovery strategies were most practical and effective with recovering lost visits due to the pandemic is an essential piece of knowledge to improve resilience to external shocks.

Finally, in aim three, our results suggest that a selection of the frailest patients admitted had a large influence on CFR during the lockdowns for non-COVID-19 conditions. Which we could not explore as the characteristics of patients at long-term care facilities or homes were outside the scope of our dataset. Studying those individuals would clarify if some avoided hospitalization during lockdowns even if they needed hospital care.

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Appendix: Chapter2

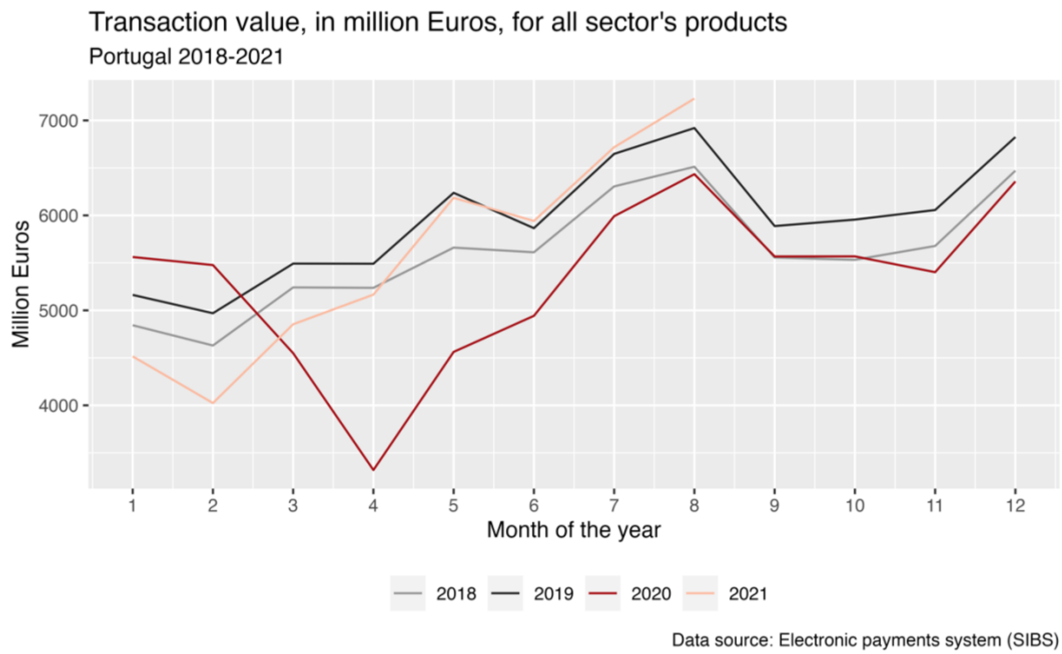

Figure 8. Transaction value, in million Euros, for all sector's products

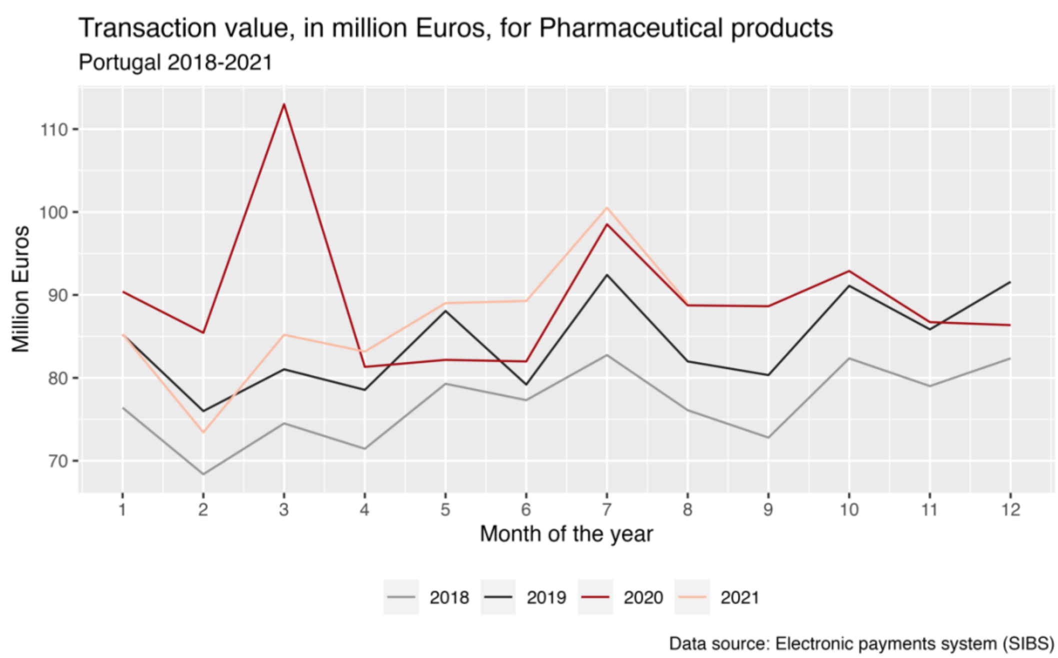

Figure 9. Transaction value, in million Euros, for Pharmaceutical products

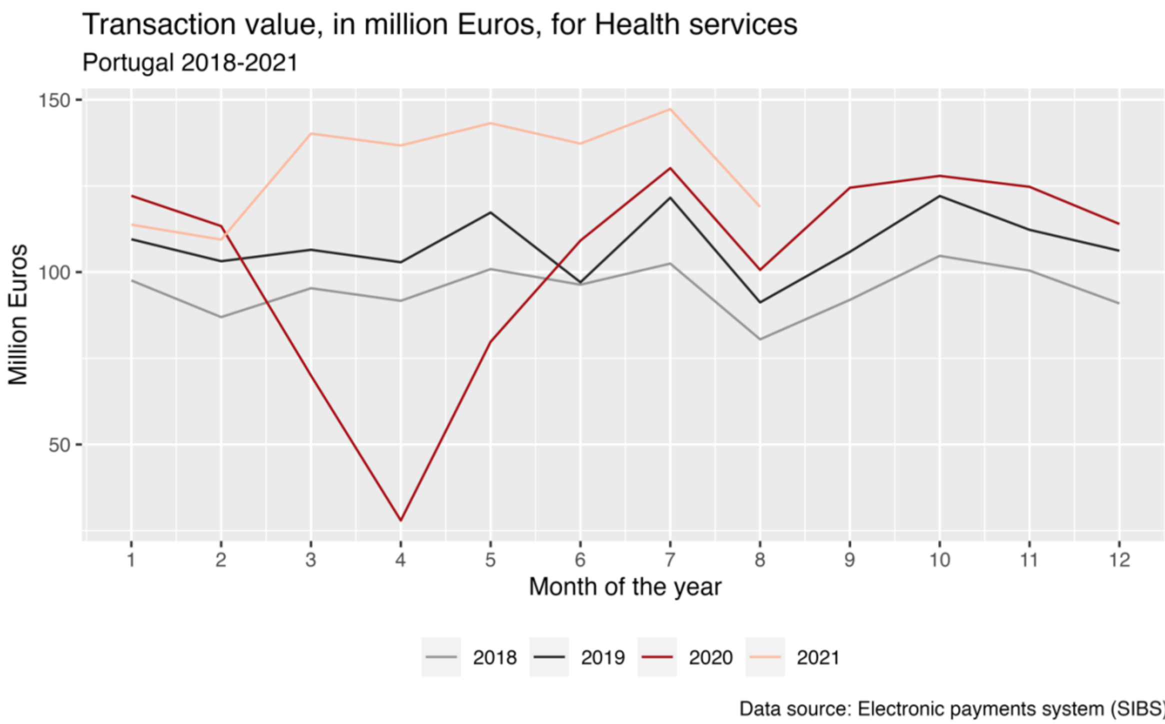

Figure 10. Transaction value, in million Euros, for Health services

Table 15. Effect of COVID-19 pandemic lockdowns on transactions value (million euros) for all sectors and services by Social Deprivation quintile

EDI quintile[a]	Term	Rate ratio (95% CI)	p value
1(least deprived)	Pre COVID-19 trend	1.01 (1.00-1.02)	>0.05
1(least deprived)	First lockdown	0.79 (0.55-1.14)	>0.05
1(least deprived)	Inter-lockdown	0.91 (0.68-1.23)	>0.05
1(least deprived)	Second lockdown	0.91 (0.63-1.30)	>0.05
1(least deprived)	Recovery	1.05 (0.70-1.57)	>0.05
1(least deprived)	Trend First lockdown	0.99 (0.77-1.29)	>0.05
1(least deprived)	Trend inter-lockdown	1.01 (0.95-1.09)	>0.05
1(least deprived)	Trend Second lockdown	1.04 (0.88-1.22)	>0.05
1(least deprived)	Trend recovery	1.00 (0.85-1.18)	>0.05
2	Pre COVID-19 trend	1.01 (1.00-1.02)	>0.05
2	First lockdown	0.79 (0.53-1.18)	>0.05
2	Inter-lockdown	0.93 (0.68-1.29)	>0.05
2	Second lockdown	0.96 (0.64-1.45)	>0.05
2	Recovery	1.15 (0.73-1.81)	>0.05
2	Trend First lockdown	1.00 (0.75-1.32)	>0.05
2	Trend inter-lockdown	1.01 (0.93-1.09)	>0.05
2	Trend Second lockdown	1.04 (0.86-1.26)	>0.05
2	Trend recovery	1.00 (0.83-1.21)	>0.05
4	Pre COVID-19 trend	1.01 (1.00-1.01)	>0.05
4	First lockdown	0.80 (0.55-1.17)	>0.05
4	Inter-lockdown	0.93 (0.68-1.25)	>0.05
4	Second lockdown	0.94 (0.65-1.38)	>0.05
4	Recovery	1.11 (0.73-1.70)	>0.05
4	Trend First lockdown	0.99 (0.76-1.29)	>0.05
4	Trend inter-lockdown	1.01 (0.94-1.08)	>0.05
4	Trend Second lockdown	1.04 (0.88-1.24)	>0.05
4	Trend recovery	1.00 (0.84-1.20)	>0.05
3	Pre COVID-19 trend	1.01 (1.00-1.02)	>0.05
3	First lockdown	0.81 (0.53-1.22)	>0.05
3	Inter-lockdown	0.92 (0.66-1.29)	>0.05

EDI quintile[a]	Term	Rate ratio (95% CI)	p value
3	Second lockdown	1.03 (0.67-1.57)	>0.05
3	Recovery	1.24 (0.77-1.99)	>0.05
3	Trend First lockdown	1.00 (0.75-1.34)	>0.05
3	Trend inter-lockdown	1.01 (0.94-1.10)	>0.05
3	Trend Second lockdown	1.05 (0.86-1.27)	>0.05
3	Trend recovery	0.98 (0.81-1.20)	>0.05
5 (most deprived)	Pre COVID-19 trend	1.01 (1.00-1.01)	>0.05
5 (most deprived)	First lockdown	0.78 (0.55-1.11)	>0.05
5 (most deprived)	Inter-lockdown	0.87 (0.66-1.16)	>0.05
5 (most deprived)	Second lockdown	0.97 (0.67-1.39)	>0.05
5 (most deprived)	Recovery	1.11 (0.74-1.65)	>0.05
5 (most deprived)	Trend First lockdown	0.96 (0.75-1.23)	>0.05
5 (most deprived)	Trend inter-lockdown	1.02 (0.95-1.09)	>0.05
5 (most deprived)	Trend Second lockdown	1.02 (0.87-1.21)	>0.05
5 (most deprived)	Trend recovery	1.01 (0.85-1.19)	>0.05

[a]Negative binomial model with month, municipality fixed effects, EDI - European Deprivation Index

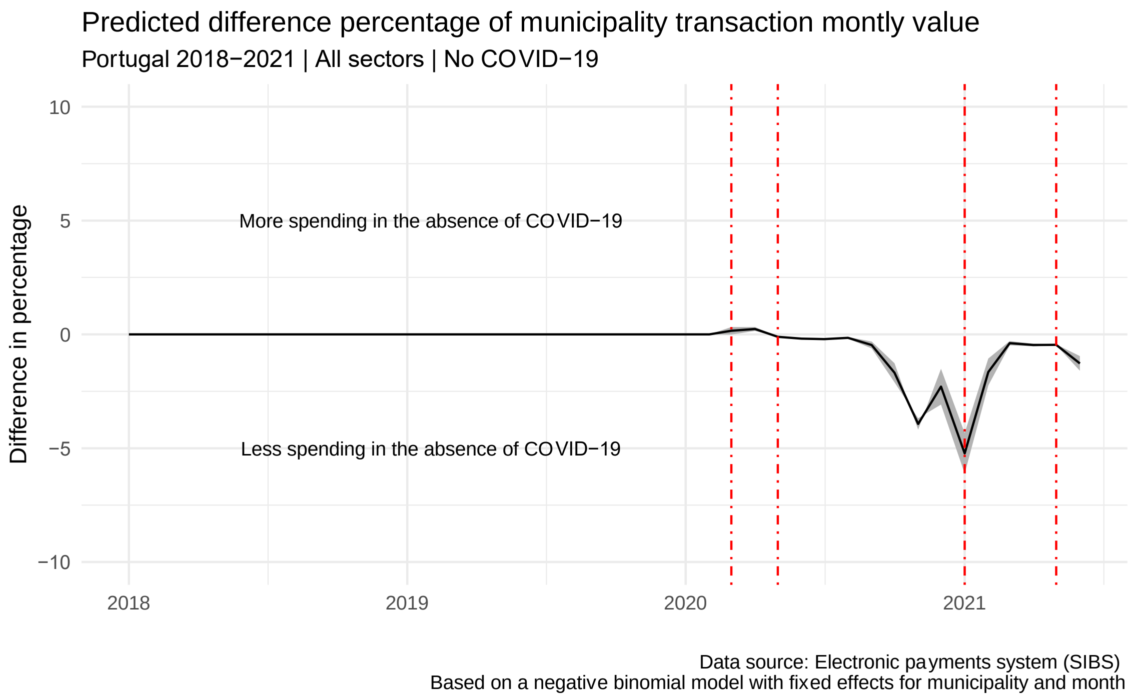

Figure 11. Predicted difference percentage of municipality transaction monthly value with no SARS-CoV-2 cases and COVID-19 deaths

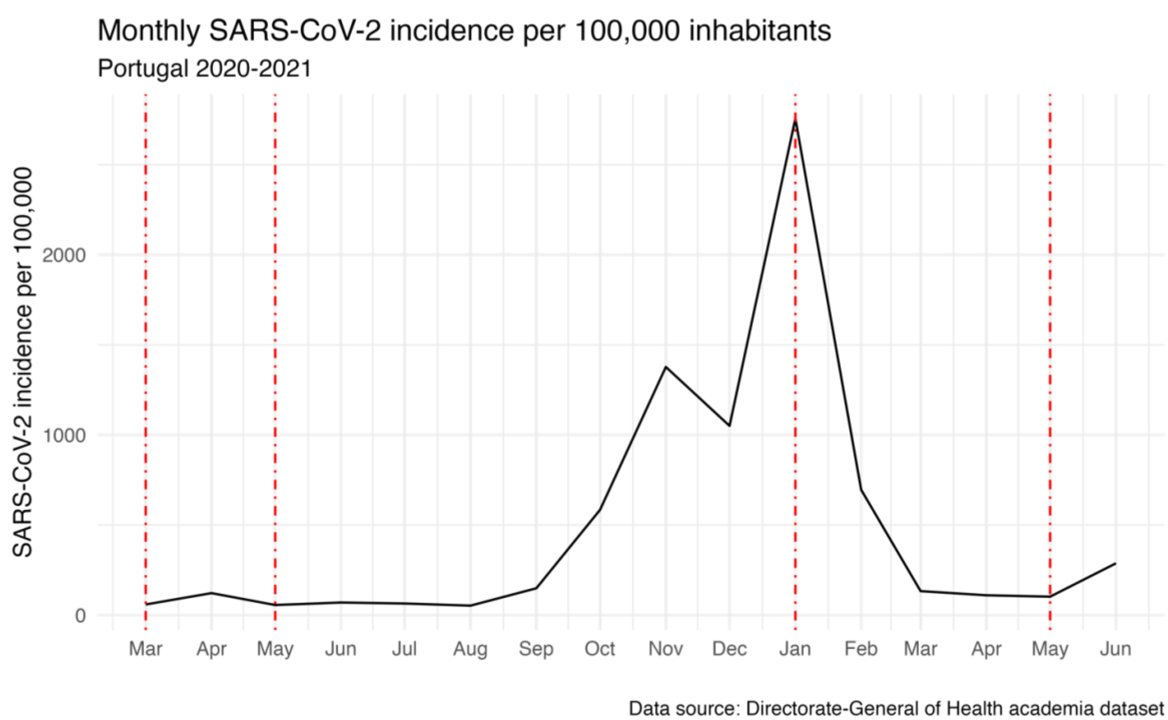

Figure 12. Monthly SARS-CoV-2 incidence per 100,000 inhabitants in Portugal

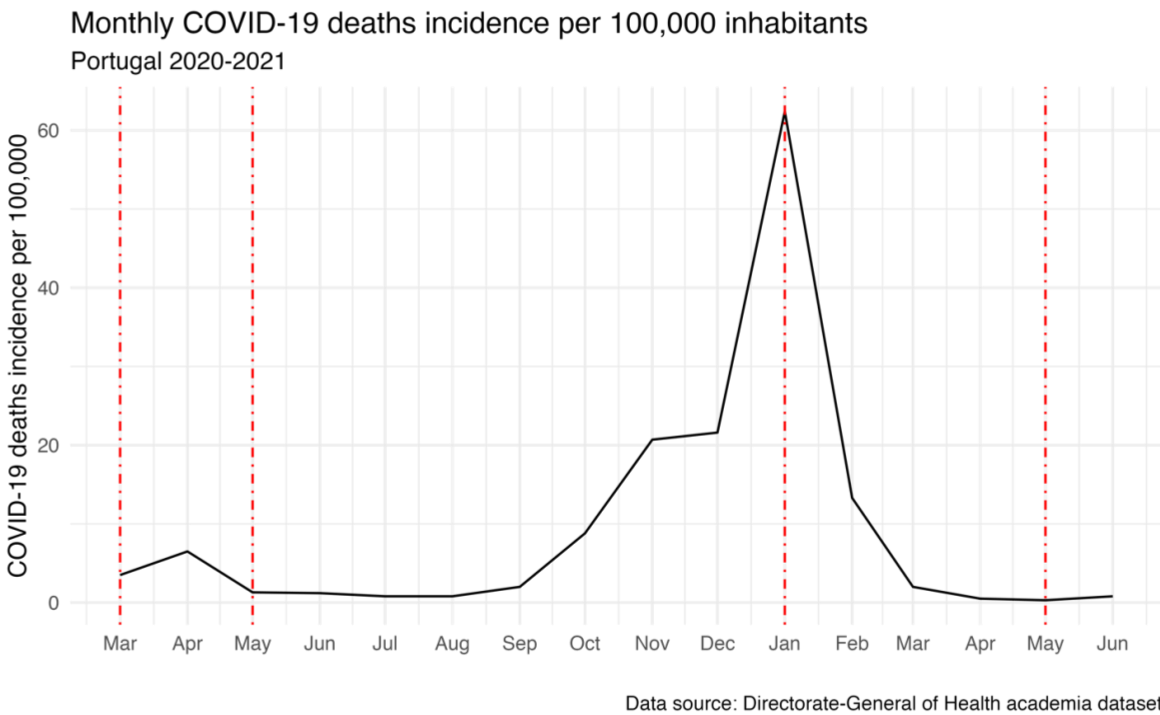

Figure 13. Monthly COVID-19 deaths incidence per 100,000 inhabitants in Portugal

Appendix: Chapter4

Hospital random effects

Table 16. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

Term[a]	CFR ratio (95% CI)	p value*[b]
Pre COVID-19 trend	1.00 (1.00-1.00)	0.016
First lockdown	1.13 (1.08-1.19)	0.000
Inter lockdown	1.17 (1.13-1.22)	0.000
Second lockdown	1.62 (1.55-1.70)	0.000
Trend first lockdown	1.13 (1.10-1.17)	0.000
Trend Inter lockdown	1.00 (0.99-1.01)	0.983
Trend second lockdown	0.83 (0.82-0.85)	0.000

[a]Negative binomial model with month,age group, sex and ICD-10 group fixed effects, and hospital random effects; [b]Case fatality rate ratio

All ICD-10 diagnosis (including COVID-19)

Table 17. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

Term[a]	CFR ratio (95% CI)	p value*[b]
Pre COVID-19 trend	1.00 (1.00-1.00)	0.039
First lockdown	1.21 (1.15-1.27)	0.000
Inter lockdown	1.14 (1.09-1.18)	0.000
Second lockdown	1.60 (1.52-1.70)	0.000
Trend first lockdown	1.09 (1.06-1.12)	0.000
Trend Inter lockdown	1.02 (1.01-1.03)	0.000
Trend second lockdown	0.83 (0.82-0.85)	0.000

[a]Negative binomial model with month,age group, sex, hospital and ICD-10 group fixed effects; [b]Case fatality rate ratio

Inpatient number of deaths for non COVID-19 conditions

Table 18. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

Term[a]	Number of deaths RR (95% CI)	p value[b]
Pre COVID-19 trend	1.00 (1.00-1.00)	0.008
First lockdown	0.94 (0.90-0.99)	0.013
Inter lockdown	1.04 (0.99-1.09)	0.126
Second lockdown	1.00 (0.94-1.08)	0.892
Trend first lockdown	1.03 (1.00-1.07)	0.062
Trend Inter lockdown	1.00 (0.99-1.01)	0.432
Trend second lockdown	0.93 (0.91-0.95)	0.000

[a]Negative binomial model with month,age group, hospital, sex and ICD-10 group fixed effects; [b]Death rate ratio

All hospitals included

Table 19. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

Term[a]	CFR ratio (95% CI)	p value*[b]
Pre COVID-19 trend	1.00 (1.00-1.00)	0.041
First lockdown	1.18 (1.13-1.23)	0.000
Inter lockdown	1.13 (1.09-1.18)	0.000
Second lockdown	1.57 (1.47-1.68)	0.000
Trend first lockdown	1.11 (1.07-1.14)	0.000
Trend Inter lockdown	1.01 (1.00-1.02)	0.014
Trend second lockdown	0.84 (0.82-0.86)	0.000

[a]Negative binomial model with month,age group, sex and ICD-10 group fixed effects, and hospital random effects; [b]Case fatality rate ratio

Exclude respiratory and other infectious diseases

Table 20. Effect of lockdowns on hospital case fatality rates for non COVID-19 diagnosis

Term[a]	CFR ratio (95% CI)	p value*[b]
Pre COVID-19 trend	1.00 (1.00-1.00)	0.334
First lockdown	1.22 (1.15-1.29)	0.000
Inter lockdown	1.12 (1.06-1.18)	0.000
Second lockdown	1.53 (1.42-1.64)	0.000
Trend first lockdown	1.09 (1.05-1.13)	0.000
Trend Inter lockdown	1.01 (1.00-1.02)	0.077
Trend second lockdown	0.82 (0.80-0.85)	0.000

[a]Negative binomial model with month,age group, sex and ICD-10 group fixed effects, and hospital random effects; [b]Case fatality rate ratio

VITA

André Peralta Santos is a Medical Doctor and Public Health Specialist from Portugal with a passion for epidemiology, health systems research and information systems. André holds a Master's degree in Public Health from NOVA University in Lisbon and a clinical research certificate from Harvard Medical School. André served as the Director of Information and Analysis at the Directorate General of Health, where he played a critical role in leading the COVID-19 response efforts in Portugal.