The Hidden Toll of the Pandemic on Non-respiratory Patients

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Abstract

Many empirical studies have focused on the health consequences of COVID-19 for infected individuals, but little attention has been dedicated to its consequences for patients with non-respiratory medical conditions. We employ a combination of machine learning and regression analysis techniques and administrative records on the universe of inpatient hospitalisations in Italy from 2012-2022 to investigate the effects of the outbreak on non-respiratory patients in one of the countries most acutely affected by the pandemic. A comparison of hospital- and population-level excess mortality suggests that 53.7% of COVID-19 deaths occurred outside hospitals. We interpret this as evidence of limited hospital resources, and we show that a higher number of hospital beds per capita is associated with a higher proportion of in-hospital deaths. We also document a 22.6% decrease in hospitalisations of non-respiratory patients, a shift towards treating non-respiratory patients with more severe conditions, and a conditional decrease of 0.5 days in the average LOS for non-respiratory patients. We attribute these changes to fear of infection and hospital resource limitations, and we show that the drop in admissions was more pronounced in areas that were more impacted by COVID-19 and that had fewer hospital beds per capita. Our findings suggest that the pandemic's direct impact corresponds to a fraction of the broader health losses in the population.

JEL codes: H40, H51, D62, I1.

Keywords: hospitalisation, Administrative data, COVID-19.

1 Introduction

The COVID-19 pandemic has had a profound impact on global health systems, with Italy – one of the hardest-hit countries – experiencing significant strain on its healthcare infrastructure and economy. The empirical literature has produced extensive evidence to establish and characterize the spread of the disease and its consequences for infected individuals (e.g. 1; 2). Yet, the medical consequences of the pandemic are not limited to COVID-19 patients because the outbreak forced policymakers and hospital managers to implement drastic measures and divert resources away from the treatment of other conditions (3), especially in the first phases, when the available resources and the specific medical knowledge on how to treat the disease were limited. On the one hand, the necessary prioritization of infected individuals in very serious conditions and hospitals' insufficient capacity has led to an impressive number of COVID-19 deaths occurring without hospitalisation (4). On the other hand, the prioritization of COVID-19 patients over other conditions and the efforts made to avoid in-hospital contagion have led to profound disruptions in hospital practices which resulted in a dramatic reduction in the level of care supplied to all other patients.

While previous works have highlighted and documented some of these aspects, those typically focus on specific areas or settings, and we are not aware of any study that has previously attempted to quantify the full extent of these phenomena. A more comprehensive understanding of the consequences of the outbreak for all patients, including those suffering from other conditions, is of crucial importance for at least three reasons. First, given the magnitude of these disruptions, any quantification of the health costs of the pandemic which focused only on infected individuals would severely underestimate the aggregate social costs of the outbreak. Second, it would be impossible to critically appraise the emergency strategies adopted to cope with the pandemic only focusing on their clinical impact on infected individuals and overlooking their consequences for other patients. Third, we expect the consequences of missed hospitalisations and reduced care to persist for years, if not for decades, and the echo of the pandemic to become one of the crucial challenges for healthcare providers in the near future.

In this study, we apply regression analysis and machine learning techniques to complete coverage administrative data for more than 50 million hospitalisation records from Italy in 2012-2021, representing all hospital discharges for acute care, to provide a precise estimate of out-of-hospital deaths and to quantify the effects of the COVID-19 pandemic on patients affected by other conditions, and thus provide a more comprehensive account of the disruptions in healthcare provision induced by the pandemic. Our results show that 53.7% of COVID-19 deaths occurred outside the hospital over the whole period. We interpret this as evidence of the scarcity of available resources and hospitals' inability to cope with the unprecedented demand increase during the pandemic. We also estimate a 22% reduction in the number of hospitalisations for non-respiratory patients, and a 0.5-day reduction in average hospital length-of-stay (LOS), conditional on patients' conditions and characteristics.

We interpret these changes as attributable to a combination of the fear of in-hospital contagion on the part of both patients and healthcare providers (5; 6; 7; 8; 9) and a significant diversion of healthcare resources away from the treatment of non-respiratory conditions. Compatible with these interpretations, both the incidence of out-of-hospital deaths and the drop in non-respiratory admissions are stronger in areas more severely hit by the pandemic as proxied by population-level excess mortality.

The literature on excess mortality associated with the COVID-19 outbreak is vast and provides estimates of the aggregate death toll of the pandemic for several countries (2). By comparing these estimates with available statistics on the officially recognized COVID-19 deaths, some authors have concluded that several COVID-19 deaths occurred without diagnosis or hospitalisation in a variety of settings, including for instance the US (10), England and Wales (11), and Lombardy (12). Focusing on the metropolitan area of Milan, Jackson et al. (4) find the phenomenon to be particularly relevant in the early phases of the pandemic, and to disproportionally affect older men, care home residents, and people with co-morbidities. Our contribution to the literature on COVID-19 excess mortality is twofold. First, we are not aware of any study that has estimated in-hospital excess mortality and compared it to the population-level excess deaths to estimate the share of COVID-19 deaths that occurred out of hospital. Second, while population-level estimates of COVID-19 excess mortality have been used extensively to test statistical associations with demographic (13; 14), environmental (15), and institutional factors (16), and to evaluate the efficacy of policy interventions (17; 18), we are not aware of any study who has previously associated excess mortality with out-of-hospital death or with reduced utilisation of healthcare services.

The empirical literature has also documented disruptions to the provision of healthcare to non-COVID-19 patients in different forms (19; 20; 21; 22), including reduced access to emergency care (23; 24; 25), a reduction in elective surgeries (26; 27; 28), and reduced hospitalisations for other conditions (29; 30; 9). Although several studies have documented these phenomena, we are aware of only one that has done so with national-level full-coverage administrative data - in this case, focusing on elective surgeries in the Netherlands (26), and to our knowledge no previous study has quantified the aggregate loss of hospitalisations for acute care at the national level. We contribute to this literature by providing the first national-level comprehensive estimate of the aggregate loss in hospitalisations for acute care patients induced by the pandemic, and by providing novel evidence of reduced LOS for non-respiratory patients conditional on their conditions and characteristics, a previously undocumented form in which the diversion of resources away from non-COVID-19 patients manifested during the period. Finally, we contribute to this literature by providing further evidence that reduced utilisation of healthcare services is primarily driven by patients with less serious conditions – a finding that is also consistent with previous works on emergency department (ED) admissions in more confined settings, as in Golinelli et al.(31)– suggesting that healthcare providers prioritised patients with higher needs. Our evidence thus suggests that the results of previous studies documenting increases in mortality for hospitalized patients (32) may be better rationalized by compositional changes of hospitalisations in favour of patients with more serious conditions rather than a direct effect of these disruptions to patients' care.

2 Data and Methods

Hospitalisation data are collected and distributed by the Italian national archive of hospital discharges, which is managed by the Ministry of Health (MoH) and keeps track of any discharge from public or private accredited hospitals in Italy, excluding only discharges from clinics, nursing homes and psychiatric institutes. We focus on ordinary regime – as opposed to day-hospital – admissions for acute care between January 1, 2012, and December 31, 2021. We exclude the last two months of 2021, as we are unable to observe the discharge of a non-negligible fraction of patients admitted in this period.

Our data include detailed patient characteristics, such as age, gender and the province of residence, plus the month of admission and discharge from the hospital, LOS, and main reason for discharge, including death.

From a clinical perspective, the archive contains patients' principal diagnoses and an exhaustive list of surgical and therapeutic procedures and interventions performed. Moreover, we can observe whether their discharges followed a planned or urgent hospitalisation, with the latter almost exclusively coming from emergency rooms. In addition, the diagnosis-related group (DRG) code is reported for each observation, following the international classification system aimed at grouping discharges with similar clinical characteristics that therefore require homogeneous resources. Each DRG is aggregated into two different classifications. The first indicates whether a hospitalisation requires surgical or medical interventions. The second refers to major diagnostic categories (MDCs), an international classification grouping all possible diagnoses into twenty-five mutually exclusive groups. Given the high number of groups, we aggregate less-represented MDCs together to ease the interpretation of the results. We keep the original classification for MDC-4 (Respiratory system, which in the pre-COVID-19 period accounts for 10% of all hospitalisations), MDC-1 (Nervous system, 8%), MDC-5 (Circulatory system, 16.8%), and MDC-8 (Musculoskeletal system & connective tissue, 14.6%). We aggregate MDC-7 (Hepatobiliary system & pancreas), MDC-11 (Kidney & urinary tract), and MDC-6 (Digestive system) into one category (Digestive/Hepatobiliary/Urinary), and we group the remaining 14 MDCs (which in pre-COVID-19 period accounted for 28.1% of all hospitalisations) into a unique residual category (Other). Our data do not include records corresponding to MDC-14 (pregnancy, childbirth and puerperal interventions), MDC-15 (newborn and other neonates, i.e., perinatal-period interventions), MDC-22 (burns), or MDC-25 (human immunodeficiency virus infection – HIV). The corresponding frequency distributions are reported in Table A.1, together with the same results for the original MDC classification.

We isolate patients admitted for respiratory conditions based on their MDC, and we use this information to quantify hospital excess mortality due to COVID-19. We define the *first* COVID-19 wave as the period from March to May 2020 and the *second* wave as the period between October 2020 and January 2021. To assess the overall COVID-19 effect, we also define the period from February 2020 – the first month with at least one case recorded by public health authorities – to the end of our sample period (October 2021) as the *overall COVID-19 period*. Clearly, not all of these patients can be considered COVID-19 cases. Yet, it is reasonable to attribute all excess mortality in respiratory patients to COVID-19. In other words, while we do not assume that all respiratory patients are COVID-19 patients, we do assume that all extra deaths in patients hospitalised with respiratory conditions are attributable to COVID-19 or complications of other conditions due to the infection, and that COVID-19 mortality primarily manifests in respiratory patients (notice that patients dying for non-respiratory conditions, for instance myocardial infarction, are still classified as respiratory patients in MoH data as long as these conditions are attributable to COVID-19). To corroborate this assumption, we show that the mortality rates for non-respiratory patients never exceeded their historical mean in the sample period. Similarly, when estimating the drops in hospital admissions for non-COVID-19 patients, we restrict the analysis to non-respiratory patients (rather than simply excluding patients explicitly classified as COVID-19). Again, this strategy does not require to assume that all respiratory patients are COVID-19 patients, but only that the vast majority of non-respiratory patients are non-COVID-19 patients.

If instead we identified COVID-19 patients based on the classification recommended by the guidelines of the MoH, we would not have been able to identify patients who were hospitalised or died because of COVID-19 with certainty, especially in the earliest phases of the pandemic. First, the MoH only issued its first official guidelines and recommendations on how to classify COVID-19 patients towards the end of March 2020 (*"Linee guida per la codifica della malattia da SARS-CoV-2 (COVID-19) e delle sue manifestazioni cliniche"*), almost 2 months after the outbreak of the pandemic and one month after the first noticeable spikes in mortality rates. Second, as recognized by the second guidelines issued by the MoH in late October 2020 (*"Integrazione dei sistemi di classificazione adottati per la codifica delle informazioni cliniche contenute nella scheda di dimissione ospedaliera e per la remunerazione delle prestazioni ospedaliere in conseguenza della nuova malattia da SARS-CoV-2"*), these classifications did not allow to identify COVID-19 with certainty as they were based on available diagnosis and disease codes, and an ad hoc code for COVID-19 patients was only introduced in October 2020. Still, the requirement of a confirmed positive COVID-19 test made this last classification not entirely reliable, especially in periods of limited testing capacity and for patients with co-morbidities. Finally, by relying on the official classifications we would wrongfully attribute the reason for the hospitalisation of any patients who tested positive for COVID-19, while in fact, COVID-19 was entirely coincidental in many of these cases (e.g. trauma patients who tested positive).

From the Italian National Institute for Statistics (*Istituto Nazionale di Statistica* – ISTAT) public data, we derive the daily number of deaths (all causes) for each province from January 1, 2012, to the end of our observation period in October 2021. From the same source, we also derive provincial age-specific populations measured on January 1 of each year, from which we derive the proportion of elderly individuals in each province. From the MoH Open Data repository, we also compute the number of hospital beds for acute care on January 1st, 2019, and the number of hospital beds per capita. These data capture the number of hospital beds available for acute care before the onset of the pandemic and don't include other kinds of beds such as intermediate care beds, some of which have been employed for COVID-19 patients during the pandemic (33).

When investigating how patients' hospital LOS changed in response to the pandemic, we need to disentangle the change in LOS that is due to changes in patient characteristics from the change attributable to changes in hospital practices. To do so, we employ machine learning techniques to build a counterfactual measure of the LOS for each patient hospitalized after the outbreak. This strategy allows us to estimate how long non-respiratory patients hospitalized during COVID-19 would have stayed in the hospital if they were hospitalized before COVID-19 and then compare this counterfactual estimate with their actual LOS. To do so, we leverage the rich set of hospitalisation and patient characteristic information available in the data to train an artificial neural network to predict patients' LOS during the pre-COVID-19 period.

An artificial neural network is a machine learning computational model that mimics the structure and functioning of the human brain, using interconnected nodes organized into layers, and adjustable weights to learn from data and make predictions or classifications. We trained separate models for hospitals with more than 100 thousand hospitalisations in the study period (60% of the sample). We then aggregate smaller hospitals and train separate models for each region. For each group we fitted a 3-layer artificial neural network with 250 nodes, employing cross-validation and a mean squared error loss function. To calibrate the predicted probabilities, we employed isotonic regressions. Among the features of the model, we included the month of hospitalisation; patients' province of residence, age, gender, and nationality (a dummy variable indicating whether the patient has Italian citizenship); indicator variables for medical/surgical and emergency/planned admissions; principal diagnosis; and principal and secondary interventions. When categorical variables are not adequately represented (less than 0.3% of the total), we aggregate them to a higher level.

With our model, we can explain approximately one-third of the between-individual variation in the LOS for non-respiratory patients (38% for hospitalisations up to 30 days). However, when we aggregate the average and counterfactual LOS to the monthly level, the level at which our analysis is conducted, we are able to explain 72% of the observed time variation in the average hospital LOS for non-respiratory patients; this figure rises to 90% when we add a linear time trend to the model. Overall, these figures suggest that the model is well suited to accurately measuring how changes in average patients' characteristics translate into changes in the average LOS over time. After training the model on the data from the pre-COVID-19 period, we employ it to predict patients' LOS after COVID-19 to build the counterfactual evolution of the average hospital LOS for non-respiratory patients whom we would have observed after the outbreak had hospitals' practices for non-respiratory patients not changed in response to the pandemic.

3 Results

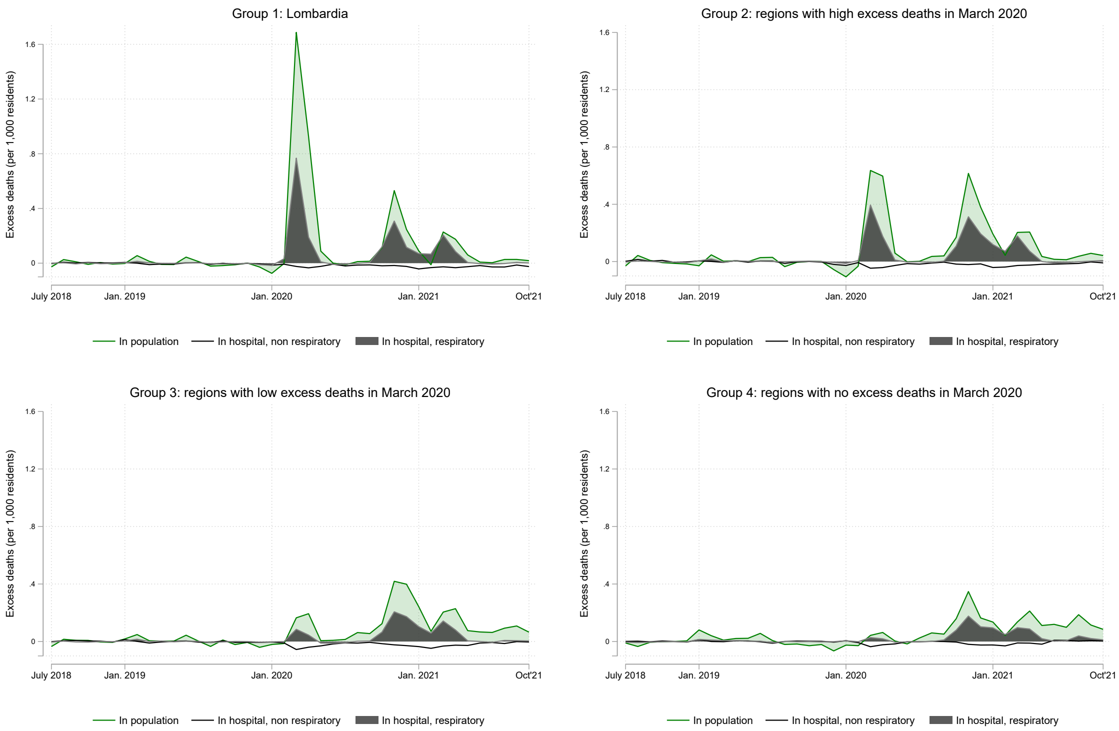
3.1 Excess mortality and out-of-hospital deaths

We begin by comparing hospital and population excess mortality rates to quantify the share of deaths that occurred inside or outside hospitals at the province-month level. To estimate the number of COVID-19 deaths that occurred in hospitals, we compute hospital excess mortality for respiratory patients only. This choice is driven by the concern that, given the observed drops in hospital admissions for non-respiratory conditions in the COVID-19 period, some non-COVID-19 deaths that in the counterfactual scenario would have occurred in hospital may instead have occurred without hospitalisation. In-hospital mortality for non-respiratory patients may thus be lower than usual, resulting in a negative excess mortality for this group and leading to an underestimation of the number of COVID-19 deaths that occurred in the hospitals if these patients were instead included in our computations. This expectation is confirmed by small but significant drops in hospital mortality in the first and second waves. Importantly, though, the observed drops in hospital mortality for non-respiratory patients are small when compared to the estimated excess mortality for respiratory patients, suggesting that our estimates are quite robust to the inclusion or exclusion of respiratory conditions from the analysis of hospital excess mortality.

Although many studies have looked at population excess mortality to quantify the death toll of COVID-19 in a variety of settings (34; 35; 36), we are not aware of any study that has compared it to hospital excess mortality. We try to elucidate both these dimensions in Figure 1, where we aggregate Italian regions according to their population excess mortality rate experienced in March 2020 (the month corresponding to the first COVID-19 peak, as shown in the Appendix in Table A.4), and we display province-month excess deaths in hospitals and in the general population.

The trends in both population- and hospital-level excess mortality are heterogeneous for the first wave of the epidemic, peaking within the range of approximately 1.6 times the historical mean in Lombardy to less than 10% above the historical mean in less affected areas, which are concentrated in the southern part of Italy. Conversely, for the second wave, excess deaths are more heterogeneous across the country.

Figure 1: Population and Hospital Excess deaths



Note: Each panel shows deviations in the general population mortality rate from the 2017-2019 average (light area), deviations in the mortality rate for in-hospital respiratory conditions from the 2017-2019 average (dark area), and deviations in the mortality rate for in-hospital non-respiratory conditions from the 2017-2019 average. Mortality rates are defined as the ratio between cases and population expressed in thousands. Regions are defined according to excess mortality in the population in March 2020 as in Table A.4: Lombardy (left, above); the group of regions with higher values of excess deaths (right, above); the group of regions with milder values of excess deaths (left, below); and the group of regions with no excess deaths (right, below). As the denominator is the same within each panel, we can observe the composition effect of deaths for each group of regions. Source: our calculations on ISTAT and MoH data.

In all four groups and for all the infection waves, the population excess mortality rate (light area) substantially exceeds the hospital excess mortality rate for respiratory conditions (dark area). We employ these estimates to quantify the proportion of deaths that occurred outside hospitals, and we interpret this share as a measure of the extent of strain on hospitals in the different phases of the pandemic.

Overall, we estimate population-level excess deaths of 157.5 thousand, +14.0% with respect to the 2017-2019 average, in line with Alicandro et al. (37), and hospital-level excess deaths for respiratory conditions of 73 thousand (+67%) in the COVID-19 period. As we interpret the former as an estimate of the total number of COVID-19 deaths and the second as the number of COVID-19 deaths that occurred in hospitals, we estimate that 53.7% of COVID-19 casualties did not occur in hospitals. Not surprisingly, this proportion decreases from 60.8% in the first wave to 34.5% in the second (as from Appendix A.5). Altogether, these figures suggest that hospitals were unable to hospitalise promptly a very high share of COVID-19 patients in very serious condition, especially in the early phases of the pandemic.

In Table A.3 in the Appendix, we report the provincial average estimated excess mortality and the average estimated share of excess deaths that occurred outside the hospital, together with some descriptive statistics on demographic characteristics and supply of hospital resources aggregated to the provincial level. The results are quite heterogeneous across Italian provinces, while the number of hospital beds and the share of elderly individuals are more equally distributed.

One caveat to these estimates is that the baseline number of deaths for respiratory conditions (that we employ for the quantification of the number of COVID-19 deaths in the hospital) may be higher than the actual number of respiratory non-COVID-19 deaths because a higher share of non-COVID-19 respiratory patients may have died without hospitalisations in the period. If this is the case, then our estimates of the number of COVID-19 deaths in the hospitals would be downward biased. This possibility is supported by the mortality trends for non-respiratory patients, which show a 10% reduction in the period. Clearly, this reduction in non-respiratory deaths may be partially explained by the fact that some of the patients that would have died from other causes, died instead from COVID-19 and thus appear as respiratory deaths in our sample. Yet, to stress the sensitivity of our estimates to this possible bias, we replicate our estimates after applying the same 10% drop in deaths observed in non-respiratory patients to the counterfactual number of respiratory deaths. This increases our estimate for the number of COVID-19 deaths that occurred in hospitals from 73 to 83.4 thousand, and thus decreases our estimate of the share of COVID-19 deaths that occurred outside the hospital from 53.7 to 47.1%, leaving our conclusion unaffected.

To investigate this further, we next estimate the cross-sectional association between the share of deaths that occurred outside hospitals in the different phases of the pandemic and a series of possible predictors of hospital strain by regressing this measure on the corresponding province-level excess mortality rate, the number of hospital beds per capita in 2019, and the share of elderly people in the province. The results of this analysis are reported in Table A.9 and summarized by the coefficient plot in Figure A.2, where all variables are measured in standard deviations (SD) to ease the interpretation.

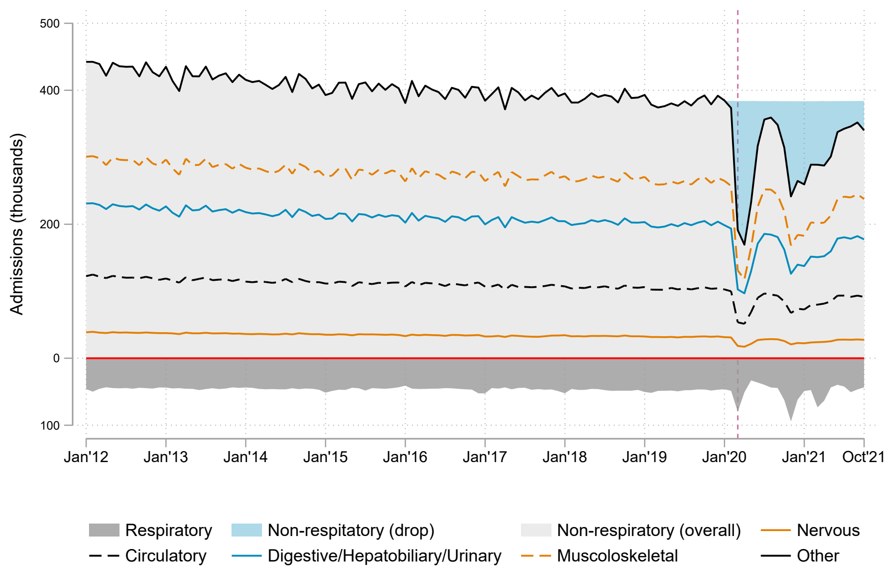
Except for the first wave of the pandemic, we find mild but significant negative associations with hospital beds, which suggests that areas with higher healthcare endowments were able to hospitalize a higher share of patients with serious conditions. Our estimates also suggest that excess mortality played a crucial role in the second wave and indicate that in areas most acutely hit by the pandemic, a higher share of deaths occurred outside the hospital. Interestingly, this association becomes insignificant when we look at the entire sample period. Finally, our results indicate that in the first wave, areas with a relatively higher share of elderly individuals in the total population were generally characterized by a lower share of deaths outside hospitals. This association is consistent with a generalized underestimation of the threat of COVID-19 for younger individuals in the first phases of the outbreak, which may have resulted in a higher proportion of missed hospitalisations in areas characterized by a higher share of younger individuals.

Altogether, these results provide novel insights that help quantify and characterize the amount of strain experienced by the Italian healthcare service during COVID-19. In light of these findings, in the following sections, we investigate how the scarcity of hospital resources during the pandemic and the forced prioritization of COVID-19 patients translated into a substantial diversion of resources away from the treatment of other conditions, which, combined with patients' fear of in-hospital infection, led to substantial reductions in the utilisation of healthcare from patients with non-respiratory diagnoses.

3.2 Consequences for non-respiratory patients: reduced number of admissions

In Figure 2, we plot the normalized series of admissions over time by diagnosis group (MDC). To emphasize the different patterns of respiratory and non-respiratory categories, we plot the corresponding trends in respiratory admissions on a reverse axis. The spikes in admissions for respiratory conditions in the first months of 2020 correspond to substantial drops in the aggregate number of admissions for all other categories. The corresponding estimated changes in the number of admissions for respiratory and non-respiratory conditions in the different phases are reported in Tables A.5-A.7 in the Appendix.

Figure 2: Total number of monthly admissions by MDC



Note: Aggregate series of admissions in Italian hospitals from January 2012 to October 2021 by MDC. *Respiratory* admissions include MDC-4 (diagnosis and diseases of the respiratory system). *Nervous* represents MDC-1 (diagnosis and diseases of the nervous system) admissions. *Circulatory* covers MDC-5 admissions (diagnosis and diseases of the circulatory system), while *Muscoloskeletal* refers to MDC-8 (diagnosis and diseases of the musculoskeletal system and connective tissue) admissions. The *Digestive/Hepatobiliary/Urinary* category covers admissions with MDC-6 (diagnosis and diseases of the digestive system), MDC-7 (diagnosis and diseases of hepatobiliary system and pancreas), and MDC-11 (diagnosis and diseases of kidney and urinary tract). All remaining 14 MDC categories are included in a unique residual group labelled as *Other*, which accounted for 28.1% of all hospitalisations in the pre-COVID-19 period. The corresponding numbers are reported in Table A.1 in the Appendix, together with the same results for the original MDC classification (without aggregation). Source: our elaborations on MoH data.

Figure 2 provides a first assessment of the magnitude of the spillover to non-respiratory patients, which negatively affected patients in all diagnostic groups. Interestingly, the drop in admissions is rather homogeneous across different medical categories and adds up to more than 20 times the corresponding excess in respiratory admissions. Similar conclusions can be drawn from Figure A.3 in the Appendix, where we plot the normalized series of hospitalisation days (instead of the number of hospitalisations) by month of admission and MDC. Further disaggregations suggest that the drop in admissions in the first wave was driven primarily by a drop in planned admissions (see Table A.8 in the Appendix). However, over the whole COVID-19 period, planned and unplanned hospitalisations experienced similar drops.

Overall, we estimate an excess of respiratory admissions of 110.7 thousand and a loss of 1.87 million admissions of patients with non-respiratory conditions in 2020-2021 (Figure 2, light-blue area). The loss in non-respiratory admissions has two peaks corresponding to the two COVID-19 waves, despite the estimated loss being sizeable throughout the entire period.

We attribute these changes to a combination of reduced demand due to patients' and healthcare providers' fear of in-hospital infection and reduced supply due to hospitals' diversion of resources for the treatment of COVID-19 patients. Indeed, while the correspondence between peaks in respiratory admissions and the drops in admissions for other conditions suggests that hospital resource limitations may have played an important role, the 17-fold difference between the two suggests that hospitals were not always operating at full capacity.

The results discussed in this section point towards major spillovers during the pandemic to non-respiratory patients. However, reducing admissions is not the only way to divert resources from non-respiratory patients. In the next section, we provide further evidence that conditional on their conditions, non-respiratory patients experienced shorter hospital stays.

3.3 Consequences for non-respiratory patients: reduced hospital LOS

As already mentioned in section 2, we leverage the detailed information in the data to train an artificial neural network to predict patients' expected LOS and disentangle the change in the average LOS that can be explained by the compositional change in patient characteristics from the change instead due to changes in hospital practices.

In the top panel of Figure 3, we plot the historical series of the LOS for respiratory and non-respiratory patients: for both, the drop in admission discussed in the previous section was coupled with an equally substantial increase in average LOS. More specifically, in March 2020 the figure shows a 25% increase in the average LOS for both respiratory and non-respiratory patients, while in the second wave the LOS increased primarily for respiratory patients. In the central panel of Figure 3, we plot the evolution of the average LOS for non-respiratory patients together with the corresponding counterfactual derived from the artificial neural network iteration procedure (non-deserialised). As the model was trained on the pre-COVID-19 data only, the counterfactual can be interpreted as the average LOS that would have been observed if hospitalized patients were treated according to pre-COVID-19 hospital practices. Hence, the evolution of the counterfactual can be interpreted as the change in average LOS that can be attributed to changes in patient characteristics, and the difference between the observed and counterfactual average LOS (plotted in the bottom panel) can be interpreted as the change in the average LOS that can be attributed to changes in hospitals' practices.

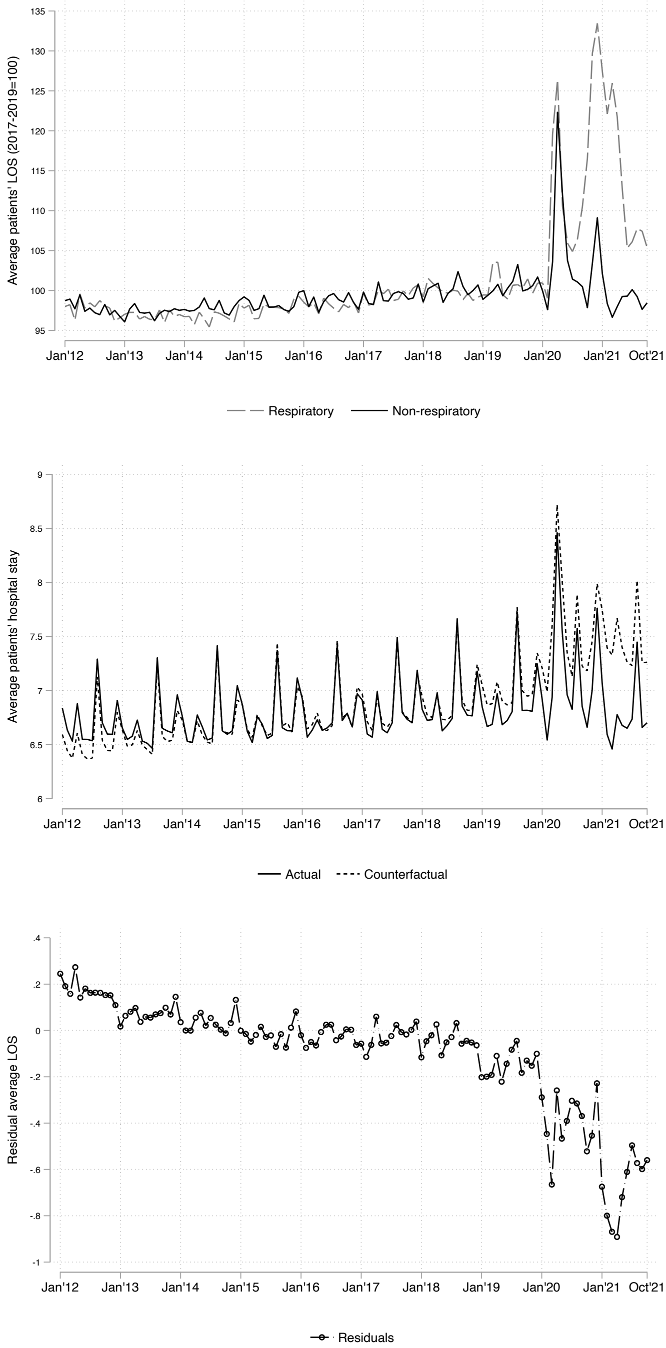
According to Figure 3, the initial spike in the average LOS observed can be entirely attributed to a compositional change in admissions in favour of patients with more serious conditions. This increase in the counterfactual LOS suggests that, as is reasonable to expect, the drop in non-respiratory admissions discussed in the previous section led to a selection and prioritization of patients in more serious condition (as proxied by their counterfactual LOS). Importantly, the counterfactual increase in LOS always exceeds the actual observed change in the period of interest. This suggests that non-respiratory patients hospitalized during COVID-19 experienced shorter LOS in the hospital. In Table A.2, we report the actual average hospital LOS for respiratory or non-respiratory admissions in each COVID-19 wave and in the pre-COVID-19 period and the counterfactual LOS for non-respiratory admissions. On average, we estimate that conditional on their characteristics, patients were discharged 0.5 days earlier on average in the years 2020-2021 than in the baseline period. In Figure A.1 in the Appendix, we show the entire series of actual LOS for different MDCs.

To test the robustness of our findings to alternative model specifications, we replicated this part of the analysis employing, instead of the predictions from the artificial neural network, an alternative benchmark model which simply imputes the average LOS observed before 2019 for patients with similar observable characteristics and conditions. More specifically, we impute the average LOS observed for patients hospitalized before 2019 in the same month with the same diagnosis, primary medical intervention, age class in 10 years bins, urgency status, and medical/surgical status. With respect to the artificial neural network model, this alternative benchmark provides a simpler and easier-to-interpret prediction, at the price of a lower level of accuracy. Furthermore, this model fails to predict LOS for patients whose combined characteristics and conditions are never observed in the baseline period (6% of the sample). Results of this robustness test are summarized in Figure A.4 and confirm our main conclusions.

3.4 Consequences for non-respiratory patients: drops in admission and changes in LOS by patient condition

In this section, we investigate how the documented changes - namely the drop in admissions and the reduction in hospital LOS - differently impacted patients with more or less serious conditions and with different diagnoses.

Figure 3: Average hospital LOS, actual, counterfactual and residual average LOS for non-respiratory admissions



Note: Top panel: average LOS for respiratory and non-respiratory patients (deserialised) by month of admission. Central panel: actual and counterfactual (artificial neural network prediction based on patients' conditions and characteristics) LOS for non-respiratory patients by month of admission. Bottom panel: residual difference between actual and counterfactual LOS for non-respiratory patients by month of admission. *Respiratory* refers to MDC-4 (diagnosis and diseases of the respiratory system). *Non-respiratory* refers to admissions from all remaining categories. Source: our elaborations on MoH data.

In panel (a) of Figure 4, we plot the estimated relative drop in admissions and the estimated drop in the conditional LOS over the expected LOS predicted by the artificial neural network, which we interpret as a proxy of patient condition. Consistent with the observed spike in the counterfactual LOS in the top panel of Figure 3, patients with a lower counterfactual LOS experienced sharper drops in admission, which suggests that the drop in admissions was more pronounced for patients with less severe conditions. More specifically, the relative drop in admission for patients in the bottom percentile of the counterfactual LOS was 70%, more than twice the estimated decrease for patients in the top percentile of the distribution (−30%). Interestingly, however, the relative drop in admission was substantial for all patients, including those with conditions that would have required a very long stay.

Looking at the estimated drop in the conditional LOS (in red), instead, we notice that all percentiles of the distribution of the counterfactual LOS experienced 5% to 10% shorter LOS with respect to identical patients hospitalized before COVID-19. A partial exception is represented by patients with very short counterfactual stays, whose LOS were probably too short to be further reduced.

In panel (b) of Figure 4, we also plot the estimated relative drops in admissions, the conditional relative drop in the LOS, and the estimated increase in counterfactual LOS (which stems from a change in admissions in favour of patients with more serious conditions) by diagnosis group. Interestingly, despite a rather homogeneous drop in admissions across categories, we estimate stronger drops in the conditional LOS for patients with musculoskeletal or digestive/hepatobiliary/urinary diagnoses.

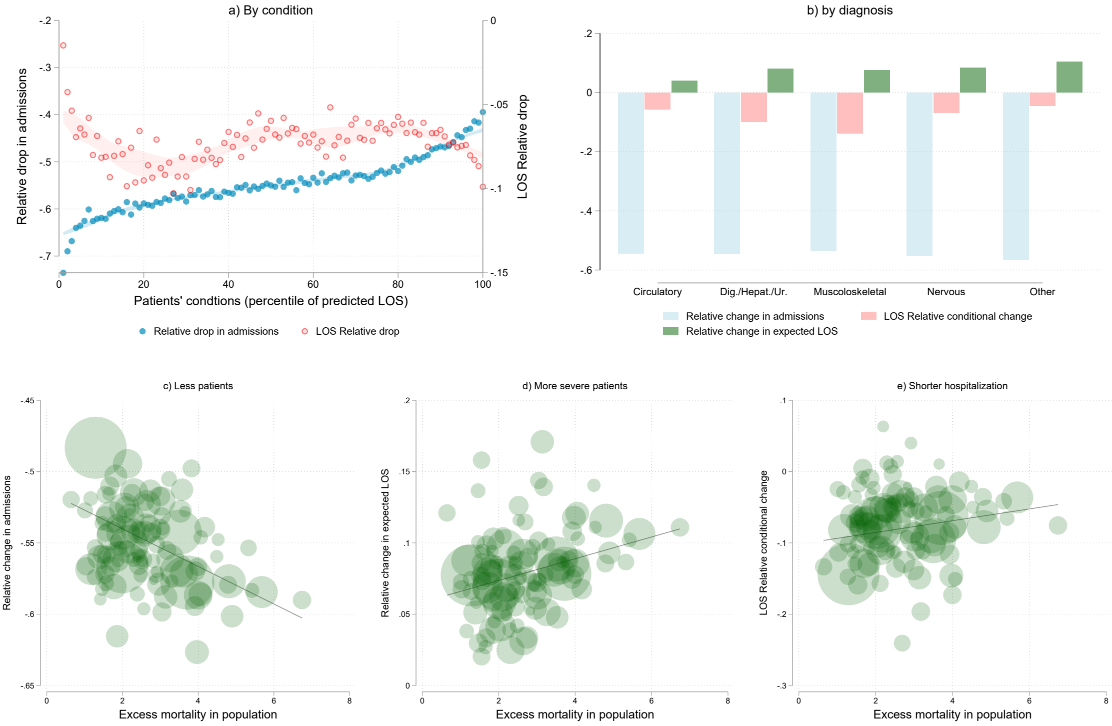
In figure A.5, we plot the estimated provincial-level drop in admission against the corresponding estimated conditional drop in the LOS (in SD), together with a population-weighted linear fit. The negative correlation between the two suggests that provinces experiencing stronger drops in non-respiratory admissions had milder decreases in the conditional drop in the LOS and suggests some degree of substitutability between the two.

3.5 Spillovers to non-respiratory patients and province characteristics

Overall, the analysis discussed in the previous sections suggests that hospitals' and patients' reactions to the pandemic resulted in a 22.6% drop in hospital admissions for non-respiratory conditions, a compositional change in admissions in favour of patients with more severe conditions (those with a greater expected LOS), and a reduction in patient stays (conditional on patient characteristics) by 0.5 days on average. In this section, we combine provincial-level estimates of the admission drop, patients' compositional change, and drop in the LOS with provincial-level excess mortality and province characteristics to further investigate the determinants of these changes.

In panels (c), (d) and (e) of Figure 4, we plot the provincial-level estimates of the drop in admission, the estimated conditional drop in the LOS, and the estimated change in patients' conditions (proxied by their predicted LOS) against the estimated population excess mortality. The figure suggests that more affected areas were characterized by stronger drops in admission, deeper compositional changes in favour of patients with more severe conditions, and milder conditional drops in LOS.

Figure 4: Spillovers by counterfactual LOS, by diagnosis and by provincial excess mortality



Note: Upper panel, left: Relative drop in non-respiratory admissions in the COVID-19 period with respect to the 2017-2019 period conditioned on the percentile of the counterfactual LOS (light blue) with 99% CI; relative change in average LOS for non-respiratory admissions in the COVID-19 period with respect to the 2017-2019 period conditioned on the percentile of the counterfactual LOS (red) with 99% CI. *Non-respiratory* admissions encompass admissions from all categories except MDC-4 (diagnosis and diseases of the respiratory system). Upper panel, right: Relative change in non-respiratory admissions, the relative change in average conditional hospital LOS and relative change in expected LOS conditioned on patient characteristics in the COVID-19 period with respect to the 2017-2019 period by MDC. *Nervous* represents MDC-1 (diagnosis and diseases of the nervous system) admissions. *Circulatory* covers MDC-5 admissions (diagnosis and diseases of the circulatory system), while *Muscoloskeletal* refers to MDC-8 (diagnosis and diseases of the musculoskeletal system and connective tissue) admissions. The *Digestive/Hepatobiliary/Urinary* category includes admissions with MDC-6 (diagnosis and diseases of the digestive system), MDC-7 (diagnosis and diseases of hepatobiliary system and pancreas) and MDC-11 (diagnosis and diseases of kidney and urinary tract). All remaining categories are included in *Other*. Lower panel (a): Relative change in the aggregate number of admissions for non-respiratory patients; (b) relative change in the expected LOS conditional on patient characteristics; (c) relative change in the unconditional average LOS. All changes are represented against excess mortality in the population during the COVID-19 period. Excess mortality is defined as the difference between the mortality rate for 1,000 residents during the COVID period and the mortality rate in previous years, namely from 2017 to 2019. In order to account for possible seasonality in the series of data, differences are calculated from monthly-specific averages. The provincial population dimension is represented by the bubble size. Linear regression fit is included. *Non-respiratory* admissions encompass admissions from all categories except MDC-4 (diagnosis and diseases of the respiratory system). The COVID-19 period started in February 2020. Source: our elaboration on ISTAT and MoH data.

To further investigate the predictors of these changes, we regress the provincial-level estimated change in admissions and the conditional change in hospital LOS on excess mortality per capita, hospital bed availability, the share aged over 75 in the population, and population density, weighting each province by the corresponding population; the results of this analysis are reported in Tables A.10 and A.11 and summarized by Figure A.6.

According to our estimates, the relative drop in non-respiratory patients' admissions was stronger in areas characterized by higher excess mortality. These associations may be rationalized both by a more widespread fear of in-hospital infections in more severely affected areas and by a greater need to divert resources from non-COVID-19 patients in these areas. Although milder and statistically non-significant, the positive associations with hospital beds per capita suggest that areas with higher hospital resources were characterized by milder drops in admissions. Together with the positive associations between excess mortality and relative change in conditional LOS, these results suggest that areas characterized by higher excess mortality experienced sharper decreases in admissions and milder reductions in non-respiratory patients' stay.

4 Discussion

Previous works have documented reductions in the utilisation of healthcare services during the pandemic. Our findings precisely characterize and confirm the general extent of this phenomenon by examining complete administrative data from one of the countries most severely affected by the pandemic and unveiling previously undocumented changes in the treatment of non-respiratory patients.

We find that 53.7% of COVID-19 deaths did not occur in hospitals and that a combination of fear of in-hospital contagion and limited hospital resources resulted in a 22.6% drop in the number of admissions of non-respiratory patients (driven primarily by patients with less serious conditions) and to a 0.5-day reduction in patients' LOS in the hospital, conditional on patient characteristics. Moreover, we document substantial heterogeneity in these changes, which vary with the demographic characteristics of the area, the number of preexisting resources, and how badly affected the area was.

In the face of an increase of 110.7 thousand in respiratory admissions (+10.2% with respect to their historical mean), we estimate a net loss of 1.87 million hospitalisations from March 2020 to October 2021. This implies that 17 non-respiratory hospitalizations were lost for every COVID-19 patient hospitalization. Based on our estimates, the COVID-19 outbreak resulted in a total loss of 12.2 million hospitalisation days for non-respiratory patients between March 2020 and October 2021, corresponding to a drop of 21.6% with respect to the historical mean. Based on these estimates and the average cost of one day of hospitalisations for non-respiratory patients (915 euros, EUROSTAT Statistics on Health Expenditures), the monetary value of these missed hospitalisations can be quantified at 6.7 billion euros per year, corresponding to 5.9% of national public healthcare spending and approximately 0.4% of Italian GDP in 2019 (1,787 billion euros, Bank of Italy). Although these estimates should be interpreted with caution, their magnitude suggests that the economic value of the healthcare loss for non-respiratory patients sums to approximately 6.4% of the GDP loss that occurred in the same period and that studies looking at the social costs of the pandemic should not overlook its indirect impact on non-COVID-19 patients.

5 Conclusion and policy implications

Our analysis suggests that the direct effects of the COVID-19 pandemic may represent only a fraction of the broader health losses in the population. The humongous loss of hospital admission during the period may translate into substantial backlogs of less urgent patients whose care was postponed, and the long-term consequences of these missed hospitalisations may be greater than previously thought.

On the one hand, the fact that these drops in hospitalisations were driven primarily by patients in less severe conditions – a result that is also compatible with previous evidence provided by Vanieri et al. (27) as they show that missed elective surgeries were more likely in categories with more potential for inappropriateness – may suggest that a fraction of the patients who did not receive care because of COVID-19 may not have sought care after the end of the critical period. On the other hand, though, the magnitude of our estimates seems too high to be entirely attributed to a reduction in inappropriate or avoidable hospitalisations. We thus expect the consequences of these missed hospitalisations to resonate for years, and the new normal to be characterized by increased demand (and pressure) on healthcare services. In fact, together with the endemicization of COVID-19, these backlogs have already translated into substantial delays (38).

To minimize disruptions and prevent excessive delays, policymakers should invest substantial resources to increase hospitals' capacity and implement both short- and medium-run solutions to improve efficiency. As suggested by van Ginneken et al. (39), possible solutions include centralising coordination and optimising planning of care, possibly favouring the interregional reallocation of patients, remodelling copayment schemes to introduce better incentive systems, and implementing digital solutions and other tools to favour productivity. Policymakers should also take the opportunities offered by the advances in digitalisation and by the increased availability of near-real-time granular information on hospital admissions, waiting times, and mortality to complement these strategies with a more timely and granular monitoring system, coordinated and harmonized by a unique body (40).

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A Additional Figures and Tables

Table A.1: Hospitalisation by Major Diagnostic Category (MDC)

		2012-2019		2020		2021	
MDC	MDC description	n. obs.	freq.	n. obs.	freq.	n. obs.	freq.
4	Respiratory sys.	4,338,683	0.101	632,519	0.153	491,656	0.136
	Subtotal, respiratory	4,338,683	0.101	632,519	0.153	491,656	0.136
1	Nervous sys.	3,408,353	0.080	305,589	0.074	263,586	0.073
	Subtotal, nervous	3,408,353	0.080	305,589	0.074	263,586	0.073
5	Circulatory sys.	7,202,852	0.168	656,748	0.159	589,870	0.163
	Subtotal, circulatory	7,202,852	0.168	656,748	0.159	589,870	0.163
6	Digestive sys.	4,456,114	0.104	382,866	0.093	338,815	0.093
7	Hepatobiliary sys. & Pancreas	2,342,783	0.055	213,074	0.052	189,405	0.052
11	Kidney & urinary tract	2,785,156	0.065	291,431	0.071	264,893	0.073
	Subtotal, digestive/hepatobiliary/urinary	9,584,053	0.224	887,371	0.215	793,113	0.219
8	Musculoskeletal sys. & connective tissue	6,253,960	0.146	593,816	0.144	549,780	0.152
	Subtotal, muscoloskeletal	6,253,960	0.146	593,816	0.144	549,780	0.152
2	Eye	561,556	0.013	40,706	0.010	33,706	0.009
3	Ear, nose, mouth & throat	1,627,236	0.038	109,093	0.026	94,689	0.026
9	Skin, subcutaneous tissue & breast	1,363,145	0.032	121,652	0.029	107,640	0.030
10	Endocrine, nutritional & metabolic sys.	1,241,092	0.029	102,286	0.025	98,451	0.027
12	Male Reproductive sys.	839,840	0.020	74,101	0.018	69,027	0.019
13	Female Reproductive sys.	1,454,832	0.034	120,468	0.029	112,466	0.031
16	Blood & immunological dis.	551,723	0.013	49,588	0.012	42,379	0.012
17	Myeloproliferative dis.	1,182,245	0.028	110,233	0.027	91,967	0.025
18	Infectious & parasitic dis.	972,802	0.023	120,026	0.029	107,463	0.030
19	Mental dis. & disorders	1,043,707	0.024	94,579	0.023	84,123	0.023
20	Alcohol, drug use or induced mental dis.	100,310	0.002	8,706	0.002	8,023	0.002
21	Injuries, poison & toxic effect of drugs	399,584	0.009	33,967	0.008	29,307	0.008
23	Factors influencing health status	642,814	0.015	61,060	0.015	53,404	0.015
24	Multiple significant Trauma	67,961	0.002	7,546	0.002	6,673	0.002
	Subtotal, other	12,048,847	0.281	1,054,011	0.255	939,318	0.259
	Total	42,836,748		4,130,054		3,627,323	
	Total, 2012-2021	50,594,125					

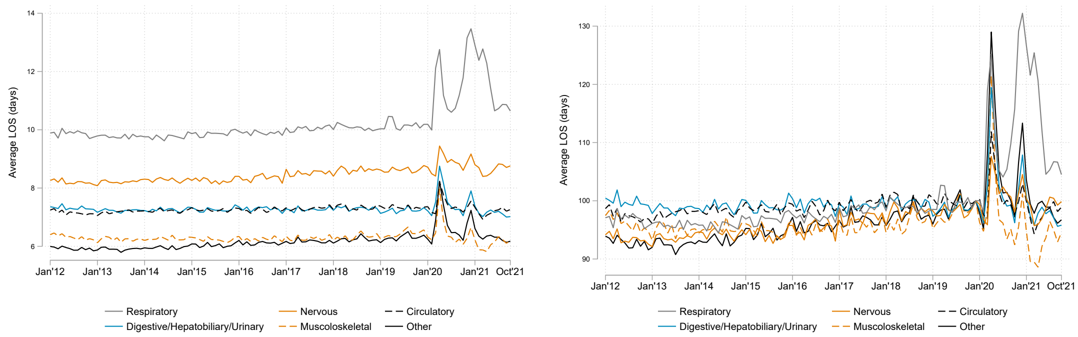
Note: The table reports the aggregate hospitalisation by MDC for years in the pre-COVID-19 period (2012-2019) and separately for years 2020 and 2021. For each time interval, the absolute number of hospitalisations and relative frequency are reported. Moreover, MDCs are aggregated into different groups and for each aggregation and time interval, the absolute number of hospitalisations and relative frequency are reported as well. The total number of observation constitute the universe of hospital discharge considered for the analysis. Source: our elaborations on MoH data.

Table A.2: Average hospital LOS (days)

		(a) Actual LOS		(b) Count. LOS	
	n obs.	Mean	SD	Mean	SD
Pre-COVID-19 period, 2012-2019					
Non-respiratory adm.	38,892,788	6.76	7.93	6.75	4.54
Respiratory adm.	4,395,646	9.78	8.51		
1^{st} *COVID-19 wave, March-May '20*					
Non-respiratory adm.	629,838	7.60	9.17	8.08	4.97
Respiratory adm.	173,924	11.95	10.91		
2^{nd} *COVID-19 wave, Oct.'20-Jan.'21*					
Non-respiratory adm.	1,080,094	7.08	8.36	7.55	4.89
Respiratory adm.	272,351	12.71	10.57		
Overall COVID-19 period					
Non-respiratory adm.	6,238,479	6.93	7.90	7.47	4.83
Respiratory adm.	1,067,212	11.65	9.78		
Overall sample, Jan. 2012-October 2021					
Total admissions	50,594,125	7.15	8.09		

Note: The table reports in columns (a) the average and SD hospital LOS for respiratory and non-respiratory admissions for the Pre-COVID-19 period and COVID waves and in columns (b) the *counterfactual* average and SD hospital LOS for respiratory and non-respiratory admissions from the neural network procedure. The counterfactual values can be interpreted as the expected LOS conditional on patient characteristics and LOS in the pre-COVID-19 period, from January 2012 to January 2020. The *first COVID-19 wave* covers the months from March to May 2020, while the *second COVID-19 wave* runs from October 2020 to January 2021. The *overall COVID-19 period* started in February 2020. Source: our elaborations on MoH data.

Figure A.1: Average LOS in hospital by month of admission and MDC



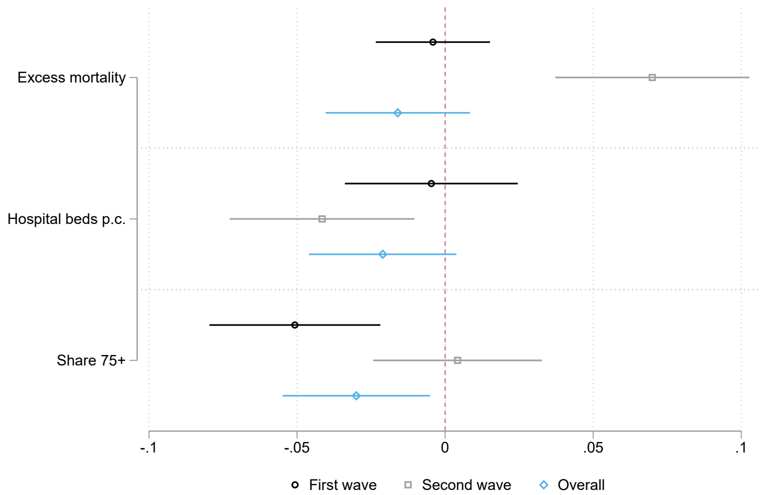
Note: Average LOS in Italian hospitals from January 2012 to October 2021 (left) and relative (2019=100) average LOS in Italian hospitals from January 2012 to October 2021. *Respiratory* includes MDC-4 (diagnosis and diseases of the respiratory system). *Nervous* represents MDC-1 (diagnosis and diseases of the nervous system). *Circulatory* covers MDC-5 (diagnosis and diseases of the circulatory system), while *Muscoloskeletal* refers to MDC-8 (diagnosis and diseases of the musculoskeletal system and connective tissue). The *Digestive/Hepatobiliary/Urinary* category includes MDC-6 (diagnosis and diseases of the digestive system), MDC-7 (diagnosis and diseases of hepatobiliary system and pancreas) and MDC-11 (diagnosis and diseases of kidney and urinary tract). All remaining categories are included in *Other*. Source: our elaborations on MoH data.

Table A.3: Province-level descriptive statistics

	n	Mean	SD	Min	Max
Population (th., '19)	103	576.56	622.29	83.47	4234.35
Share 75+ (%)	103	12.38	1.69	7.92	16.34
Hospital beds per 1'000 residents ('19)	103	2.45	0.52	1.13	3.61
Population and hospital excess mortality, COVID-19 period					
Hospital excess mortality, respiratory	103	1.18	0.70	-0.19	3.60
Population excess mortality	103	2.69	1.15	0.64	6.74
COVID-19 deaths outside hospital (%)	103	56.74	19.60	-38.82	111.37

Note: Descriptive statistics at the provincial level for demand and supply factors of healthcare utilisations and for in-hospital and in-population excess mortality during the overall COVID-19 period, i.e. after February 2020. Due to several administrative changes in the sample period and the impossibility of reconstructing some of the population variables in a consistent way over time, we treated the provinces of Sardinia as a unique unit of observation. In the table we include the resident population and the share of over-75, the number of hospital beds for acute care at the end of 2019 and, in the lower panel, the estimated excess mortality for respiratory admission in hospitals and in the general population and the estimated share of excess deaths that occurred outside the hospital. Hospital and population excess mortality indices are defined as the differences between hospitals and population mortality rates for 1,000 residents during the COVID period and their pre-COVID (2017-2019) averages. Source: our elaborations on MoH data.

Figure A.2: Predictors of out-of-hospital deaths, coefficient plot



Note: Estimated coefficients alongside 90% confidence intervals (CIs) from ordinary least squares (OLS) regression. See Table A.9 for details.

Table A.4: Deaths per 1,000 residents, 2019 = 1

	2016	2017	2018	2019	2020		
					Jan	Feb	Mar
Italy (mean)	0.977	1.028	0.995	1.000	0.933	0.979	**1.379**
Italy (sd)	0.019	0.025	0.020		0.057	0.051	0.482
Group 1: Lombardy alone							
Lombardy	0.948	0.994	0.992	1.000	0.907	0.996	**3.088**
Pop. (th.)	*9,875*	*9,889*	*9,908*	*9,936*	*9,955*		
Group 2: High excess deaths in March 2020							
Emilia-Rom.	0.985	1.012	0.990	1.000	0.924	0.988	**1.799**
P.A. Bolzano	0.964	0.994	0.998	1.000	0.972	1.104	**1.735**
V. d'Aosta	0.969	1.001	0.981	1.000	0.894	0.987	**1.665**
P.A. Trento	0.996	1.044	1.044	1.000	0.822	1.069	**1.657**
Liguria	0.984	1.046	1.037	1.000	0.858	0.907	**1.646**
Piedmont	0.963	1.016	1.009	1.000	0.833	0.950	**1.602**
Marche	0.998	1.055	0.983	1.000	0.961	0.968	**1.517**
Pop. (th.)	*13,001*	*12,986*	*12,964*	*12,951*	*12,929*		
Group 3: low excess deaths in March 2020							
Veneto	0.978	1.010	1.002	1.000	0.983	0.976	**1.249**
Abruzzo	1.007	1.068	1.007	1.000	0.972	1.041	**1.180**
F. V. Giulia	1.002	1.033	1.016	1.000	1.039	0.970	**1.156**
Tuscany	0.976	1.022	0.989	1.000	0.933	0.951	**1.155**
Puglia	0.957	1.030	0.988	1.000	0.982	0.995	**1.151**
Umbria	1.005	1.045	0.977	1.000	0.937	0.963	**1.113**
Pop. (th.)	*15,958*	*15,916*	*15,871*	*15,836*	*15,790*		
Group 4: no excess deaths in March 2020							
Sardinia	0.949	0.993	0.975	1.000	0.991	0.970	**1.086**
Molise	0.998	1.076	1.010	1.000	0.902	0.904	**1.066**
Lazio	0.985	1.043	0.994	1.000	0.944	0.948	**1.052**
Campania	0.987	1.041	0.992	1.000	0.981	0.993	**1.040**
Calabria	0.961	1.034	0.977	1.000	0.954	0.936	**1.034**
Sicily	0.953	1.040	0.983	1.000	0.954	0.912	**1.010**
Basilicata	0.960	0.997	0.960	1.000	0.850	1.031	**0.953**
Pop. (th.)	*20,847*	*20,805*	*20,738*	*20,663*	*20,552*		

Note: Deaths per 1,000 residents with respect to 2019, which is set equal to 1. Source: our elaboration on ISTAT data.

Table A.5: Cumulative COVID-19 effect

		Observed n^*	Expected $\bar{n}$	Difference $n^* - \bar{n}$	% change $100\frac{n^*-\bar{n}}{\bar{n}}$
Admissions (th.)	Overall	7,305.7	9,063.4	-1,757.7	-19.0
	Respiratory	1,067.2	956.5	110.7	10.2
	Non resp.	6,238.5	8,106.9	-1,868.4	-22.6
Adm., non deaths (th.)	Overall	6,913.4	8,720.0	-1,806.7	-20.3
	Respiratory	891.5	853.8	37.7	3.4
	Non resp.	6,021.8	7,866.2	-1,844.4	-23.0
Adm., deaths (th.)	Overall	392.3	343.4	49.0	13.5
	Respiratory	175.7	102.6	73.0	67.0
	Non resp.	216.6	240.7	-24.1	-9.7
Hosp. days (mil.)	Overall	55.7	64.9	-9.2	-14.0
	Respiratory	12.4	9.5	2.9	28.2
	Non resp.	43.2	55.4	-12.2	-21.6
Deaths in pop. (th.)	Overall	1,273.2	1,115.7	157.5	14.0

Note: We report the cumulative effects of the pandemic during the entire COVID-19 period on variables pertaining to hospital access, i.e., admissions, aggregate number of days spent in hospital and deaths in the population. For each variable, we report cumulative observed values (n^*) and their counterfactual based on the 2017-2019 monthly-specific averages ($\bar{n}$), alongside absolute ($n^* - \bar{n}$) and relative ($100\frac{n^*-\bar{n}}{\bar{n}}$) differences. The differences can be interpreted as relative or absolute deviations from the historical mean. Admissions are divided into admissions that ended with or without patients' death and are detailed for patients with a *respiratory* diagnosis, i.e., those admitted with MDC-4 (diagnosis and diseases of the respiratory system), and for patients with *non-respiratory* admissions, which cover admissions from all remaining categories. The *overall COVID-19 period* started in February 2020. Source: our elaboration on ISTAT and MoH data.

Table A.6: Cumulative COVID-19 effect, March-May 2020

		Observed n^*	Expected $\bar{n}$	Difference $n^* - \bar{n}$	% change $100\frac{n^*-\bar{n}}{\bar{n}}$
Admissions (th.)	Overall	803.8	1,372.9	-569.2	-41.7
	Respiratory	173.9	145.7	28.2	16.7
	Non resp.	629.8	1,227.2	-597.4	-48.9
Adm., non deaths (th.)	Overall	740.3	1,323.5	-583.2	-44.3
	Respiratory	139.1	130.9	8.1	4.1
	Non resp.	601.3	1,192.6	-591.3	-49.9
Adm., deaths (th.)	Overall	63.4	49.4	14.0	26.8
	Respiratory	34.8	14.8	20.1	127.6
	Non resp.	28.6	34.6	-6.1	-17.4
Hosp. days (mil.)	Overall	6.9	9.7	-2.9	-29.7
	Respiratory	2.1	1.5	0.6	39.0
	Non resp.	4.8	8.3	-3.5	-42.4
Deaths in pop. (th.)	Overall	211.8	160.5	51.3	31.1

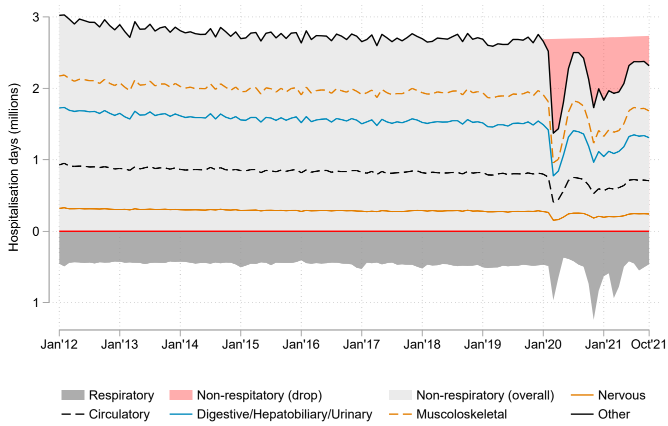
Note: We report the cumulative effects of the pandemic during the entire COVID-19 period on variables pertaining to hospital access, i.e., admissions, aggregate number of days spent in hospital and deaths in the population. For each variable, we report cumulative observed values (n^*) and their counterfactual based on the 2017-2019 monthly-specific averages ($\bar{n}$), alongside absolute ($n^* - \bar{n}$) and relative ($100\frac{n^*-\bar{n}}{\bar{n}}$) differences. The differences can be interpreted as relative or absolute deviations from the historical mean. Admissions are divided into admissions that ended with or without patients' death and are detailed for patients with a *respiratory* diagnosis, i.e., those admitted with MDC-4 (diagnosis and diseases of the respiratory system), and for patients with *non-respiratory* admissions, which cover admissions from all remaining categories. The *first COVID-19 wave* includes months from March to May 2020. Source: our elaboration on ISTAT and MoH data.

Table A.7: Cumulative COVID-19 effect, October 2020-January 2021

		Observed n^*	Expected $\bar{n}$	Difference $n^* - \bar{n}$	% change $100\frac{n^*-\bar{n}}{\bar{n}}$
Admissions (th.)	Overall	1,352.4	1,767.9	-415.5	-23.6
	Respiratory	272.4	203.1	69.2	38.4
	Non resp.	1,080.1	1,564.8	-484.7	-31.2
Adm., non deaths (th.)	Overall	1,253.6	1,695.1	-441.5	-26.2
	Respiratory	217.1	180.7	36.4	23.9
	Non resp.	1,036.5	1,514.4	-477.9	-31.8
Adm., deaths (th.)	Overall	98.9	72.8	26.1	38.1
	Respiratory	55.2	22.4	32.8	157.7
	Non resp.	43.6	50.4	-6.8	-13.0
Hosp. days (mil.)	Overall	11.1	12.8	-1.7	-13.1
	Respiratory	3.5	2.0	1.4	76.6
	Non resp.	7.6	10.8	-3.1	-29.1
Deaths in pop. (th.)	Overall	287.8	232.2	55.6	25.5

Note: We report the cumulative effects of the pandemic during the entire COVID-19 period on variables pertaining to hospital access, i.e., admissions, aggregate number of days spent in hospital and deaths in the population. For each variable, we report cumulative observed values (n^*) and their counterfactual based on the 2017-2019 monthly-specific averages ($\bar{n}$), alongside absolute ($n^* - \bar{n}$) and relative ($100\frac{n^*-\bar{n}}{\bar{n}}$) differences. The differences can be interpreted as relative or absolute deviations from the historical mean. Admissions are divided into admissions that ended with or without patients' death and are detailed for patients with a *respiratory* diagnosis, i.e., those admitted with MDC-4 (diagnosis and diseases of the respiratory system), and for patients with *non-respiratory* admissions, which cover admissions from all remaining categories. The *second COVID-19 wave* runs from October 2020 to January 2021. Source: our elaboration on ISTAT and MoH data.

Figure A.3: Aggregate hospitalisation days by MDC



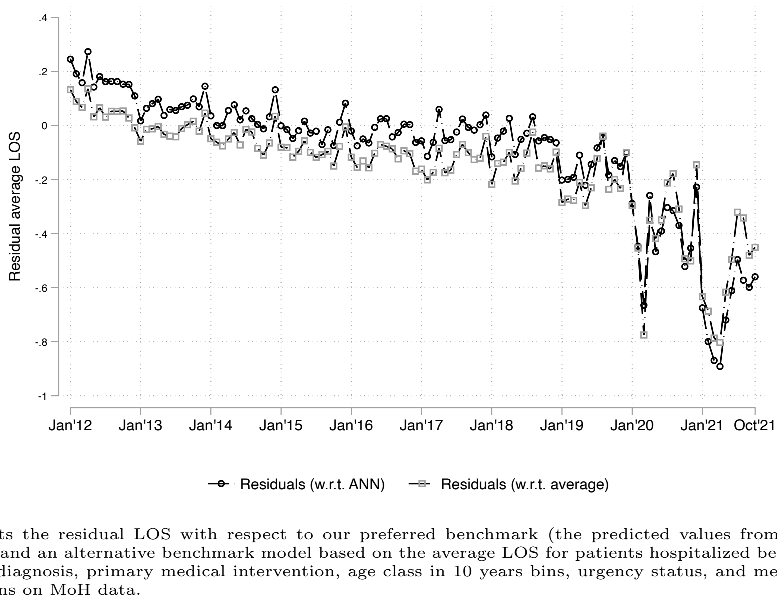
Note: Aggregate series of total hospitalisation days from January 2012 to October 2021 by MDC. *Respiratory* admissions include MDC-4 (diagnosis and diseases of the respiratory system). *Nervous* represents MDC-1 (diagnosis and diseases of the nervous system) admissions. *Circulatory* covers MDC-5 admissions (diagnosis and diseases of the circulatory system), while *Muscoloskeletal* refers to MDC-8 (diagnosis and diseases of the musculoskeletal system and connective tissue) admissions. The *Digestive/Hepatobiliary/Urinary* category includes admissions with MDC-6 (diagnosis and diseases of the digestive system), MDC-7 (diagnosis and diseases of hepatobiliary system and pancreas) and MDC-11 (diagnosis and diseases of kidney and urinary tract). All remaining categories are included in *Other*. Source: our elaborations on MoH data.

Table A.8: Average volume of admissions for urgent and planned hospitalisations

		Pre-COVID-19 period	1^{st} COVID-19 wave	2^{nd} COVID-19 wave	COVID-19 period
Panel A: Planned hospitalisations, monthly average (thousands)					
Overall	n	211.798	77.716	136.808	154.676
	(sd)	(16.807)	(18.266)	(20.053)	(37.862)
Respiratory	n	7.894	5.628	7.249	6.176
	(sd)	(0.933)	(1.295)	(1.235)	(0.95)
Non-respiratory	n	203.904	72.088	129.559	148.500
	(sd)	(15.905)	(18.819)	(20.678)	(37.975)
Panel B: Urgent hospitalisations, monthly average (thousands)					
Overall	n	248.244	175.998	200.005	200.087
	(sd)	(10.322)	(11.381)	(15.214)	(17.984)
Respiratory	n	38.459	49.074	59.743	45.279
	(sd)	(2.333)	(22.281)	(18.898)	(14.236)
Non-respiratory	n	209.785	126.925	140.261	154.808
	(sd)	(11.377)	(19.131)	(10.704)	(20.768)

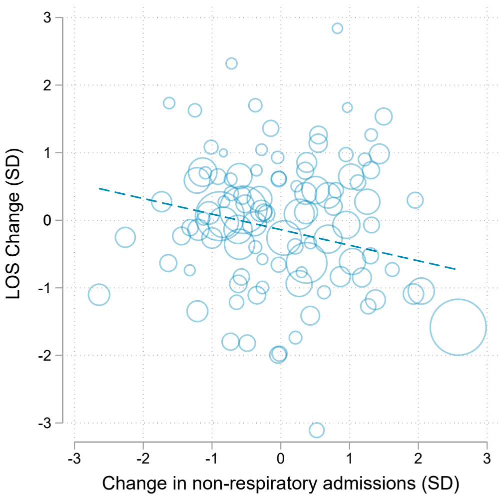
Note: We calculate the average number of admissions for hospitalisations that followed a planned or urgent hospitalisation, with the latter almost exclusively coming from emergency rooms. Admissions are detailed for patients with a *respiratory* diagnosis, i.e., those admitted with MDC-4 (diagnosis and diseases of the respiratory system), and for patients with *non-respiratory* admissions, which cover admissions from all remaining categories. The *first COVID-19 wave* covers the months from March to May 2020, while the *second COVID-19 wave* runs from October 2020 to January 2021. The *overall COVID-19 period* started in February 2020. Source: our elaborations on MoH data.

Figure A.4: Residual LOS, alternative benchmark



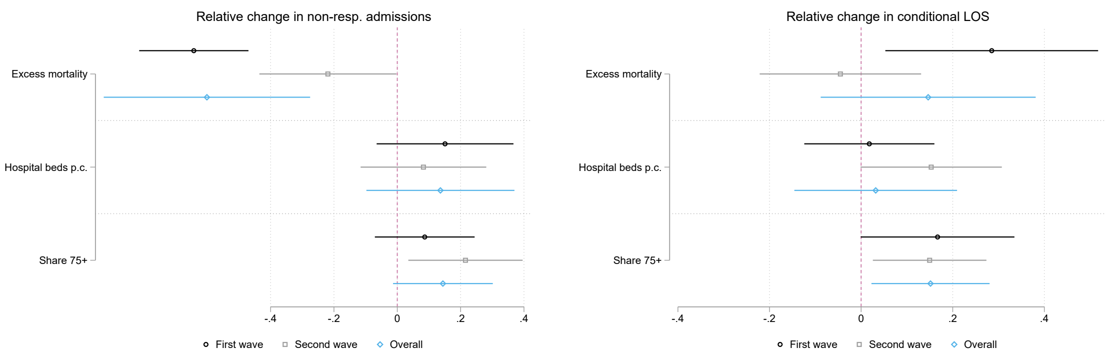
Note: The Figure plots the residual LOS with respect to our preferred benchmark (the predicted values from the artificial neural network model, ANN) and an alternative benchmark model based on the average LOS for patients hospitalized before 2019 in the same month with the same diagnosis, primary medical intervention, age class in 10 years bins, urgency status, and medical/surgical status. Source: our elaborations on MoH data.

Figure A.5: Fewer patients vs. faster discharge



Note: Provincial change in the average LOS and change in non-respiratory admissions in the overall COVID-19 period. The provincial population dimension is represented by the bubble size. Linear regression fit is included. *Non-respiratory* admissions encompass admissions from all categories except MDC-4 (diagnosis and diseases of the respiratory system). The COVID-19 period started in February 2020. Source: our elaborations on MoH data.

Figure A.6: Fewer patients and faster discharge, coefficient plot



Note: Estimated coefficients alongside 90% CIs from OLS regression. See Table A.10 and A.11 for details.

Table A.9: Predictors of out-of-hospital deaths, regression table

	(1)	(2)	(3)
	Share of deaths in hospital		
Excess mortality	-0.004	0.070***	-0.016
	(0.012)	(0.020)	(0.015)
Hospital beds p.c.	-0.005	-0.042**	-0.021
	(0.018)	(0.019)	(0.015)
Share 75+	-0.051***	0.004	-0.030**
	(0.017)	(0.017)	(0.015)
Population density	0.010	-0.003	-0.013
	(0.011)	(0.013)	(0.009)
Observations	93	101	103
Adjusted R-squared	0.031	0.092	0.042
Period	First wave	Second wave	Overall

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The dependent variable is the share of provincial and monthly deaths that occurred outside hospitals with respect to the total number of deaths that occurred in the general population. All variables are measured in SD. Separate OLS regressions are estimated for each period considered; in particular, the *first COVID-19 wave* covers the months from March to May 2020, while the *second COVID-19 wave* runs from October 2020 to January 2021. The *overall COVID-19 period* started in February 2020. Regressions are estimated in SD with population weights and robust standard errors. Excess mortality is defined as the difference between the mortality rate for 1,000 residents during the COVID period and the mortality rate in previous years, namely from 2017 to 2019. In order to account for possible seasonality in the series of data, differences are calculated from monthly-specific averages. Coefficients are plotted in Figure A.2. Source: our calculations on ISTAT and MoH data.

Table A.10: Predictors of relative drop in admissions, regression table

	(1)	(2)	(3)
	Relative change in non-resp. admissions		
Excess mortality	-0.643***	-0.219*	-0.601***
	(0.104)	(0.130)	(0.196)
Hospital beds p.c.	0.151	0.083	0.136
	(0.130)	(0.119)	(0.141)
Share 75+	0.087	0.215*	0.144
	(0.095)	(0.109)	(0.095)
Population density	-0.065	-0.106*	-0.042
	(0.054)	(0.054)	(0.065)
Observations	103	103	103
Adjusted R-squared	0.342	0.120	0.233
Period	First wave	Second wave	Overall

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The dependent variables are the (a) relative change in the aggregate number of admissions for non-respiratory patients and (b) relative change in the conditional average LOS. All variables are measured in SD. Separate OLS regressions are estimated for each period considered; in particular, the *first COVID-19 wave* covers the months from March to May 2020, while the *second COVID-19 wave* runs from October 2020 to January 2021. The *overall COVID-19 period* started in February 2020. *Non-respiratory* admissions encompass admissions from all categories except MDC-4 (diagnosis and diseases of the respiratory system). All regressions also include population density among the covariates. Regressions are estimated in SD with population weights and robust standard errors. Coefficients are plotted in Figure A.6. Source: our elaboration on ISTAT and MoH data.

Table A.11: Predictors of reduced LOS, regression table

	(1)	(2)	(3)
	Relative change in conditional LOS		
Excess mortality	0.285**	-0.045	0.146
	(0.140)	(0.106)	(0.141)
Hospital beds p.c.	0.018	0.153	0.032
	(0.086)	(0.093)	(0.107)
Share 75+	0.167	0.150**	0.151*
	(0.101)	(0.075)	(0.078)
Population density	0.106***	0.111***	0.065
	(0.039)	(0.037)	(0.049)
Observations	103	103	103
Adjusted R-squared	0.179	0.057	0.048
Period	First wave	Second wave	Overall

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The dependent variables are the (a) relative change in the aggregate number of admissions for non-respiratory patients and (b) relative change in the conditional average LOS. All variables are measured in SD. Separate OLS regressions are estimated for each period considered; in particular, the *first COVID-19 wave* covers the months from March to May 2020, while the *second COVID-19 wave* runs from October 2020 to January 2021. The *overall COVID-19 period* started in February 2020. *Non-respiratory* admissions encompass admissions from all categories except MDC-4 (diagnosis and diseases of the respiratory system). All regressions also include population density among the covariates. Regressions are estimated in SD with population weights and robust standard errors. Coefficients are plotted in Figure A.6. Source: our elaboration on ISTAT and MoH data.