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Lockdown, Essential Sectors, and Covid-19: Lessons from Italy *

Edoardo Di Porto[†] Paolo Naticchioni[‡] Vincenzo Scrutinio[§]

10th January 2022

Abstract

This paper investigates how economic activity impacted Covid-19 infections and all-cause mortality. To this purpose, we exploit the distribution of essential sectors, which were exempted from a national lockdown enacted in Italy during the first wave of the pandemic, across provinces and rich administrative data in a difference-in-differences framework. We find that a standard deviation increase in essential workers per built square kilometre leads to 1.1 additional daily cases and 0.32 additional daily deaths per 100,000 inhabitants. Back of the envelope calculations suggest that about one third (47,000) of the Covid-19 cases and about 13% (13,000) of deaths between March and May of 2020 can be attributed to the less stringent lockdown for these sectors. The effect is heterogeneous across sectors. Finally, we find that the local health system played a relevant role in reducing fatalities with a higher number of general practitioners and hospital beds per capita being associated with a lower mortality.

Keywords: Covid-19, lockdown, essential sectors
JEL classifcation: J18, I18

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[†]CSEF, INPS, University of Naples Federico II
[‡]INPS, University of Roma Tre, IZA
[§]University of Bologna, CEP, IZA

1 Introduction

Governments relied on a wide range of non-pharmaceutical interventions (NPIs) to slow down the pace of infections during the Covid-19 epidemic. Social distancing, lockdown, and a temporary stop to some economic activities have long been among the most common policy tools to confront infectious diseases (Cipolla, 1981; Hatchett et al., 2007), and they still play an important role. France (Martinier et al., 2020), Italy (Bertacche et al., 2020), Spain (Marcos, 2020), India (The Economic Times, 2020), many US states (Taryn, 2020), and numerous other countries allowed only a limited set of essential sectors to keep operating during the pandemic. These were sectors deemed necessary to sustain citizens' livelihoods and to produce and deliver necessary goods to navigate the pandemic (e.g. grocery shops, manufacturing plants building medical equipment, and banks).

Large scale lockdowns, however, entail costs including lost revenues for firms, lower productivity, and higher unemployment (Auray and Eyquem, 2020; Kong and Prinz, 2020). This prompted a heated debate among entrepreneurs, legislators, and the epidemiological expert community (Wong, 2020), with some countries refraining from introducing strict nationwide measures. In order to determine whether the costs of large scale lockdowns are worth it, governments need to know how economic activity increases infection rates and mortality. In this article, we contribute to this debate by focusing on the health costs, in terms of higher contagion rates and mortality, from allowing certain economic activities to continue during a nationwide lockdown.

The assessment of the causal impact of the effect of economic activity on infection rates and mortality has so far received limited attention in empirical studies. In this work, we contribute to this line of research by estimating the impact of the exemption of essential sectors from Italy's national lockdown on reported infections and all-causes of death mortality. To do so, we exploit the distribution of these sectors, detailed in the DPCM (Prime Minister Decree) of the 22$^{\text{nd}}$ March 2020, at the province level (NUTS3 — according to European Regional Classification) on the local dynamic of the pandemic in a difference-in-differences strategy. The distribution of essential economic activity *prior* to the onset of the epidemic is arguably exogenous to the current dynamic of infections, and

it, hence, offers an ideal identification framework. Our main measure of interest is the density of essential workers, measured as the number of workers in essential sectors per built square kilometre at the province level, which accounts for both their local number and geographic concentration.

We find that a higher density of essential workers causes more local infections, with 100 essential workers per built square kilometre leading to 0.255 additional daily cases and 0.073 additional deaths per 100,000 inhabitants. A standard deviation change in the density of essential sectors (441 workers per built square kilometre) leads to a 19% increase in daily cases with respect to an average of 5.95 per 100,000 inhabitants after the policy implementation, and to a 7.72% increase in daily mortality with respect to an average value of 4.17 deaths per 100,000 inhabitants. These are sizeable effects. Results are heterogeneous across geographic areas, with a smaller impact in areas marginally touched by the pandemic (the South of the country), and across sectors with services — "Finance, Professional Services and Commerce"[1] — having a much stronger impact on infections and deaths. Our estimates are robust to a wide range of identification and robustness checks.

Back-of-the-envelope calculations suggest that about one third (47,000) of all registered Covid-19 cases and about 10% of overall mortality (13,000 deaths) during the first Covid-19 wave in Italy (03/22/2020—05/03/2020) could be attributed to the less stringent lockdown for these workers. This had a limited direct impact on the National Health System (NHS) budget (128 to 159 millions Euro or about 0.15% of the annual budget). Our estimate, however, does not consider several margins (e.g. follow up of patients after hospital discharge) and it should be considered a lower bound.

Finally, we find that the characteristics of the local health system (General Practitioner (GPs) and bed availability) played a role in mitigating the impact of the epidemic on mortality. Both the capacity to detect early more severe cases and availability of beds to accommodate people requiring additional assistance were important in reducing mortality.

This work contributes to a growing literature assessing the impact of policy measures to face the Covid-19 pandemic. Several studies exploit theoretical models to assess the impact

[1]This sector includes: Financial and Insurance activities; Wholesale and Retail Trade; Professional, Scientific and Technical Activities.

of lockdown measures on the spread of the virus and on the economy. Ferguson et al. (2020) focus on the role of different NPIs to curb infections, while Acemoglu et al. (2020) and Greenstone and Nigam (2020) assess the characteristics of an optimal lockdown and its monetary gains. Clark et al. (2020), instead, develop a cost-benefit well-being approach which could allow a more efficient timing of the lockdown. Other works empirically investigate the role of public policies to contain the epidemic. In their seminal work, Hatchett et al. (2007) provide evidence on the role of public policies in containing the Spanish flu epidemic in the US. Early work on China by Fang et al. (2020) show that mobility restrictions limited the spread of the disease to other areas. Hsiang et al. (2020), instead, provide a cross-country (China, South Korea, Iran, Italy, France, and the United States) analysis of Covid-19 policies and show that interventions substantially reduced the daily growth rate of infections and prevented or delayed about 61 million confirmed cases in the early period of the pandemic. Several articles investigated the effects of Shelter-in-Place policies in the US (Friedson et al., 2020; Dave et al., 2020a,b, 2021), and they found that these interventions reduce the infection and mortality rate. In a recent contribution on essential sectors, Song et al. (2021) find that being employed in an essential sector raises the risk of infection of the workers as well as of their cohabiting individuals and family members.

Our work provides several contributions to the existing literature. First, although a number of studies assess the effects of Shelter-in-Place policies, which often encompass closure of non-essential sectors, no study, to our knowledge, has so far specifically isolated the impact on infections and mortality of lower constraints on economic activity. Because budget and welfare concerns make it difficult to limit economic activity, understanding how to intervene less on the economy while preserving public health is crucial. Our study provides novel evidence to address this policy question in a clear causal framework with rich administrative data. Second, our estimates concern one of the developed countries most affected by the Covid-19 pandemic. Italy shares many similarities with other developed countries in terms of demographics, economic structure, and institutions. This makes our results applicable to a wide range of settings and improves the external validity of our findings and their policy relevance. Third, while some evidence on non-pharmaceutical

interventions is available for the US, much less is available for Europe, although many countries imposed such policies during the pandemic. Fourth, we provide some tentative evidence on the role of local health sector structure in preventing additional deaths.

The rest of the paper is structured as follows: Section 2 describes the data; Section 3 describes the institutional setting and reports our empirical strategy; Section 4 presents our main results; Section 5 reports our robustness checks, and, Section 6 concludes.

2 Data

This study is based on rich administrative data from the Italian Civil Protection and INPS (Italian Social Security Institute).

We consider two main outcome variables: the number of newly reported COVID infections, and the number of total deaths. First, we obtain the number of Covid-19 cases for the 106 Italian provinces from the Civil Protection website. This includes daily information on new infections at the provincial level, along with related deaths, hospitalized patients, and tests at regional the level (NUTS 2).[2] The last information is particularly salient since it allows to capture possible increases in positive cases due to a higher frequency of tests rather than infections. We use data from the 24$^{\text{th}}$ of February, when the data collection on Covid-19 cases started, until the 4$^{\text{th}}$ of May 2020, when most restrictions on local mobility were lifted.[3]

Our main analysis is based on new daily cases of Covid-19 for 100,000 inhabitants, which accounts for the different population across provinces, and it is a classical measure of incidence in the epidemiological literature. Reported cases are most likely an underestimation of the actual number of infections as, in many cases, the disease led only to minor symptoms or was entirely asymptomatic. In addition, testing capacity and precision was lower at the beginning of the pandemic. The number of reported infections should, however, reasonably capture the most severe cases, which are a relevant outcome from a public health perspective. As lockdown policies influence mortality also through other channels,

[2]There are 20 regions in Italy which we group in three macro areas: North, Centre and South.

[3]Since we groups days by three in a part of the analysis, we drop the 4$^{\text{th}}$ of May to keep groups uniform in size. This is immaterial for our results.

e.g. traffic fatalities (Oguzoglu 2020), focusing on infections rather than mortality provides a more direct assessment of this policy on the pandemic.

Mortality is, however, a crucial outcome from a welfare standpoint and so we extend the analysis to assess the impact of essential sectors on this important dimension.[4] We obtain daily data on deaths for the 7,900 municipalities in Italy between 2015 and end of May 2020 from social security records, together with some demographics such as gender and age of the deceased. Unfortunately no information is available on the cause of death. For homogeneity with epidemiological data, we aggregate data at the province level.

Finally, we combine this information with rich administrative data on the universe of private non-agricultural employees from the INPS archives. More specifically, we rely on UNIEMENS mandatory forms, which firms submit monthly for the computation of the social security contributions for their employees. The data contain information on workers' characteristics, together with some firm characteristics, such as sector, and the municipality where the work takes place. We use data from 2019 as a proxy for the sectoral distribution at the beginning of 2020. Using data from before the pandemic allows us to have a causal interpretation of our parameter of interest. A measure considering the number of workers who were employed during the pandemic would be endogenous to the pandemic dynamic: some firms, for example, might suspend their activity due to a lack of clients.

We obtain the number of workers in essential sectors, and then normalize it by the built square kilometres in the province, which is drawn from the Global Human Settlement Layer of the European Commission (Corbane et al. 2018). This provides us with a measure of density of the essential economic activity.

Table 1 reports summary statistics for our main variables of analysis. Both our main dependent variables show substantial variability, and they are strongly right skewed. This highlights the strong time and geographic variability of the phenomenon under study. The pandemic had a clear geographic dimension with a very strong impact in

[4]Information on Covid-19 related deaths were not made available at the province level, so it is not possible for us to investigate this more direct outcome of the pandemic. At the same time, overall mortality is more likely to capture additional margins and hence it allows form a more comprehensive assessment.

some northern regions. The density of workers in essential sectors also shows marked differences across provinces, and it ranges between 200 and 2300 workers per built square kilometre. On average, there are about 700 essential workers per built square kilometre per province.[5] Among private sectors employees, the share working in essential sectors goes from a minimum of 29% up to 60%. On average about 50% of employees work in sectors considered essential. Figure 1 gives a graphical representation of the geographic distribution of the density of essential workers and, for the sake of comparison, of the population density. Figure 1a plots the density of essential workers across Italian provinces. This is generally higher in the northern part of Italy, but several southern regions show levels comparable to those in the North. Figure 1b reports the population density at the start of 2020 (hundreds of inhabitants per built square kilometre). Although there is a strong correlation between these two measures, there are enough differences to isolate the effect of essential workers' density.

In addition, we also report summary statistics for other variables at the province level, as well as their correlation with the density of essential workers. Figures are reported in Table B2 and in Table B3 in the Appendix. The density of essential workers is related to several characteristics of the regional health system (level of expenditure and general practitioners per thousand of inhabitants), demographics (population density, % population below 12 years of age), and economic indicators (local employment and unemployment rate). In most cases, however, the correlation is small with the exception of the population density per built Km2. This could be problematic for our identification strategy if these variable were to determine differential trends across areas for our outcome variables. In order to investigate this issue, we run a number of robustness checks in Section 5.

3 Institutional Framework and Methods

The increase in Covid-19 diffusion during February and early March 2020 led the Italian government to implement strict policies to slow the pace of infections. Initially, the

[5]This number might appear large but two considerations are in order: first, although the surface of a province is sizeable, the built surface is actually a small share of it (in the case of Rome, for example, the province encompasses an area of about 5,360 square km but only 746 square km are actually with buildings); second, a relatively large share of the economy was considered essential.

government acted on a few selected regions, with mild restrictions on gatherings and some restrictions on schools, museums, public offices, sport and cultural events. Very rigid rules were introduced in only a few municipalities (the so called red zones), where the first cluster of cases appeared. Following the rapid increase in infections, the government enacted more stringent restrictions nationwide, which were introduced with a decree of the Prime Minister (DPCM) on the 9th of March. This introduced restrictions for non-work related mobility, and suspended sport, cultural events, and in-person schooling. In addition, shops that could not guarantee a minimum distance between employees were required to close, and restaurants could be open only between 8.00 am and 6.00 pm. Although these measures were rather severe, most of the economy was still active and faced few limitations.

Restrictions became drastically stricter after the 22nd of March 2020 (d.l. n. 6/2020)[6] when the national lockdown was implemented. The law imposed an immediate suspension of all commercial and industrial activities, except for "essential" sectors. These were the economic activities which were considered essential to sustain citizens and support the economy during the pandemic (see Table B1 in the Appendix for the full sector list). Firms in other sectors could remain active only with remote work, or if they received a special authorization for specific reasons and ensured that employees would respect regulations on social distancing. In addition, the government imposed strong limitations on personal mobility, and individuals could move to a different municipality only for proven work or emergency reasons.

We exploit the distribution of essential sectors at the provincial level to investigate the causal effect of the continuation of economic activities on Covid-19 contagion in a standard difference-in-differences (see Goodman-Bacon and Marcus 2020): we compare changes before and after the implementation of the lockdown in the number of infected individuals and deaths in provinces with a high density of essential workers with the number of infections and deaths in provinces with a low density of essential workers. This allows us to identify the causal effect of essential sectors under the assumption that the number of new cases would have shown a similar trend across provinces, if no sectors had been

[6]d.l. stands for Law decree and it is a temporary normative intervention by the government originally developed for emergencies requiring quick legislative responses.

exempted from the lockdown ("parallel trends" assumption). In practice, we estimate the equation:

$$\Delta Y_{jt} = \alpha + \beta post03/22_t X Ess.perKm2_j + \sum_{h=1}^{p} \delta_h EpTrend_{jt}^h + \theta_t + \eta_j + \varepsilon_{jt}, \qquad (1)$$

where the dependent variable is the number of new individuals with a positive Covid-19 test per 100,000 inhabitants in province j on day t, $post03/22_t$ is a dummy that takes the value 1 after the 22nd of March 2020 and 0 in the days before, and $Ess.perKm2_j$ captures the density of workers in essential sectors, in terms of hundred workers per built square kilometre. The β coefficient is our parameter of interest: it represents how many daily additional new cases per 100,000 inhabitants a province experienced for an additional one hundred workers in essential sectors per built square km. We also include a fourth order polynomial trend ($EpTrend^p$), day (θ_t), and province (η_j) fixed effects, which account for any time constant differences across provinces. The trend starts from the first day after a Covid-19 infection is detected in the province to account for the local dynamic of the epidemic. We cluster standard errors at the province level, and weight observation by the population of the province at the start of 2020 to obtain nationally representative estimates.

Our policy setting provides several advantages in terms of identification. First, the policy was implemented nationwide, so it is not correlated in either timing or intensity with our main variable of interest (i.e. the density of essential workers before the pandemic).

Second, the policy introduction was sudden, and this left local authorities and businesses no room to adjust pre-emptively to its implementation. A few measures were introduced before the 22nd of March but these were more limited: they were generally short lived and much milder with respect to the later nationwide lockdown. Moreover, we flexibly control for time specific regional differences with a set of day by region fixed effects in one of our specifications, and this does not affect our main conclusions.

A third possible issue is geographic spillovers: individuals travelling to different locations for work might spread the infection to other localities, and this might create downward

bias in our estimates if the disease spreads to areas with a lower presence of essential sectors.[7] This would be an issue for our estimates, but there are several factors that address our concerns. First, mobility strongly declined in the period of the lockdown due to severe restrictions (Bonaccorsi et al., 2020). Second, our level of geographic aggregation reduces the possibility of downward bias in our estimates. Italian workers show substantial mobility for work reasons, and about 50% of workers commuted to a different municipality for work in 2017 (based on reports from the National Statistical Institute; ISTAT 2018).[8] However, this mobility tends to be relatively local: about 20% travelled outside their province. Finally, we tackle this issue in two additional ways: by accounting for the presence of essential sectors in neighbouring provinces; and by performing our analysis on mortality at Local Labour Market level to account for workers' mobility patterns. In both cases, the results remain close to our main estimates.

4 Results

4.1 Essential Sectors and the Covid-19 Epidemic

4.1.1 Main Effects

The different exposure to essential industries had an important impact on the local number of detected Covid-19 cases and total deaths per 100,000 inhabitants. We report the estimates for our main equation (Equation 1) in Table 2. Panel A reports the effect of the density of essential workers on the number of daily detected Covid-19 infections per 100,000 inhabitants, while Panel B reports the effect on the number of deaths per 100,000 inhabitants.

We start from the number of infections. An additional one hundred workers per square kilometre leads to about 0.40 new cases per 100,000 inhabitants per day. The coefficient is only mildly affected by the introduction of population density and local age structure of

[7] In this framework, we expect workers to commute to locations with a higher density of essential sectors, and then move back to locations with lower density. This would determine a number of cases higher than the one predicted from the local density of workers in essential sectors.

[8] Unfortunately, we do not have mobility data by sector and so it is not possible to compute this statistic for workers emplyed in essentila sectors.

the population in Column (2), and it declines to about 0.255 once we include province- and day fixed effects (Column 3). This will be our preferred specification throughout the rest of the paper. It remains relatively stable thereafter. To provide a better assessment, we can look at what would happen with a standard deviation change in the density of essential workers (about 441 essential workers per built square kilometre): this would imply about 1.1 additional cases per day per 100,000 inhabitants, which corresponds to about 19% of the average number of daily cases in the period after the policy implementation (5.95 per 100,000 inhabitants per day). Column (4) includes regional controls for the number of tests, daily Covid-19 deaths, and dismissed patients to better account for the pandemic dynamic and to ensure that more testing is not driving higher reported cases. The main coefficient is barely affected. Column (5) includes daily fixed effects interacted with 20 regional fixed effects, and hence it only exploits within region variability across provinces in the density of essential workers for the estimates. This is relevant since, although the Health system is national, regions play an important role in managing local health services. These fixed effects allow us to account for any additional regional policies at the daily level. Our main coefficient remains always close to our main specification and highly statistically significant.

In Column (6), we decompose the effect by macro area. Since the northern part of the country was hit by the pandemic more severely and earlier, and it shows stronger economic indicators, this appears an important dimension of heterogeneity. The effect of essential sectors was similar across areas with a possibly smaller impact in the South (difference is not precisely estimated). This might hint at the fact that keeping essential sectors open in areas where the epidemic was very mild could have had limited detrimental effects, but this is not conclusive evidence. Finally, Column (7) considers the state of the epidemic and focuses on the peak of infections. Indeed, the effect on further infections might depend on the probability that workers meet a person already infected. To investigate this possible interaction, we consider the week around the time of the maximum number of new cases per province (which we define as the peak of the epidemic; the dummy "peak" will be one for the days from three days before the peak and three days after). We then add the triple interaction between our difference-in-differences term ($post03/22_t XEss.perKm2_j$) and the

dummy *peak* together with all double interactions. Results show that looser restrictions lead to more infections in this period, suggesting that the density of economic activity becomes even important when daily infections are high.

We further explore this issue in two additional ways: first, by looking at the state of the pandemic at the start of the lockdown (in practice we compute quartiles of new cases on the 23rd March 2020 and identify provinces in the top quartile of the distribution); second, by checking how the trend varied in relation to time and to the density of essential workers (by including interactions between the density and our polynomial trend for the pandemic and then predicting the number of new cases).[9] We report our results in Table B4, which also contains variations in how we define the state of the epidemic at the start of the lockdown, and in Figure C2 in the Appendix. Several coefficients and the polynomials suggest that the cost of a higher density of essential sector workers is higher when the contagion is already underway. However, our results are not very precise and should be interpreted with caution.

We assess how the density of essential sectors affected overall mortality in Panel B of Table 2. We find a positive effect of the density of essential sectors on the number of deaths per 100,000 inhabitants. The coefficient shows that an additional 100 essential workers lead to 0.115 additional deaths per 100,000 inhabitants per day per province. It remains remarkably stable across the different specifications. In our preferred specification, reported in Column (3), an additional one hundred workers lead to 0.073 additional deaths per 100,000 inhabitants. This is equivalent to a 1.8% increase with respect to the average mortality rate across provinces. One standard deviation change in our measure of essential sector density leads to a 7.7% increase in mortality with respect to the average for the period (0.322 additional deaths over 4.17 deaths per day). Column (6) shows that there was strong regional heterogeneity with no effect of essential sector in the South. Finally, Column (7) indicates that the effect on mortality might have been larger when the epidemic was already at a more advanced stage. In this case, however, estimates are very imprecise and additional evidence is needed.[10]

[9] We predict the trend by assuming a standard deviation change in the density of essential workers, with a baseline value set to zero: the prediction also includes the treatment effect (interaction between the density and the post dummy).

[10] Additional estimates based on different ways to assess the local state of the pandemic, reported in

We further extend our analysis of mortality by assessing the effect of a higher density of essential workers on different demographic groups. It is, unfortunately, not possible to replicate a similar investigation for Covid-19 cases since detailed data on demographics for people who got infected with the disease were not released. We estimate our preferred specification (Column 3 of Table 2) on the number of total daily deaths by province per 100,000 inhabitants by group, and Table 3 report our results. The effect is heterogeneous across age groups: the largest effect is registered among people who are 80 years of age or above (Column 2); a smaller effect can be found for those between 60 and 79 years of age (Column 3); and no effect is detected for those below 60 years of age (Column 4). This is in line with mortality statistics from the National Health System, which reported a median age of deaths due to Covid-19 around 80 years of age (Istituto Superiore Sanità, 2021). Only small differences can be detected between males and females, with female mortality being slightly more affected (Column 5 and Column 6).

4.1.2 Parallel Trends

We now provide evidence concerning the parallel trends assumption of our estimation strategy. If this was not satisfied, our parameter would not be able to isolate the causal effect of the density of essential sector workers. Although it is not possible to directly test what would have happened to different areas if essential sectors had not been excluded from the lockdown, we can provide supporting evidence by looking at the dynamic of our variables of interest before the policy implementation.[11] We estimate the following variation of Equation 1:

$$\Delta Y_{it} = \alpha + \sum_{h=v}^{m} \beta_h \mathbb{1}(date = h) XEss.perKm2_j + \\ + \sum_{h=1}^{p} \delta_h EpTrend_{jt}^{h} + \theta_t + \eta_j + \varepsilon_{jt}, \tag{2}$$

where $I(date = h)$ is a dummy variable taking the value one at date h and zero otherwise. The set of coefficients β_h provides a test for our parallel trends assumption, as well as

Table B4 and in Figure C2, are not precise and do not provide clear evidence.

[11] We provide additional evidence in a placebo test using data on mortality for previous years in Section 5.1.

information concerning the dynamic of the effect. If the coefficients for the period before the lockdown are close to zero, then provinces were not on different trends before the lockdown based on the density of workers in essential sectors. This would make it more plausible to assume that provinces would have remained on parallel trends without the selective shutdown of economic activities. Then, coefficients for the period after the 22$^{\text{nd}}$ of March describe how the difference in the outcome evolves over time based on the exposure to higher density of essential workers. To gain stability in the coefficients and improve efficiency, we group dates in three day periods, and we use the period between the 5$^{\text{th}}$ of March and the 7$^{\text{th}}$ of March as a reference period.

We start by looking at new Covid-19 cases. We report coefficients for the interaction terms in Figure 2 (Panel a) with their 95% confidence intervals. The results are reassuring. On the one hand, coefficients for the period before the 22$^{\text{nd}}$ of March are small and not statistically significant. This supports our identification assumption. On the other hand, coefficients for periods after the 22$^{\text{nd}}$ are consistently larger than zero and highly statistically significant after about 10 days from the start of the lockdown. This lag in the effect is in line with the medical literature, which shows an incubation period of up to 12 days before the onset of the symptoms (5 days median, see Lauer et al. 2020), and an additional 4/5 days for the symptoms to worsen (Chen et al. 2020). Results for mortality, reported in Panel (b), are consistent with the pattern for reported cases, and they do not show any pre-trend in deaths per 100,000 inhabitants.

4.2 Heterogeneous Effects by Sector

This aggregate effect of the density of economic activity hides substantial heterogeneity. Workers have different levels of interactions with colleagues and clients, possibilities for social distancing, and work tasks depending on their sector of activity. To assess sector heterogeneity in the treatment effect, we decompose our main difference-in-differences variable into several terms that describe the density of workers in each sector at the local level and run a regression allowing for heterogeneous effects. We restrict our attention to essential sectors, so workers in "Manufacturing" represent workers who were employed in essential subsectors in "Manufacturing".

We group sectors according to their NACE Rev. 2 classification.[12] To ease interpretation, we compute the effect of a standard deviation change in the density of workers in each sector and plot the resulting estimates with their 95% confidence intervals in Figure 3.[13] Panel (a) reports the effect on number of Covid-19 cases, while Panel (b) reports the effect on mortality. The figure points at a strong heterogeneity: while manufacturing workers seem to have no impact on contagion, other sectors such as Finance, Prof. Services and Commerce, and Health and Social Work played a more relevant role. A standard deviation change in "Finance, Prof. Services and Commerce" leads to about 4 additional daily cases per 100,000 inhabitants, and 1.5 additional deaths.[14] A formal test for the equality of the effect for all sectors strongly rejects the null hypothesis for both new infections and deaths (we report p-values at the bottom of the graphs).

The more direct interaction with both co-workers and clients could explain this difference with respect to other sectors. Note that, since the number of workers in the health sector is computed prior to the onset of the epidemic, it does not reflect possibly higher hiring as a consequence of the pandemic. It is, however, also possible that the effect of the health sector is related to the proximity of sick patients, and more susceptible individuals in hospitals and nursery homes. Hence, it is difficult to draw policy conclusions, but this is a minor concern since the share of the Health sectors is small and this sector is difficult to downsize during the epidemic. Similar concerns, to a different extent, could be related to part of the workers employed in "Finance, Prof. Services and Commerce". Some activities, such as food retail commerce, are necessary for social order, especially in such extreme circumstances, so policymakers will have less scope to stop them. Hence, other interventions (e.g. stricter controls or access rationing) could be more appropriate.

[12] For the relative contribution of each sector to the overall density see Figure C1 in the Appendix.

[13] For the raw coefficients see Figure C3 in the Appendix.

[14] "Finance, Prof. Services and Commerce" collects three different sectors: Financial and Insurance activities; Wholesale and Retail Trade; Professional, Scientific and Technical Activities. The three sectors contribute about one third each to the aggregate category. The most relevant effect is the one of Professional Services with 6 additional cases per standard deviation, followed by commerce (2 cases) and Finance (-1.9 cases). A similar pattern is present for mortality with 2 additional deaths per standard deviation for Professional Services, 0.5 for Commerce, -0.8 Finance. We report graphs with the additional level of decomposition in Figure C4 in the Appendix.

4.3 Back-of-the-Envelope Calculation: the Implications of Exemption of Essential Workers from the National Lockdown

4.3.1 The Impact of Essential Workers on Infections and Deaths.

Based on the available evidence, we provide a back-of-the-envelope calculation of the contribution of essential sectors to the pandemic in Italy.[15] We use our measure of essential workers' density, and the estimate for the effect on infections from Column (3) of Table 2. We multiply the coefficient of the interaction term by the density of essential workers by province for the period after the 22nd of March, and by the population in the province (in 100,000). We then add up all these daily contributions for the period 03/22/2020—05/03/2020 and for all provinces. Cases related to essential sectors appear to represent a relevant share of Covid-19 registered cases in Italy in the first wave, about 30% (47,000 over 150,000). The continuation of economic activity had a non-trivial impact on the development of the contagion.

Similarly, we use the same procedure to compute the contribution of essential sectors to overall mortality and we find that allowing these sectors to remain open led to an additional 13,000 deaths, about 13% of the overall mortality (105,013 total deaths between 03/22/2020 and 05/03/2020).[16] This is a substantial contribution which highlights the substantial trade-off policy makers face in their lockdown decision. Note that this effect conflates all causes of deaths, and several elements (e.g. crowding out of other medical services) could have all contributed to our figure. As we lack data on causes of death, we leave this promising line of research to further studies.

[15] As our measure of interest does not take values below 2.28, our measure does not allow us to have an estimate of the effect of essential sectors for lower densities. In order to perform our exercise we make a linearity assumption to extend the application of our coefficient to the low part of the distribution. However, the effect of the density for very low levels could be smaller than the average effect: with a low density, the probability that an individual gets infected by coming into contact with an essential worker is low. In this perspective, these estimates could be considered an upper bound.

[16] Note that mortality from Covid was severely underestimated during the early stage of the pandemic. Later estimates for excess mortality for the first wave go up to 50,000 excess deaths (Scortichini et al., 2020; Dorrucci et al., 2021; Modi et al., 2021), with highest levels reached in March/April 2020.

4.3.2 The Cost of Reducing Mortality.

These estimates can be informative about the trade-off policy makers face while considering restrictions on different sectors to reduce mortality. This is crucial information from a policy perspective. We start by looking at Column (1) in Table 3. We target a reduction in daily national mortality of one unit, which implies an average reduction in the mortality rate of 0.0016 deaths per 100,000 inhabitants. Then, we compute by how much the number of essential workers should decline in order to have such a reduction. In order to achieve this target, a decline of about 38,870 workers in essential sectors nationwide would be needed.[17] This number is much larger than the back-of-the-envelope calculations by Friedson et al. (2020), who estimated about 400 job *losses* per additional life saved. This cost, however, refers to a decline in overall deaths over their whole 31 day period, while our computations target a decline in mortality per day. A similar reduction with their estimate would entail about 12,400 job losses. In addition, our computation considers workers subject to lockdown rather than job loss, and, since not all workers under lockdown would be laid off, our estimate provides an upper bound for job separations.

Better targeting could make this trade-off drastically more efficient: much of the negative effect of economic activity is concentrated in only a few sectors. If we consider the main sector according to estimates in Figure C3 (Finance, Prof. Services and Commerce), the cost in terms of workers subject to lockdown would be reduced to 1,850 essential workers.

4.3.3 The Impact of Essential Sector Induced Infections on Health Sector Expenditures.

Finally, we quantify the economic costs of these additional cases in terms of health expenditure in the first wave of the pandemic. This requires a number of assumptions on hospitalization and the costs of treatment during hospital stay. Estimates for hospital admission of Covid-19 patients during the first wave go from as high as 40% (Giorgi Rossi et al., 2020; Carrillo-Vega et al., 2020) to 3% (Salje et al., 2020), with many estimates around 20% (Reilev et al., 2020; Team et al., 2020; Nakamichi et al., 2021). Fatality estimates present a similar uncertainty, from 0.5% in France (Salje et al., 2020) to 21% in

[17] We report details of the computation in Appendix A.1.

NY (Bonanad et al., 2020). For consistency with our period of analysis, we refer to rates computed for the first wave of the pandemic, when both hospitalization and fatality rates were likely overestimated due to a strong underestimation of cases. A few studies reported hospitalization and fatality rates in Italy: during the first wave, the hospitalization rate was 30%—40% (Giorgi Rossi et al., 2020; Mugnai and Bilato, 2020) and mortality ranged from 7% (Onder et al., 2020) to 13% (Barone-Adesi et al., 2020). Throughout this section, we assume a constant hospitalization rate of 30% and a mortality rate of 13%. Both are in line with aggregate statistics for the period of the first Covid-19 wave (February—May 2020) in Italy, which showed a 32% hospitalization rate (Cicchetti et al., 2020), and 13% fatality rate (Ministero della Salute, 2020).

Then, we need to impute costs for hospitalization. We refer to a classification of treatments and their shares for Covid-19 patients admitted to hospitals based on the outcome of the hospitalization reported by Cicchetti and Di Bidino (2020), who provided a provisional description of hospitalizations and costs nationwide, and Pellegrini (2020), who detailed Diagnostic Related Groups (DRG) classifications and costs for patients treated in one Italian province until November 2020 (Alto Adige).[18] We compute the average cost per patient based on these shares and then compute the total cost for the national health system. We assume that all patients who die were previously hospitalized, that the distribution of DRG is constant across provinces and over time and that the treatment of patients is uniform nationwide. Further, we assume zero expenditures for Covid-19 positive individuals who were not hospitalized.

Based on reported DRG, the overall hospitalization cost for the average Covid-19 patient ranges from 8,475 (Cicchetti and Di Bidino, 2020) to 11,219 Euro (Pellegrini, 2020). Given the contribution in terms of additional Covid-19 cases and our hospitalization (and mortality) rate, we get a total cost for the National Health System ranging from 128 to 159 million of Euros, which seems relatively contained with respect to the overall Health sector budget (about 114.4 billion euros in 2019). The computation of this effect on expenditure depends on the choice of the estimated costs. If we use data from Cicchetti and Di Bidino (2020), we multiply the number of additional cases with the share of hospitalized

[18] We report their figures in Table B5 in the Appendix

individuals and with the average costs for hospitalized but not deceased patients. Then, we add the additional expenditures deriving from patients who died. We assume a 30% hospitalization rate and we experiment with two fatality rates derived from the literature (7.5%—13%). If, instead, we use data from Pellegrini (2020), we simply multiply the the number of extra COVID-19 cases with the share of hospitalized individuals and with the average cost. We do not consider any costs arising from the period before hospitalization or after the hospital discharge due to lack of data. A useful exercise is also to compare these additional costs with the expenditure of the National Health System only for the 42 days in which Italy was under lockdown, this expenditure would represent only about 1.2% of the total expenditure by the Health sector.[19] In face of these estimates, the choice to keep the "essential sectors" in the economy active during the pandemic seems to come at a relatively low economic cost for the Health sector.

As the present calculation does not consider several additional margins, such as delayed services to other patients (which might generate onset of more severe conditions later), management of long term effect of Covid-19 (Fraser, 2020; Yelin et al., 2020; Del Rio et al., 2020; Mahase, 2020; Carfì et al., 2020; Shah et al., 2021) and their possible impact on job careers, and extra investment in personnel and infrastructure, it should be considered a lower bound.

5 Robustness Checks

We perform a series of robustness checks for the validity of our research design and the stability of our estimates. We start by performing a placebo test based on mortality in the years before the pandemic. Then we consider different specifications for our model both in terms of confounders and alternative definitions of our main variables. Finally, we explore the role of the local health system in the pandemic and check to what extent this interacted with the national lockdown.

[19]This percentage is obtained by dividing the upper bound of our estimated costs by the the total expenditure (114.4 billion euros) divided by 365 (to get daily average expenditure for the NHS) and multiplied by 42 (number of days we consider). Unfortunately, since data on monthly health sector expenditure are not available, it is not possible to further refine this computation.

5.1 Placebo: Essential Sectors and Mortality before 2020

A remaining worry is that this dynamic in mortality reflects different seasonal local patterns, and our results would then be conflating both the effect of the essential sectors and the ordinary behaviour of mortality rates. To explore this possibility, we perform a placebo test with mortality data from 2019, and estimate the same model described above by defining the post period as the dates between 22nd of March 2019 and the 3rd of May 2019. The coefficients, reported in Figure 4, are in line with our expectations. The effects are small, and far from being statistically significant. This further corroborates our interpretation of the results.

5.2 Confounders and Main Variable Definitions.

We further validate our estimates by performing a battery of robustness checks, and report the results in Table 4. We report our baseline result, Column (3) of Table 2, in Column (1) for the sake of comparison. As a first step, we assess whether weekends, which can be peculiar days for the detection of cases, play a role in our estimates. We report results by excluding these days in Column (2). Our main coefficient is barely affected. We also assess the influence of single provinces on our estimates, since some of them experienced extreme outcomes and might be driving our results. We run our main regression model (Column 3 of Table 2) and exclude one province at a time. We then report our difference-in-differences coefficient for each of these estimates in Figure C5 together with their 95% confidence intervals and the baseline estimate (red line). Our results are very robust and the exclusion of single provinces does not affect them substantially.

Then, we assess whether the observed pattern could be explained by other factors, possibly related to the density of essential sectors in the province. We include several characteristics of the province together with interactions with the post 22nd period. If the observed pattern in the data is related to other trends in observable characteristics of the province, then we would expect that the additional difference-in-differences terms should at least partly absorb the effect of the density of workers in essential sectors. We include population density per built square kilometre, share of individuals in the province above the age of

65, share of children below 12, the average age of individuals in the province, employment and unemployment rates, level of family income and the share of income coming from government transfers in Column (3). Our main effect is stable, although less statistically significant. Our results are also consistent if we include interactions between these characteristics or dummies for terciles in the distribution of controls with date dummies in a more flexible specification.[20] We also include more flexible trend polynomials by interacting our fourth order polynomial with regional dummies. We report results in Column (4) and the coefficient is remarkably stable.

Then we move to variations in the definitions of our variables of interest. We start by excluding the health sector, that might be mechanically related to new cases, from essential sectors in Column (5). Our results are almost unchanged. We experiment with an additional measure of the presence of essential workers by normalizing for the area of the province and population in Columns (6) and (7). While results for workers in essential sectors per km2 show a lower impact on infections for a standard deviation change in this measure (0.51 vs 1.1), estimates based on the number of essential workers per inhabitant are in line with our main result, with a standard deviation change leading to about one additional case. The different effect of the density of essential workers based on the area of the province could be explained by the fact that the two measures show relevant differences with a correlation close to 0.4. Since we are interested in the geographical concentration of workers, the number of workers per built square kilometre appears to be the most sensible choice.

We exclude population weights in Column (8), which leads to negligible variations in our estimates, and we explicitly consider possible geographic spillovers. Since mobility of infected workers to different provinces could generate downward bias, we assess whether the density of essential workers in neighbouring provinces affected the local dynamic of the epidemic. We compute the weighted average of the density of essential workers in bordering provinces (weighted by the size of the workforce in those provinces), and we include this variable together with its interaction with the post dummy in our equation. This does not seem to affect our main result, and the additional interaction term, reported

[20]Estimates are reported in Table B6, Column (1) and Column (2) in the Appendix.

together with the main one in Column (9), is not statistically different from zero. This is in line with our expectation of lower geographic mobility for work related reasons during the lockdown.

Finally, we consider possible measures that might have affected the density of essential workers. We use the density of essential workers based on the number of workers in essential sectors in 2019 to exclude possible changes in the density of the essential workers determined by the dynamic of the pandemic. However, it is possible that our proxy works poorly later in the sample period due to the widespread use of the Short-Time Work Scheme (*Cassa Integrazione*, STW throughout the rest of the paper). This policy was particularly salient in this period since firms faced substantial limitations to firing as a consequence of a legislative intervention early in the pandemic which prohibited firms from laying off workers for economic or organization reasons.[21] Indeed, the unemployment rate declined from 9.9 to 9.1 and the activity rate experienced only a minor deterioration between 2019 and 2020 in Italy for individuals between 20 and 64 years of age according to preliminary Eurostat data.[22] STW was extended to basically all firms in the Italian economy and to all types of workers, and it was widely used to reduce costs in the most severe period of the recession caused by the lockdown. Due to lower economic activity, which could have been even more severe in the presence of higher contagion rates, firms in essential sectors could face lower demand and in turn increase their use of STW. This would lead to a decline in the precision of our proxy correlated with our measure of interest. Exploiting INPS archives, we obtain monthly firm level information on the use of STW by firms in essential sectors and aggregate them at the province level. Then, we compute the average number of hours per day and per worker and include them in our regression, together with an interaction term for the period after the implementation of a nationwide lockdown. Note that the number of hours of STW is endogenous to the local dynamic of the pandemic, and it is difficult to give a causal interpretation to parameters associated with this variable. Including these additional terms leaves our coefficient of interest almost unchanged, while the coefficient on the use of STW is positive (and significant at 10%), in line with the assumption that STW use was more prominent in areas where the epidemic

[21] art. 46 of the d.l. 17th March 2020, n. 18.
[22] Accessed on the 10/25/2021

was more severe. The interaction term is large and negative but imprecise. This makes it difficult to say whether the relationship between STW use and the pandemic dynamic changed during the lockdown. The stability of our result to the inclusion of this important additional variable provides supportive evidence about the robustness of our results.

The same set of robustness checks for mortality is reported in Table B7 in the Appendix. Results are in line with main estimates and we do not elaborate on them but for two further extensions: in the first, we look at excess mortality; in the second, we explore the possible effects of geographic mobility by performing the analysis at the Local Labour Market level.

We start by computing daily excess mortality, i.e. mortality in deviation with respect to the average mortality in the same province and in the same calendar day in the five years before the pandemic. This allows to further control for possible confounding trends in mortality over the year and across provinces. The results based on this measure, reported in Column (10), are similar to estimates from our main specification. Then we move to Local Labour Markets. They are geographic units (about 680), periodically defined by the National Statistical Office (ISTAT), which identifies areas in which workers mostly commute for work reasons. Hence, they allow us to minimize the risk of workers moving across provinces. We compute mortality per 100,000 inhabitants and the share of essential workers in the population at this level and replicate our main analysis. The coefficient of interest, reported in Column (13), is similar to one in Column (8), that uses the share of essential workers in the population in our preferred specification. This again supports our main findings and reduces the likelihood that mobility generates bias in the estimates.

Finally, we estimate a lagged dependent variable model, which shows that part of the effect of essential sectors come from shifting the contagion and mortality curve rather than from the contemporaneous effect of the presence of essential sectors (the lagged dependent variable absorbs part of the effect of the density of essential sectors). This is particularly relevant for mortality. In all cases, however, the effect of the density of essential sectors is still present and statistically significant, albeit smaller in magnitude. We report the results and additional discussion in section A.2 of the Appendix.

Overall, these results provide supporting evidence about the reliability of the causal interpretation of our estimates, and about the stability of our findings.

5.3 The Role of the Health Sector

As a last check, we look at possible interaction with regional health systems. Regions have substantial autonomy in the management of the local health system, and the resulting heterogeneity (e.g. in 2019, the Autonome province of Bolzano, in the North-East of the country, spent 2434.13 Euros per inhabitant on its health system while Campania, in the South, spent 1808.79 Euros per capita) in services might be related with the economic structure of the area and interact with the epidemic. We perform this analysis in two ways: first, we assess whether the observed effect of the essential sectors is related to features of the health system; second, we consider how past Covid-19 infections affect later overall mortality and investigate whether different health investments and strategies influence this relationship. To account for possible interactions between essential sectors and the local health system, we consider several elements as the number of general practitioners per thousand inhabitants, the number of hospital beds per ten thousand inhabitants, and the number of resuscitator anaesthetist per thousand inhabitants.[23] These data, extracted from the National Statistical Institute website, are only available at the regional level so we assign to each province the value for the region. All data were collected in 2019 except beds per capita, which were collected in 2018 (last available information). We normalize our variables so that the coefficient represents the impact of a standard deviation change in the variable of interest.

We report results in Table 5. Columns (1) and (2) basically extend the set of robustness checks in Table 4, and include interactions between the post dummy and the density of essential sectors together with the interaction of the post dummy and our health variables. This analysis provides two findings. First, our main coefficients, representing the effect of essential sectors on new Covid-19 cases (Column 1) and on mortality (Column 2), barely changes in this augmented equation with respect to the baseline (Column 3 of Table 2)

[23]We exclude expenditure per capita as it determines some of the other dimensions, and its inclusion could make it difficult to identify their main effects. If present, it absorbs part of the effect of hospital beds and Anesthetists.

and hence local health system characteristics do not seem to be relevant confounders. Second, the interaction terms between health system variables and our post dummy are usually far from being statistically significant. The only exception is beds per ten thousand inhabitants, for which the coefficient is positive, large, and highly significant. Hence, most of these variables do not seem to have played a different role during the lockdown.

Finally, we provide suggestive evidence on how local health resources directly influenced the number of deaths with respect to past infections. The pandemic put local health services under severe stress and the availability of additional resources might have played an important role in preventing fatalities. To assess the relevance of these elements, we check how cumulative cases of Covid-19 affected mortality depending on the characteristics of the local health system. We compute the cumulative number of Covid-19 cases in the previous twelve days and look at how they affect current mortality. Then we interact this variable with the characteristics of the local health system. Results, reported in Column (3), show that more Covid-19 infections increased local levels of mortality, but health resources dampened this effect. More GPs and beds per capita reduced the impact of Covid-19 infections on mortality, with GPs having the largest impact, while resuscitator anesthetists seem to have played a more marginal role. The effects are sizeable: a standard deviation increase in the number of GPs per thousand inhabitants (0.11) could reduce the impact of cumulative infections on mortality by about 44%, while a standard deviation increase in beds (34.6) could reduce the impact of mortality by 34%.[24]

These results suggest that the availability of medical personnel and facilities was a crucial factor in the first wave of the pandemic. The role of GPs appears to have been particularly relevant. Early screening and identification of severe cases before the development of critical conditions or hospitalization (see also Goyal et al. 2020 and Zhou et al. 2020) as well as bed capacity to accommodate patients in need of additional assistance seem to make the health system more resilient to such extreme shocks.

[24]If standard errors are clustered at the regional level rather than at the province level, the main coefficients remain significant at the same level (but the interaction between the density of essential workers and the post dummy, which is now significant at 5%).

6 Conclusions

This paper investigates how the exclusion of sectors deemed essential to preserve citizens' livelihood and to keep the economy operating from a nationwide lockdown impacted Covid-19 infections and overall mortality in Italy. We use rich administrative data and compare the evolution of these two outcomes across provinces exposed to different density of essential sector workers before and after the lockdown in a difference-in-differences strategy. Italy was among the countries most severely affected by the Covid-19 epidemic, and it offers an excellent case study for other advanced economies.

Our results show that a stronger presence of essential activities led to more infections and deaths: a standard deviation increase in essential workers per square kilometre leads to about 1.1 additional daily cases and 0.32 additional daily deaths per 100,000 inhabitants. Overall, the contribution of these sectors was substantial for the epidemic, and we compute that about one third of Covid-19 cases and 13% of the overall mortality from the end of March to early May in 2020 could be attributed to a less stringent lockdown for these workers. These findings are robust across a wide range of robustness checks.

We find suggestive evidence that the effect of the policy was heterogeneous across geographic areas, with smaller effects on new Covid-19 cases and mortality in areas that were mostly spared by the epidemic at the time of the policy implementation, and across sectors, with essential services to firms and individuals showing the largest impact. We compute that, in order to prevent one death per day nationwide, it would have been necessary to extend the lockdown to an additional 38,870 essential workers. However, focusing on the most relevant sector would have reduced the cost to only 1,850 workers under lockdown to achieve the same objective. We also find that the presence of GPs and higher bed availability reduced how past Covid infections impacted later mortality. This provides important guidance on where to focus action to minimize the economic costs of this policy.

Overall, our results show that allowing the economy to operate during a pandemic comes at substantial health costs. However, these costs seem to be generated by a small share of these activities, so additional interventions on them could generate relevant health benefits with a smaller impact on the economy.

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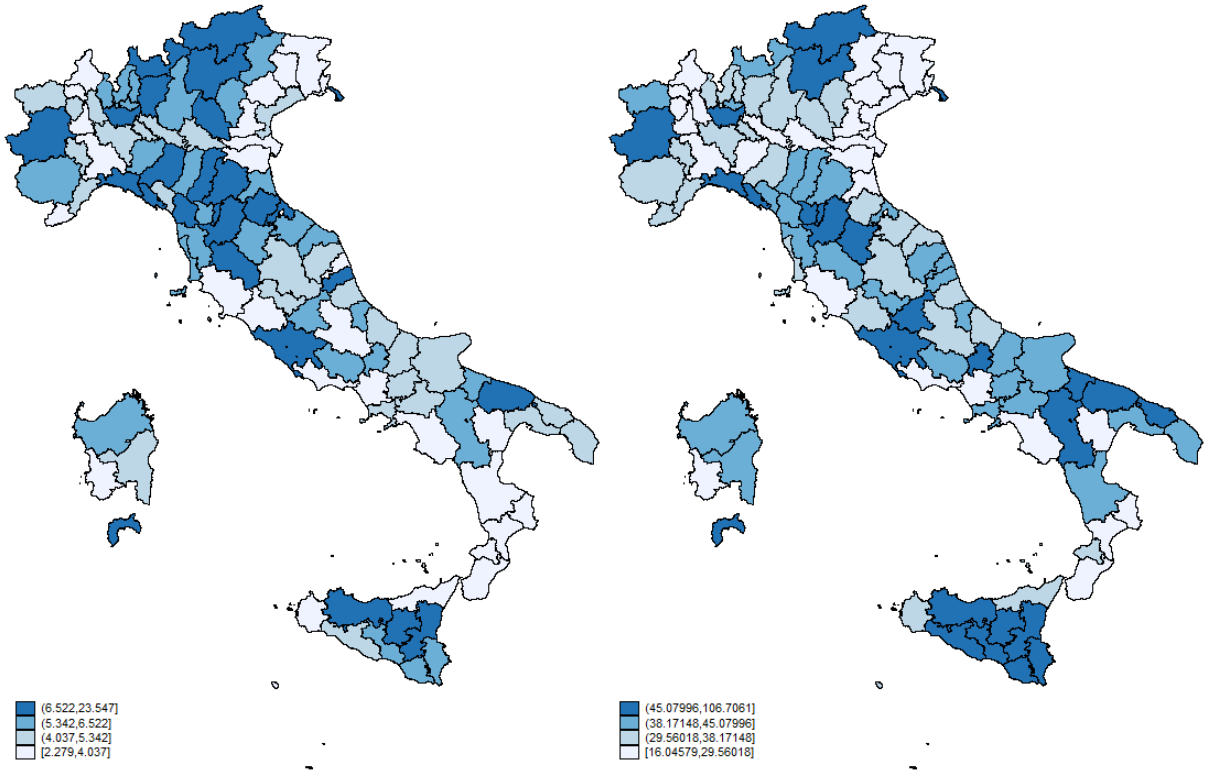
Figures

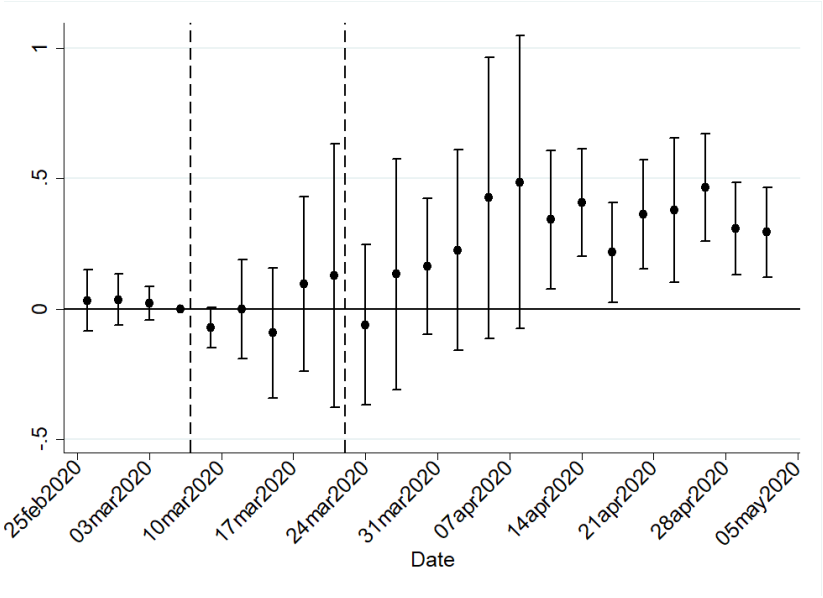
Figure 1: Density across Provinces



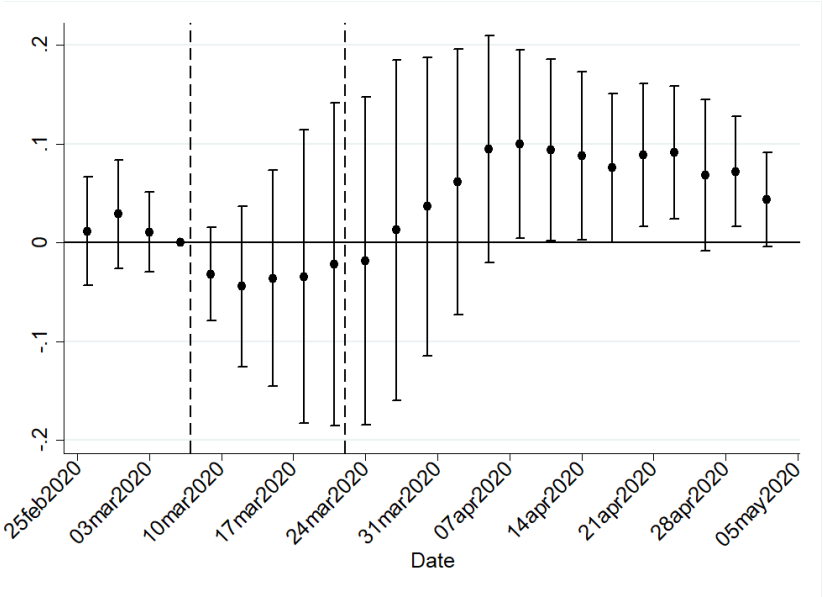
(a) Density of Essential Workers (b) Density of Population

Note: Hundreds of individuals per built square kilometre based on social security administrative and national statistics data.

Figure 2: Density of Essential Workers and its Effect over Time on Infections and Mortality



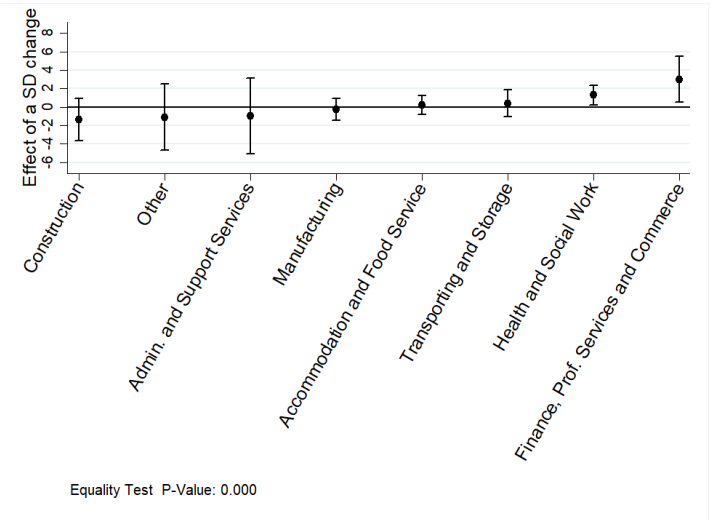
(a) Cases per 100,000 of Population



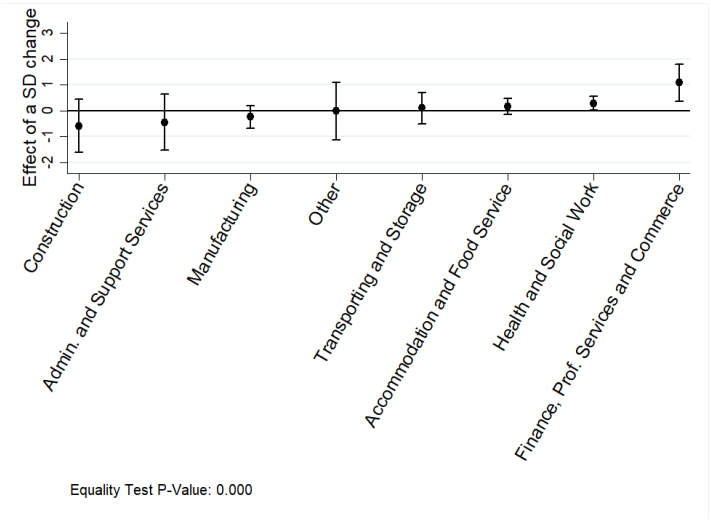
(b) Deaths per 100,000 of Population

Note: Estimates for the effect of the density of essential workers before and after the policy implementation as described in Equation 2 for 2020 on Covid-19 infections and mortality. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2019 per built square kilometre. Panel (a) reports effects for the number of reported cases for 100,000 inhabitants while Panel (b) reports the effect on number of deaths per 100,000 inhabitants. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dates collected in three days groups to improve readability. The regression includes a 4th order polynomial trend from the first registered Covid-19 case in the province, and date (three days groups) and province fixed effects. The period between 5th and the 7th of March is used as a reference period. Observations weighted by the population in the province at the start of 2020. Confidence intervals at 95% based on standard errors clustered at the province level reported.

Figure 3: Effect of Density of Essential Sectors on Covid-19 Infections and Mortality by Sector: Effect of Standard Deviation Change



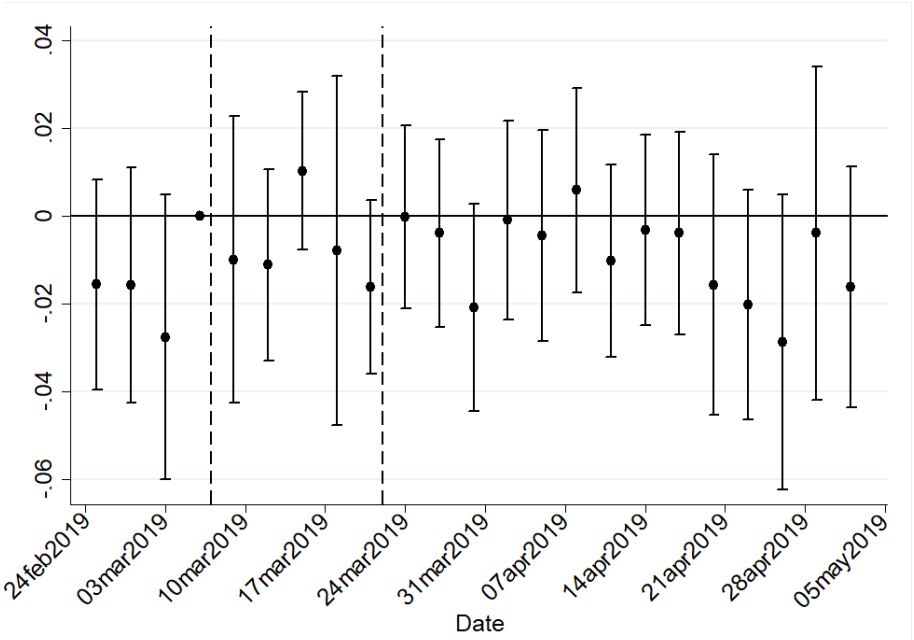
(a) Cases per 100,000 of population



(b) Deaths per 100,000 of population

Note: Estimates for the effect of density of essential workers in different sectors on Covid-19 infections and mortality. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2019 per built square kilometre. Panel (a) reports effects for the number of reported cases for 100,000 inhabitants while Panel (b) reports the effect on number of deaths per 100,000 inhabitants. Reported coefficients and standard errors computed for a standard deviation change in the density of workers in a specific sector. We report the p-value for a F-test for the equality of coefficients at the bottom of each graph. The regression includes a 4^{th} order polynomial trend from the first registered Covid-19 case in the province, and date and province fixed effects. Regression based on daily data for 106 Italian provinces between the 25^{th} of February and the 3^{rd} of May 2020. Observations weighted by the population in the province at the start of 2020. Confidence intervals at 95% based on standard errors clustered at the province level reported. Services to firms and ind. includes: Financial and Insurance activities; Wholesale and Retail Trade; Professional, Scientific and Technical Activities. Other category includes: Agriculture, Forestry and Fishing; Water Supply; Sewerage, Waste Management and Remediation Activities; Other Service Activities; Construction; Electricity, Gas, Steam and Air Conditioning Supply; Information and Communication; Education; Public Administration and Defence; Compulsory Social Security; Mining and Quarrying.

Figure 4: Effect of Density of Essential Workers on Mortality in 2019



Note: Estimates for the effect of the density of essential workers before and after the policy implementation as described in Equation 2 for 2019 on mortality. We report the effect of density of essential sector workers on number of deaths per 100,000 inhabitants. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2018 per built square kilometre. Regression based on daily data for 106 Italian provinces between the 25^{th} of February and the 3^{rd} of May 2019. Dates collected in three days groups to improve readability. The period between 5^{th} and the 7^{th} of March is used as a reference period. The regression includes a 4^{th} order polynomial trend from the first registered Covid-19 case in the province, and date (three days groups) and province fixed effects. Observations weighted by the population in the province at the start of 2019. Confidence intervals at 95% based on standard errors clustered at the province level reported.

Tables

Table 1: Summary Statistics for Main Variables

Stats	Daily change Covid-19 cases	Daily deaths	Density essential workers
Mean	5.011	4.114	7.329
Sd	7.366	2.590	4.410
Minimum	0	0	2.279
25th percentile	0.452	2.718	4.335
50th percentile	2.089	3.413	5.874
75th percentile	7.037	4.640	8.396
Maximum	95.159	30.097	23.547

Note: Summary statistics for main variables in the analysis. Both daily change in Covid-19 cases and Daily deaths by province are normalized by 100,000 inhabitants in the province on the 1st of January 2020. Density of essential workers is the number (in hundreds) of workers employed in essential sectors in 2019 per built squared kilometre. Observations weighted by the population in the province at the start of 2020.

Table 2: Effect of Density of Essential Sectors on Number of New Daily Covid-19 Cases and Deaths per 100,000 Inhabitants.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Panel A: New Cases			
Hundreds Ess. Workers per Built Km2	-0.092	0.167*					
	(0.106)	(0.096)					
Post 03/22	-6.829***	-5.569***					
	(1.803)	(1.525)					
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.402***	0.394***	0.255***	0.251***	0.288**	0.241***	0.258***
	(0.068)	(0.067)	(0.073)	(0.086)	(0.124)	(0.068)	(0.073)
Hundreds Ess. Workers per Built Km2 X Post 03/22X Centre						-0.006	
						(0.119)	
Hundreds Ess. Workers per Built Km2 X Post 03/22 X South						-0.100	
						(0.095)	
Peak New Infections							18.941***
							(5.685)
Hundreds Ess. Workers per Built Km2 X Peak New Infections X post 03/22							2.026**
							(0.976)
Peak New Infections X post 03/22							-15.116**
							(7.268)
Hundreds Ess. Workers per Built Km2 X Peak New Infections							-0.560
							(0.601)
Mean Dep.	5.95	5.95	5.95	5.95	5.95	5.95	5.95
				Panel B: Deaths			
Hundreds Ess. Workers per Built Km2	-0.041	0.016					
	(0.048)	(0.035)					
Post 03/22	-2.116**	-1.802**					
	(0.874)	(0.749)					
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.115***	0.113***	0.073***	0.058***	0.103*	0.078***	0.073***
	(0.030)	(0.029)	(0.027)	(0.019)	(0.054)	(0.027)	(0.028)
Hundreds Ess. Workers per Built Km2 X Post 03/22X Centre						-0.016	
						(0.032)	
Hundreds Ess. Workers per Built Km2 X Post 03/22 X South						-0.081**	
						(0.035)	
Peak New Infections							1.567
							(1.525)
Hundreds Ess. Workers per Built Km2 X Peak New Infections X post 03/22							0.082
							(0.128)
Peak New Infections X post 03/22							-1.559
							(1.587)
Hundreds Ess. Workers per Built Km2 X Peak New Infections							-0.066
							(0.124)
Mean Dep.	4.17	4.17	4.17	4.17	4.17	4.17	4.17
Observations	7,314	7,314	7,314	7,314	7,245	7,314	7,314
SD Essential	4.41	4.41	4.41	4.41	4.41	4.41	4.41
Ep. Trend 4th	YES	YES	YES	YES	YES	YES	YES
Controls	NO	YES	YES	YES	YES	YES	YES
Province FE	NO	NO	YES	YES	YES	YES	YES
Date FE	NO	NO	YES	YES	YES	YES	YES
Reg. Controls	NO	NO	NO	YES	NO	NO	NO
RegionXDate FE	NO	NO	NO	NO	YES	NO	NO

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new reported Covid-19 cases per 100,000 inhabitants in Panel A and number of deaths per 100,000 inhabitants in Panel B. Hundred Ess. Workers per Built km2 is the number of workers (in hundreds) in essential sector in 2019 in the province per built square kilometre. Mean dep. is the average of the dependent variable after the 22nd of March 2020. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Controls include population per built square kilometre, share of population above 65 years of age, and below 12. Population is computed based on figures at the start of 2020. Regional controls are the daily number of tests, healed and deceased patients in the region. Region and date fixed effects are interactions between daily dummies and regional dummies. Peak is a dummy taking value one if the date is within 3 days from the peak of new Covid-19 cases (maximum number of new cases registered in a day at the province level). Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

Table 3: Effect of Density of Essential Sectors Deaths per 100,000 Inhabitants by Demographic Group.

VARIABLES	(1) Deaths	(2) Above 79	(3) 60-79	(4) Below 60	(5) Male	(6) Female
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.073***	0.717**	0.080**	0.002	0.069***	0.076**
	(0.027)	(0.313)	(0.031)	(0.001)	(0.026)	(0.031)
Observations	7,314	7,314	7,314	7,314	7,314	7,314
Mean Dep.	4.17	37.35	5.19	.32	4.12	4.2
SD Essential	4.41	4.41	4.41	4.41	4.41	4.41
Ep. Trend 4th	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of deaths per 100,000 inhabitants. Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in 2019 in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. The dependent variable is the number of deaths per 100,000 inhabitants in aggregate, by age group or by gender. Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

Table 4: Effect of Partial Lockdown of Essential Sectors on Number of New Daily Covid-19 Cases: Robustness Checks

VARIABLES	(1) New Cases	(2) No Week Ends	(3) New Cases	(4) Regional Trends	(5) New Cases	(6) New Cases	(7) New Cases	(8) No Weights	(9) Bordering Provinces	(10) Hours of STW
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.255***	0.226***	0.239*	0.253**				0.246***	0.261***	0.230***
	(0.073)	(0.073)	(0.130)	(0.105)				(0.083)	(0.067)	(0.067)
Hundreds Population per built Km2 X post 03/22			-0.014							
			(0.032)							
% Above 65 X post 03/22			1.895**							
			(0.919)							
% below 12 X post 03/22			-0.499							
			(1.321)							
Average Age X post 03/22			-2.395							
			(1.911)							
Employment Rate X Post 03/22			0.326**							
			(0.126)							
Transfer Share of Income X Post 03/22			-17.013***							
			(6.407)							
Family Income X Post 03/22			-0.364*							
			(0.215)							
Unemployment Rate X Post 03/22			0.370**							
			(0.185)							
Hundreds Ess. Workers (no health) per Built Km2 X post 03/22					0.271***					
					(0.079)					
Hundreds Ess. Workers per Km2 X post 03/22						0.334				
						(0.249)				
Ess. workers per hundreds inhab. X post 03/22							0.190***			
							(0.049)			
Hundreds Ess. Workers per Built Km2 (bordering) X post 03/22									0.023	
									(0.194)	
STW Essential Workers (Hours per worker per day)										11.634*
										(6.623)
STW Essential Workers (Hours per worker per day) X Post 03/22										-6.828
										(4.646)
Observations	7,314	5,194	7,314	7,314	7,314	7,314	7,314	7,314	7,245	7,314
R-squared	0.533	0.538	0.546	0.605	0.533	0.530	0.532	0.501	0.533	0.536
Mean Dep.	5.97	5.76	5.97	5.95	5.95	5.95	5.95	5.95	5.95	5.95
SD Essential	4.41	4.41	4.41	3.41	4.13	1.54	5.6	3.41	3.41	3.41
Ep. Trend 4th	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new reported Covid-19 cases per 100,000 inhabitants. Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Regional controls are the daily number of tests, healed and deceased patients in the region. Observations weighted by inhabitants on the 1st of January 2020. Column (2) excludes Saturday and Sunday from the sample. Column (3) includes trend breaks in other province characteristics. Variables are (in parentheses the level of measurement level and the latest available issue of the data before the pandemic): Population per Km2 (province, 01/01/2020); % Population above 65 (province, 01/01/2020); % Population below 12 (province, 01/01/2020); Average Age (province, 01/01/2020); Average Family Income in thousand of Euro (region, 2018); % Transfers in family income (region, 2018); Employment Rate (province, 2019) and Unemployment rate (province, 2019). For all regional level variables the same value is assigned to all the provinces in the same region. Column (4) includes fourth order polynomial trends by region. Column (5) excludes the Health sector from the computation of essential workers per square kilometre. Column (6) reports the effect of the number of essential workers per squared kilometre. Column (7) reports a similar specification where the number of essential workers is divided by the size of the population. Column (8) reports results from the estimation of the same specification in Column (1) but without the population weights. Column (9) considers the density of essential workers in neighbouring provinces weighted by the number of essential workers in those provinces. Column (10) considers the possible confounding effect of short time work measured as hours of STW by essential worker per day. The variable is computed at monthly level. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

Table 5: Effect of Partial Lockdown of Essential Sectors on Number of Covid-19 Infections and Total Deaths: Regional health system

VARIABLES	(1) New Cases	(2) Deaths	(3) Deaths
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.236***	0.077**	
	(0.072)	(0.030)	
GP pc X Post 03/22	0.964	0.169	
	(0.659)	(0.248)	
Hospital Beds pc X Post 03/22	2.033***	0.365**	
	(0.610)	(0.143)	
Resuscitator anesthetist pc X Post 03/22	0.288	-0.045	
	(0.254)	(0.067)	
Covid cases in last 12 days			0.023***
			(0.005)
Covid cases X GP pc			-0.010***
			(0.002)
Covid cases X hospital beds pc			-0.008**
			(0.003)
Covid cases X resuscitator anesthetist pc			-0.002*
			(0.001)
Observations	7,314	7,314	7,314
Mean Dep.	4.17	4.17	4.17
Ep. Trend 4th	YES	YES	YES
Controls	YES	YES	YES
Province FE	YES	YES	YES
Date FE	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1 augmented with regional health statistics. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new diagnosis of Covid-19 for 100,000 inhabitants for Column (1) and the number of daily deaths per 100,000 inhabitants for Columns (2) and (3). Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. General Practitioner (GP) is the number of general practitioners per thousand inhabitants. Hospital beds per capital is the number of hospital beds per ten thousand of inhabitants. Resuscitator anesthetist per capita is the number of resuscitator anesthetist per thousand of inhabitants. All variables are measured in 2019 with the exception of beds per capita in Euro measured in 2018 (last available information). The data are reported at regional level and the regional value is assigned to all provinces in the region. Health system variables are normalized to have zero mean and one standard deviation. Corresponding standard deviations for the main variables are: .109 for GP per thousand of inhabitants; 34.58 for beds per 10,000 inhabitants; .023 for Resuscitator anesthetist per thousand of inhabitants. Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

A Notes and Additional Results

A.1 Back of the Envelope: Lockdown and Deaths

In order to assess how many additional workers in lockdown would be needed in order to reduce mortality, we exploit our estimates in Table 3 and estimates of essential workers by sector reported in Figure C3. The results are reported in Table B8. We report both weighted (Column 1 and 2) and unweighted regressions (Column 3 and 4). Throughout this exercise we use coefficients from the unweighted regressions, but estimates are very close, and this makes little difference in practice. We start with a reduction in mortality attained by extending the lockdown to a representative workers of the essential sector. We first compute the reduction in mortality rate which would be necessary to reduce mortality by one unit per day. As Italy had about 60,244,000 inhabitants at the start of 2020, the mortality reduction in terms of deaths per 100,000 inhabitants is 0.00166. Assuming that this is achieved by a uniform reduction in mortality for all provinces, we rescale the desired decline in daily mortality rate by the coefficient of the interaction between the dummy for the period after the 23$^{\text{rd}}$ of March and the density of essential workers (hundred per built squared kilometre, β_3 in Equation 1). Namely:

$$\Delta Density = \frac{\frac{1}{602.44}}{\beta_3}$$

Then we multiply it by the average square kilometre built per province (150.97) and by the number of provinces (106) to attain the total number of workers to whom the lockdown should be extended to reduce daily deaths by one unit. This amounts to 38,870 workers or 0.3% of the total employment in the private sector. A similar procedure is applied for the computation of the number of workers by sector. To this purpose, we use the estimates of the difference-in-differences decomposed by sector. We consider the only effect highly statistically significant beyond the Health sector, that is "Finance, Professional Services and Commerce", and replicate the computations above. The resulting estimate provides a much lower opportunity cost in terms of workers lockdown per unit death reduction,

about 1,850 extra workers.

A.2 Lagged Dependent Variable

As an additional check, we estimate a dynamic specification of our model by including the lagged dependent variable in the equation. This allows us to investigate the channel through which essential sectors impact our dimensions of interest: essential sectors affect mortality and infection both through their contemporaneous effect and by the compounded effect of the additional new Covid-19 cases and deaths they generate. By including the lagged dependent variable, the second part of the effect of essential sectors is captured by the higher number of past infections in provinces with a higher density of these sectors. In this case, our main coefficient, the one on the interaction between the density of essential workers and the post dummy, only captures the direct effects of mobility of workers and it should be lower with respect to baseline estimates.

We run two sets of lagged dependent variable estimates for both our dependent variables of interest (new cases and deaths per 100,000 inhabitants), by first excluding and then including province fixed effects. This allows us to perform a bounding exercise on the relevance of the autocorrelation of the dependent variable. It is well known from the panel econometric literature that the true value for the autocorrelation parameter lies between these two estimates (Wooldridge 2002). We report these results together with our main estimates for the sake of comparison in Table A1. Both processes show autocorrelation, and this is stronger for mortality than for new infections. Our parameter of interest becomes smaller as the effect of the lagged dependent variable becomes larger but it remains positive and highly significant in all specifications. This shows that a relevant share of the effects comes by shifting the contagion curve upward and increasing the rate of infections. This is particularly marked for mortality. It is worth noting that, even when using this dynamic specification, the treatment effect remains positive and significant, meaning that we cannot rule out the presence of a direct differential effect of the essential sectors on new infections and deaths, no matter the model specification. As the overall effect of essential sectors includes both the direct and the indirect effects, we refer to the originally estimated parameter as our policy relevant effect. In addition, as discussed in

Angrist and Pischke (2008), the lagged dependent variable specification underestimates the treatment effect if the difference-in-differences assumptions are correct.

Table A1: Effect of Density of Essential Sectors on Number of New Daily Covid-19 Cases and Deaths per 100,000 Inhabitants: Lagged Dependent Variable.

VARIABLES	(1) New Cases	(2) New Cases	(3) New Cases	(4) Deaths	(5) Deaths	(6) Deaths
Hundreds Ess. Workers per Built Km2 X Post 03/23	0.255***	0.113***	0.165***	0.073***	0.013***	0.022***
	(0.073)	(0.032)	(0.047)	(0.027)	(0.005)	(0.006)
Lagged New Cases		0.549***	0.348***			
		(0.052)	(0.060)			
Lagged Deaths					0.844***	0.725***
					(0.049)	(0.087)
Observations	7,314	7,208	7,208	7,314	7,208	7,208
Mean Dep.	5.97	5.97	5.97	4.3	4.3	4.3
SD Essential	4.41	4.41	4.41	4.41	4.41	4.41
Ep. Trend 4th	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES
Province FE	YES	NO	YES	YES	NO	YES
Date FE	YES	YES	YES	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new reported Covid-19 cases per 100,000 inhabitants in Panel A and number of deaths per 100,000 inhabitants in Panel B. Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in 2019 in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Controls include population per built square kilometre, share of population above 65 years of age, and below 12. Population is computed based on figures at the start of 2020. Regional controls are the daily number of tests, healed and deceased patients in the region. Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

B Tables

Table B1: List of Essential Sectors

ATECO CODE	LABEL
1	Agriculture and animal products
3	Fishing
5	Coal mining
6	Oil and Gas extraction
9.1	Support for oil and gas extraction
10	Food industry
11	Beverage industry
13.96.20	Technical textile and industrial products production
13.95	Textile excluding clothing
14.12.00	Work clothing production
16.24	Wood Packing production
17	Paper production
18	Printing and replication of recorded products
19	Coke and oil related products production
20	Chemicals production
21	Pharmaceuticals products
22.2	Plastic material production
23.13	Hollow glass production
23.19.10	Pharmaceutical and laboratory glass products production
25.21	Metal containers for heating production
25.92	Light metal packing production
26.6	Electromedical equipment production
27.1	Engine, power generators and tools for distribution and control of electricity production
27.2	Batteries and storage batteries production
28.29.30	Automatic machinery for packing and storage production
28.95.00	Machinery for paper industry production
28.96	Machinery for rubber industry production
32.5	Medical and dental tool production
32.99.1	Protective clothing production
32.99.4	Funerary tools production
33	Repair and installation for machinery
35	Distribution of gas and electricity
36	Collection and distribution of water
37	Sewers management
38	Waste collection and disposal
39	Waste management services
42	Civil engineering
43.2	Electrical and hydraulic system installation and management
45.2	Repair of auto vehicles
45.3	Commerce of auto vehicles parts and accessories
45.4	Motorcycle repair and commerce of parts and accessories
46.2	Wholesale commerce of live animals and raw materials
46.3	Wholesale commerce of food, beverage, and tobacco
46.46	Wholesale commerce of pharmaceutical products
46.49.2	Wholesale commerce of books and journals
46.61	Wholesale commerce of agricultural tools and machinery
46.69.91	Wholesale commerce of tools for scientific use
46.69.94	Wholesale commerce of tools fire and accident protection tools
46.71	Wholesale commerce of oil products and heating fuel
49	Land and pipe transport
50	Water transport
51	Aerial Transport
52	Stockage and support activities for transportation
53	Postal services

Table B1: List of Essential Sectors (cont.)

ATECO CODE	LABEL
53	Postal services
55.1	Hotel and similar activities
58	Publishing activities
59	Video, television programs production and recording activities
60	Broadcasting activities
61	Telecommunication
62	Software programming, information technology consulting and related activities
63	News services and information technology services
64	Financial services but insurance and pension funds
65	Insurance and pension funds
66	Auxiliary financial activities
69	Legal and accounting services
70	Management and consulting activities
71	Engineering and architecture services and consulting
72	Scientific research and development
74	Scientific and technical professional activities
75	Veterinary services
78.2	Temporary work agencies
80.1	Private surveillance services
80.2	Services related to surveillance activities
81.2	Cleaning and disinfestation
82.2	Call Centre
82.92	Packing services
82.99.2	Distribution of books and newspapers
82.99.99	Other services for firms support
84	PA and defence
85	Education
86	Healthcare
87	Social services for housing
88	Social services not for housing
94	Activities of Associations
95.11.00	Computer repair and support
95.12.01	Phones repair and support
95.12.09	Other communication devices repair and support
95.22.01	Home electric equipment repairs and support
97	Domestic workers

Table B2: Summary Statistics for Additional Variables

Variable	Mean	Sd	Min	25th percentile	Median	75th Percentile	Maximum
Hundreds Ess. Workers per Built Km2	7.329	4.410	2.279	4.335	5.874	8.396	23.547
Health Exp. pc	0.000	1.000	-1.399	-0.742	-0.076	0.351	4.358
GP	0.000	1.000	-2.447	-0.802	-0.071	0.568	2.761
Hospital beds	0.000	1.000	-1.294	-0.915	-0.055	1.024	1.470
Anesthetists	0.000	1.000	-1.839	-0.537	-0.103	0.765	3.369
Pop per built Km2	42.908	16.028	16.046	33.346	39.809	55.407	106.706
% Pop above 65	23.135	2.393	17.892	21.636	22.800	24.598	29.367
% Pop below 12	10.134	0.836	7.624	9.658	10.274	10.610	12.402
Avg Age	45.173	1.623	41.632	44.370	44.940	46.302	49.134
Avg Family Income	31.479	4.329	23.879	26.887	33.055	35.673	40.606
% Transfers	0.857	0.043	0.774	0.823	0.847	0.885	1.005
Emp. Rate	59.316	11.462	35.837	49.457	64.597	68.103	74.050
Unemp. Rate	10.559	6.095	2.900	5.900	8.300	14.300	28.800

Table reports summary statistics for variables at province and regional level. Variables are (in parentheses the level of measurement level and the latest available issue of the data before the pandemic): Hundred of essential workers per built Km2 (province, 2019); Health Exp. per capita (region, 2019); Number of GP per thousand of inhabitants (region, 2019); Number of hospital beds per ten thousand inhabitants (region, 2018); Number of Anesthetists per thousand of inhabitants (region, 2019); Population per Km2 (province, 01/01/2020); % Population above 65 (province, 01/01/2020); % Population below 12 (province, 01/01/2020); Average Age (province, 01/01/2020); Average Family Income in thousand of Euro (region, 2018); % Transfers in family income (region, 2018); Employment Rate (province, 2019) and Unemployment rate (province, 2019). For all regional level variables the same value is assigned to all the provinces in the same region. Health related variables are normalized to have mean zero and standard deviation one.

Table B3: Cross-correlation Table

Variables	Hund. Ess. Workers per Built Km2	Health Exp. pc	GP	Hospital beds	Anesthetists	Pop per built Km2	% Pop above 65	% Pop below 12	Avg Age	Avg Family Income	% Transfers	Emp. Rate	Unemp. Rate
Hund. Ess. Workers per Built Km2	1.000												
Health Exp. pc	0.401	1.000											
	(0.000)												
GP	-0.209	-0.158	1.000										
	(0.032)	(0.106)											
Hospital beds	0.185	0.407	-0.769	1.000									
	(0.058)	(0.000)	(0.000)										
Anesthetists	0.188	0.380	0.134	-0.039	1.000								
	(0.054)	(0.000)	(0.172)	(0.691)									
Pop per built Km2	0.727	0.104	0.228	-0.318	0.237	1.000							
	(0.000)	(0.290)	(0.019)	(0.001)	(0.014)								
% Pop above 65	-0.039	0.413	0.044	0.347	0.396	-0.154	1.000						
	(0.692)	(0.000)	(0.652)	(0.000)	(0.000)	(0.115)							
% Pop below 12	0.203	-0.192	-0.290	0.013	-0.331	0.129	-0.857	1.000					
	(0.037)	(0.048)	(0.003)	(0.894)	(0.001)	(0.188)	(0.000)						
Avg Age	-0.050	0.412	0.032	0.336	0.391	-0.189	0.986	-0.892	1.000				
	(0.612)	(0.000)	(0.742)	(0.000)	(0.000)	(0.052)	(0.000)	(0.000)					
Avg Family Income	0.262	0.428	-0.735	0.857	-0.009	-0.275	0.327	0.038	0.341	1.000			
	(0.007)	(0.000)	(0.000)	(0.000)	(0.925)	(0.004)	(0.001)	(0.700)	(0.000)				
% Transfers	-0.186	-0.199	0.537	-0.613	0.309	0.092	-0.045	-0.172	-0.021	-0.490	1.000		
	(0.056)	(0.041)	(0.000)	(0.000)	(0.001)	(0.347)	(0.647)	(0.078)	(0.827)	(0.000)			
Emp. Rate	0.309	0.575	-0.577	0.797	0.125	-0.213	0.455	-0.102	0.477	0.909	-0.465	1.000	
	(0.001)	(0.000)	(0.000)	(0.000)	(0.203)	(0.028)	(0.000)	(0.299)	(0.000)	(0.000)	(0.000)		
Unemp. Rate	-0.260	-0.518	0.579	-0.757	-0.091	0.208	-0.396	0.086	-0.417	-0.858	0.528	-0.925	1.000
	(0.007)	(0.000)	(0.000)	(0.000)	(0.356)	(0.033)	(0.000)	(0.379)	(0.000)	(0.000)	(0.000)	(0.000)	

Table reports pairwise correlation between variables. P-values reported in parenthesis below correlation coefficient. For variable description see notes of Table B2

Table B4: Effect of Density of Essential Sectors on Number of New Daily Covid-19 Cases and Deaths per 100,000 Inhabitants: Timing and the Effect of Essential Sectors.

VARIABLES	(1) New Cases	(2) New Cases	(3) New Cases	(4) New Cases	(5) New Cases	(6) Deaths	(7) Deaths	(8) Deaths	(9) Deaths	(10) Deaths
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.262**	0.262***	0.263**	0.248**	0.305***	0.049**	0.071***	0.050***	0.043**	0.054***
	(0.102)	(0.068)	(0.101)	(0.115)	(0.064)	(0.019)	(0.023)	(0.019)	(0.021)	(0.014)
Hundreds Ess. Workers per Built Km2 X Above 50th perc. New Cases X post 03/22	0.003		-0.012			0.048		0.041		
	(0.116)		(0.114)			(0.031)		(0.026)		
Hundreds Ess. Workers per Built Km2 X Above 75th perc. New Cases X post 03/22		-0.084	-0.069				-0.046	-0.065		
		(0.363)	(0.354)				(0.113)	(0.111)		
Hundreds Ess. Workers per Built Km2 X Above 75th perc. Avg. New Cases X post 03/22				0.053					0.078	
				(0.183)					(0.060)	
Hundreds Ess. Workers per Built Km2 X Above 75th perc. Cum. Cases X post 03/22					-0.067					0.037
					(0.151)					(0.056)
Observations	7,314	7,314	7,314	7,314	7,314	7,314	7,314	7,314	7,314	7,314
Mean Dep.	5.95	5.95	5.95	5.95	5.95	4.17	4.17	4.17	4.17	4.17
SD Essential	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41
Ep. Trend 4th	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Reg. Controls	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
RegionXDate FE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new reported Covid-19 cases per 100,000 inhabitants in Panel A and number of deaths per 100,000 inhabitants in Panel B. Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in 2019 in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Controls include population per built square kilometre, share of population above 65 years of age, and below 12. Population is computed based on figures at the start of 2020. Dummies for the ranking of provinces in terms of infections at the time of the lockdown computed based on the number of cases on the 23rd of March 2020, first day of the national lockdown, in Columns from (1) to (3) and from (7) to (9). The distribution in Column (4) and Column (10) is based on average new cases in the week before the lockdown, while Column (5) and Column (11) use the total number of cases up to the 23rd of March 2020. Regional controls are the daily number of tests, healed and deceased patients in the region. Region and date fixed effects are interactions between daily dummies and regional dummies. Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

Table B5: Estimates of Share of Patients by Diagnostic Related Groups and Related Costs for Hospitalized Covid Patients

Panel A: Estimates from Cicchetti and Di Bidino (2020)					
Diagnostic Related Groups (DRG, Italy)	Description	Share	Cost	Share	Cost
		All		Deceased	
79	respiratory infections and inflammations age>17 w cc	0.600	5744	0.500	4050
80	respiratory infections and inflammations age>17 w/occ	0.050	4422	0.070	1555
100	respiratory signs and symptoms w/occ	0.050	3679	0.020	1566
421	viral illness age>17	0.050	4540	0.010	1700
541	trach w mv 96+hrs or pdx exc face, mouth, and neck dx w/maj or	0.025	51919	0.050	74395
542	trach w mv 96+hrs or pdx exc face, mouth, and neck dx w/o mj or	0.025	34546	0.050	27287
565	respiratory system diagnosis with ventilator support >96 hours or peripheral extracorporeal membrane oxygenation (ecmo)	0.100	15595	0.150	11128
566	respiratory system diagnosis with ventilator support <=96 hours	0.100	6764	0.150	5730
	Average	8475.98		9794.97	
Panel B: Estimates from Pellegrini (2020)					
Diagnostic Related Groups (DRG, Italy)	Description	Share	Cost		
542	trach w mv 96+hrs or pdx exc face, mouth, and neck dx w/o mj or	0.037	74545.19		
565	respiratory system diagnosis with ventilator support >96 hours or peripheral extracorporeal membrane oxygenation (ecmo)	0.064	33770.76		
80	respiratory infections and inflammations age>17 w/occ	0.332	6244.32		
79	respiratory infections and inflammations age>17 w cc	0.233	7741.29		
421	viral illness age>17	0.072	6419.46		
99	respiratory signs and symptoms	0.072	5394.34		
566	respiratory system diagnosis with ventilator support <=96 hours	0.041	7268.72		
	other drg	0.149	8390.04		
	Average		11219.48		

Note: Estimates for share of patients by Diagnostic Related Groups (DRG, Italy) and unit costs for the first wave (February to May 2020) in Italy. Panel A reports estimates from Cicchetti and Di Bidino (2020) for the whole Italy while Panel B reports from Pellegrini (2020), who reports costs per patient for Alto Adige (provincia Autonoma di Bolzano), one of the Italian provinces. Share columns report the share of patients classified by DRG while Cost columns report the expected expenditure per hospitalization with that code. Amounts are reported in Euro for the full hospitalization.

Table B6: Effect of Essential Sectors on Number of New Daily Covid-19 Cases and Deaths: Robustness with Controls and Date Interactions

VARIABLES	(1) New Cases	(2) New Cases	(3) Deaths	(4) Deaths
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.224*	0.247**	0.091	0.078**
	(0.134)	(0.095)	(0.056)	(0.039)
Observations	7,314	7,314	7,314	7,314
Mean Dep.	5.95	5.95	4.17	4.17
SD Essential	4.41	4.41	4.41	4.41
Ep. Trend 4th	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Date FE	YES	YES	YES	YES
Char. Trends	YES	NO	YES	NO
Char. cat. Trends	NO	YES	NO	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of new reported Covid-19 cases per 100,000 inhabitants in Column (1) and Column (2) and total deaths per 100,000 inhabitants in Column (3) and Column (4). Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in the province in 2019 per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Char. Trends indicates the inclusion in the equation of population density, share of inhabitants above 65 years of age, share of inhabitants below 12 years of age, average age, average family income and share of income coming from government transfers, employment and unemployment rate interacted with date dummies. Char. cat. Trends indicates the inclusion in the equation of dummies for terciles in distribution across provinces of the previous variables interacted with date dummies. Observations weighted by inhabitants on the 1st of January 2020. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

Table B7: Effect of Essential Sectors on Number of Deaths per 100,000 Inhabitants: Robustness

VARIABLES	(1) Deaths	(2) No Week Ends	(3) Deaths	(4) Regional Trends	(5) Deaths	(6) Deaths	(7) Deaths	(8) No Weights	(9) Exc. Mortality	(10) Bordering Provinces	(11) Hours of STW	(12) SLL
Hundreds Ess. Workers per Built Km2 X Post 03/22	0.073***	0.069**	0.095*	0.099**				0.068***	0.067**	0.072***	0.064***	
	(0.027)	(0.029)	(0.055)	(0.045)				(0.021)	(0.026)	(0.024)	(0.024)	
Hundreds Population per built Km2 X post 03/22			-0.010									
			(0.012)									
% Above 65 X post 03/22			0.485*									
			(0.270)									
% below 12 X post 03/22			-0.261									
			(0.458)									
Average Age X post 03/22			-0.714									
			(0.625)									
Employment Rate X Post 03/22			0.093*									
			(0.053)									
Transfer Share of Income X Post 03/22			-4.419*									
			(2.432)									
Family Income X Post 03/22			-0.073									
			(0.077)									
Unemployment Rate X Post 03/22			0.140									
			(0.091)									
Hundreds Ess. Workers (no health) per Built Km2 X post 03/22					0.079***							
					(0.029)							
Hundreds Ess. Workers per Km2 X post 03/22						0.206***						
						(0.072)						
Ess. workers per hundreds inhab. X post 03/22							0.052***					
							(0.019)					
Hundreds Ess. Workers per Built Km2 (bordering) X post 03/22										-0.048		
										(0.080)		
STW Essential Workers (Hours per worker per day)											4.629	
											(3.299)	
STW Essential Workers (Hours per worker per day) X Post 03/22											-2.563	
											(2.435)	
Ess. workers per hundreds inhab. X post 03/22												0.052***
												(0.016)
Observations	7,314	5,194	7,314	7,314	7,314	7,314	7,314	7,314	7,314	7,245	7,314	41,440
R-squared	0.575	0.575	0.582	0.677	0.575	0.575	0.574	0.565	0.559	0.576	0.579	0.365
Mean Dep.	4.17	4.22	4.17	5.95	4.17	4.17	4.17	4.17	1.31	4.17	4.17	2.12
SD Essential	4.41	4.41	4.41	3.41	4.13	1.54	5.6	3.41	3.41	3.41	3.41	3.19
Ep. Trend 4th	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of deaths per 100,000 inhabitants. Hundreds Ess. Workers per Built Km2 is the number of workers (in hundreds) in essential sector in the province per built square kilometre. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Regional controls are the daily number of tests, healed and deceased patients in the region. Observations weighted by inhabitants on the 1st of January 2020. Column (2) excludes Saturday and Sunday from the sample. Column (3) includes trend breaks in other province characteristics. Variables are (in parentheses the level of measurement level and the latest available issue of the data before the pandemic): Population per Km2 (province, 01/01/2020); % Population above 65 (province, 01/01/2020); % Population below 12 (province, 01/01/2020); Average Age (province, 01/01/2020); Average Family Income in thousand of Euro (region, 2018); % Transfers in family income (region, 2018); Employment Rate (province, 2019) and Unemployment rate (province, 2019). For all regional level variables the same value is assigned to all the provinces in the same region. Column (4) includes fourth order polynomial trends by region. Column (5) excludes the Health sector from the computation of essential workers per square kilometre. Column (6) reports the effect of the number of essential workers per squared kilometre. Column (7) reports a similar specification where the number of essential workers is divided by the size of the population. Column (8) reports results from the estimation of the same specification in Column (1) but without the population weights. Column (9) expresses mortality in difference with respect to average mortality by day in the five years before the pandemic (2015-2019). Column (10) considers the density of essential workers in neighbouring provinces weighted by the number of essential workers in those provinces. Column (11) considers the possible confounding effect of short time work measured as hours of STW by essential worker per day. The variable is computed only at monthly level. Column (12) perform the same analysis of Column (7) at the 680 Local Labour Market level. Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

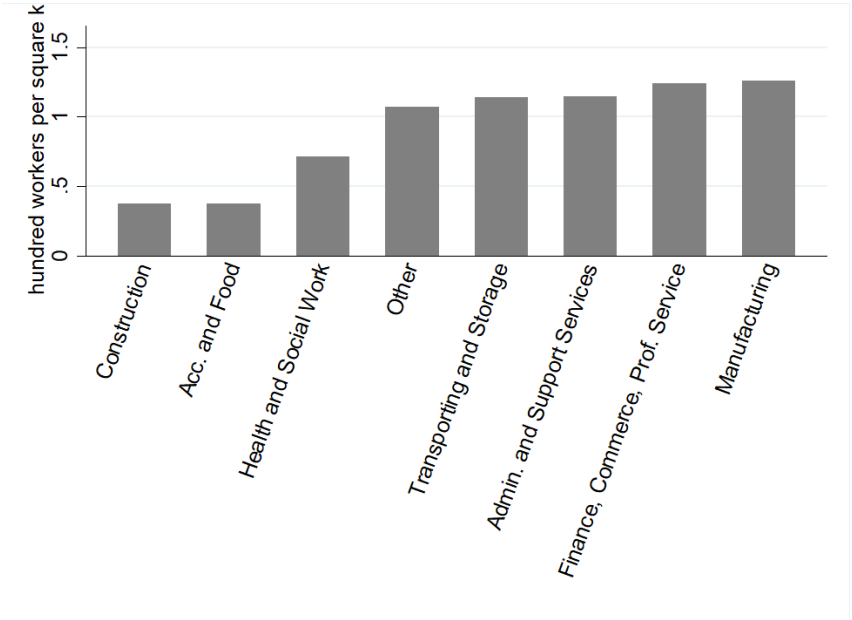
Table B8: Effect of Essential Sectors on Number of Deaths per 100,000 Inhabitants: Aggregate Effect and Effect by Sector.

VARIABLES	(1) Weighted	(2) Weighted	(3) Not Weighted	(4) Not Weighted
Essential Sector (aggregate)	0.073***		0.068***	
	(0.027)		(0.021)	
Accommodation and Food Service		0.199		0.090
		(0.197)		(0.129)
Construction		-3.260		-0.529
		(2.887)		(1.944)
Manufacturing		-0.347		-0.349
		(0.320)		(0.270)
Admin. and Support Services		-0.493		-0.335
		(0.609)		(0.425)
Health and Social Work		0.852**		0.862**
		(0.423)		(0.362)
Finance, Prof. Services and Commerce		1.148***		1.436***
		(0.387)		(0.501)
Transporting and Storage		0.098		-0.247
		(0.329)		(0.278)
Other		-0.026		-0.699
		(0.709)		(0.457)
Observations	7,314	7,314	7,314	7,314
R-squared	0.575	0.582	0.565	0.569
Ep. Trend 4th	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Date FE	YES	YES	YES	YES

Note: OLS regressions for the difference-in-differences model reported in Equation 1. Regression based on daily data for 106 Italian provinces between the 25th of February and the 3rd of May 2020. Dependent variable is the number of deaths per 100,000 inhabitants. All variables are interaction terms between the density of essential workers by sector ('00 of essential workers per built squared kilometre) interacted with a dummy for the period after the 23rd of March 2020. Ep.Trend 4th is a fourth order polynomial for a trend since the first positive registered case of Covid-19 in the province. Observations weighted by inhabitants on the 1st of January 2020 in Column (1) and Column (2), and not weighted in Column (3) and Column (4). Standard errors clustered at the province level reported in parenthesis. Level of significance: ***, 0.01; **, 0.05; *, 0.1.

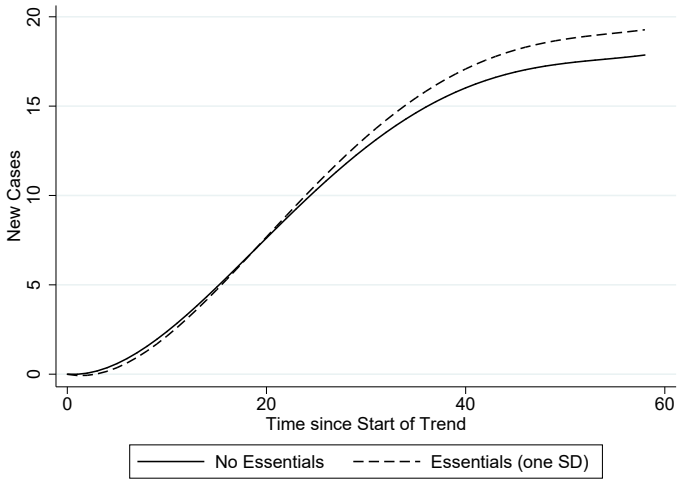
C Figures

Figure C1: Average Density of Essential Sectors

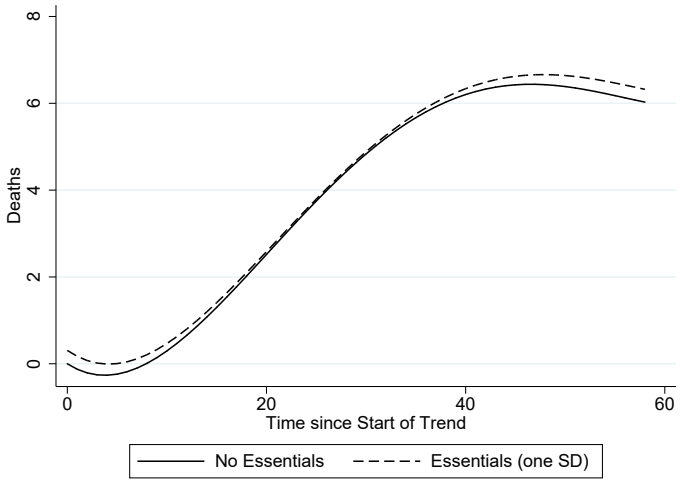


Note: Figure plots the average density of essential workers by sectors across Italian provinces. Density is measured as the number of workers in essential sectors (in hundreds) in 2019 per built square kilometre. Data weighted by population in 2020. Services to firms and ind. includes: Financial and Insurance activities; Wholesale and Retail Trade; Professional, Scientific and Technical Activities. Other category includes: Agriculture, Forestry and Fishing; Water Supply; Sewerage, Waste Management and Remediation Activities; Other Service Activities; Construction; Electricity, Gas, Steam and Air Conditioning Supply; Information and Communication; Education; Public Administration and Defence; Compulsory Social Security; Mining and Quarrying.

Figure C2: Effect of Density of Essential Sectors on Covid-19 Infections and Mortality: Interaction with Time Trend



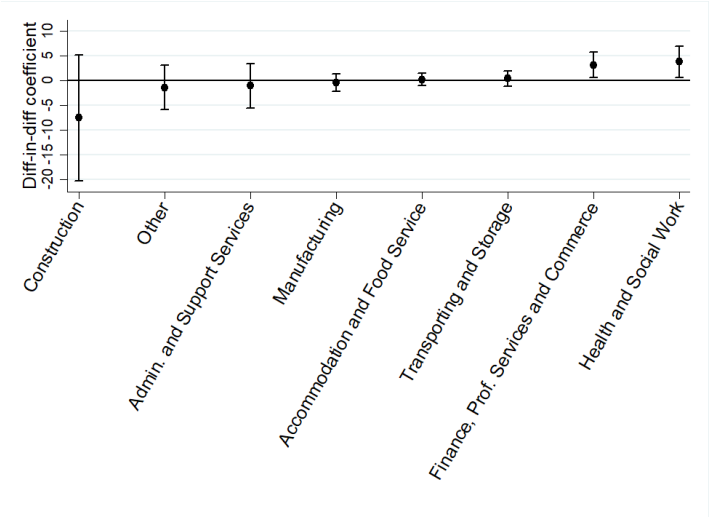
(a) Cases per 100,000 of population



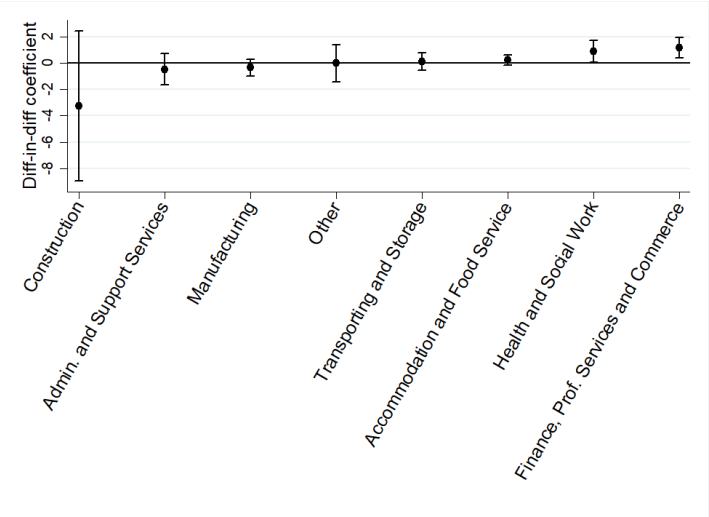
(b) Deaths per 100,000 of population

Note: Predicted polynomials for the number of new Covid-19 infections in Panel (a) and daily deaths in Panel (b). Polynomials estimated by using the equation used in Column (3) of Table 2 with the addition of a fourth order polynomial interacted with the density of workers in essential sector. The prediction includes the coefficient of the interaction between the density in essential sectors and the post 03/22 dummy, the polynomial trend and the interaction between the polynomial trend and the density of essential sector. The prediction with higher density of essential workers sets the density at one standard deviation (441 workers per built km2). Estimation based on the whole sample between the 25$^{\text{th}}$ of February and the 3$^{\text{rd}}$ of March. Observations weighted by the population in the province on the 1$^{\text{st}}$ of January 2020.

Figure C3: Effect of Density of Essential Sectors on Covid-19 Infections and Mortality by Sector: Coefficients



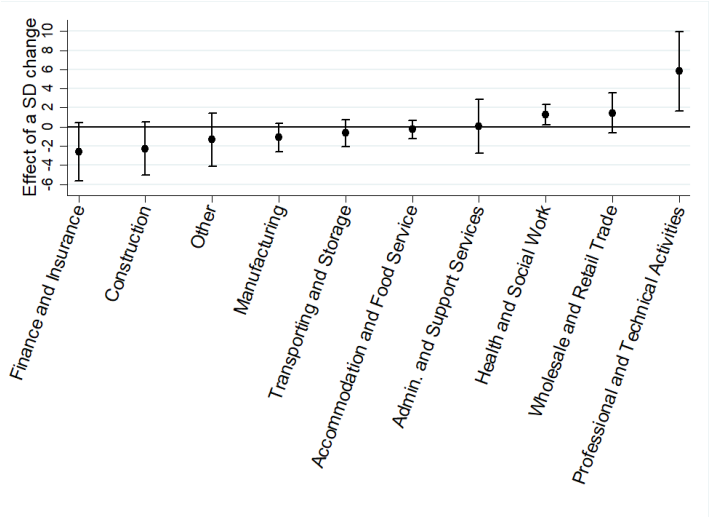
(a) Cases per 100,000 of population



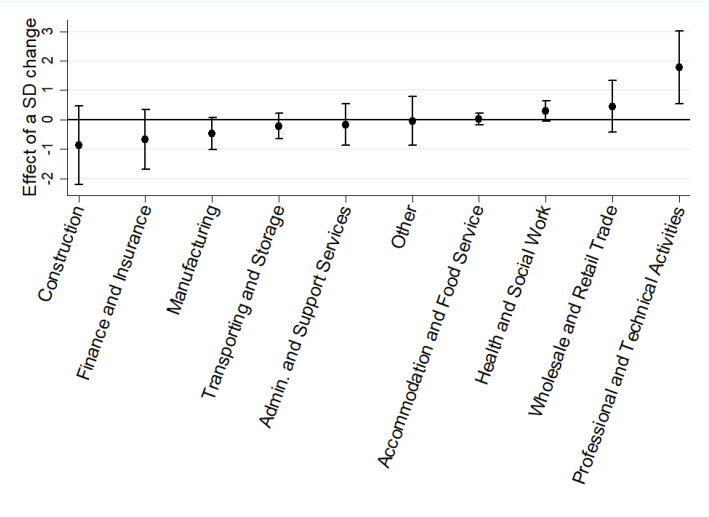
(b) Deaths per 100,000 of population

Note: Estimates for the effect of density of essential workers in different sectors on Covid-19 infections and mortality. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2019 per built square kilometre. Panel (a) reports effects for the number of reported cases for 100,000 inhabitants while Panel (b) reports the effect on number of deaths per 100,000 inhabitants. The regression includes a 4^{th} order polynomial trend from the first registered Covid-19 case in the province, and date and province fixed effects. Regression based on daily data for 106 Italian provinces between the 25^{th} of February and the 3^{rd} of May 2020. Observations weighted by the population in the province at the start of 2020. Confidence intervals at 95% based on standard errors clustered at the province level reported. Services to firms and ind. includes: Financial and Insurance activities; Wholesale and Retail Trade; Professional, Scientific and Technical Activities. Other category includes: Agriculture, Forestry and Fishing; Water Supply; Sewerage, Waste Management and Remediation Activities; Other Service Activities; Construction; Electricity, Gas, Steam and Air Conditioning Supply; Information and Communication; Education; Public Administration and Defence; Compulsory Social Security; Mining and Quarrying.

Figure C4: Effect of Density of Essential Sectors on Covid-19 Infections and Mortality by Sector (more detailed disaggregation): Effect of a Standard Deviation Change



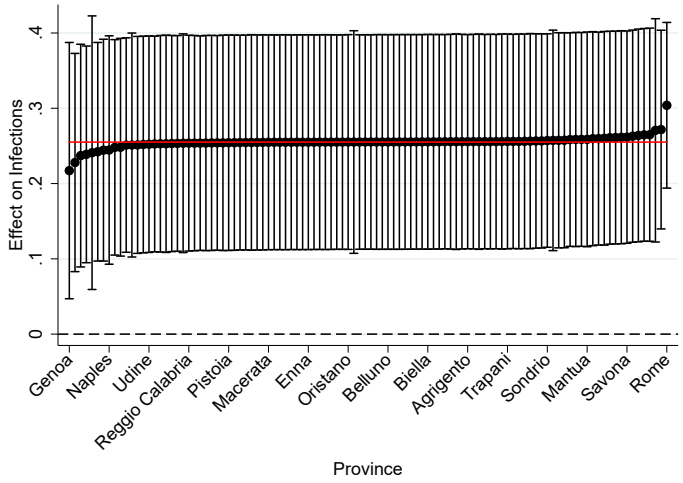
(a) Cases per 100,000 of population



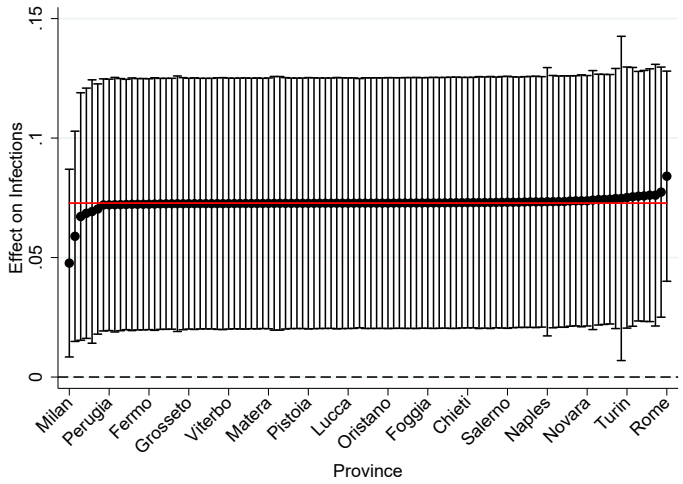
(b) Deaths per 100,000 of population

Note: Estimates for the effect of density of essential workers in different sectors on Covid-19 infections and mortality. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2019 per built square kilometre. Panel (a) reports effects for the number of reported cases for 100,000 inhabitants while Panel (b) reports the effect on number of deaths per 100,000 inhabitants. Reported coefficients and standard errors computed for a standard deviation change in the density of workers in a specific sector. The regression includes a 4^{th} order polynomial trend from the first registered Covid-19 case in the province, and date and province fixed effects. Regression based on daily data for 106 Italian provinces between the 25^{th} of February and the 3^{rd} of May 2020. Observations weighted by the population in the province at the start of 2020. Confidence intervals at 95% based on standard errors clustered at the province level reported. Other category includes: Agriculture, Forestry and Fishing; Water Supply; Sewerage, Waste Management and Remediation Activities; Other Service Activities; Construction; Electricity, Gas, Steam and Air Conditioning Supply; Information and Communication; Education; Public Administration and Defence; Compulsory Social Security; Mining and Quarrying.

Figure C5: Effect of Density of Essential Sectors on Covid-19 Infections and Mortality: Sensitivity of Estimates to Single Provinces



(a) Cases per 100,000 of population



(b) Deaths per 100,000 of population

Note: Estimates for the effect of density of essential workers on Covid-19 infections and mortality. Each dot reports the coefficient of our difference-in-differences variable in the main equation by excluding the province reported on the x axis. Label reports one province every seven provinces for the sake of clarity. Density of workers in essential sectors is measured as the number of workers (in hundreds) employed in essential sectors in 2019 per built square kilometre. Panel (a) reports effects for the number of reported cases for 100,000 inhabitants while Panel (b) reports the effect on number of deaths per 100,000 inhabitants. Red line reports the corresponding OLS baseline estimate of Column 3 of Table 2. The regression includes a 4^{th} order polynomial trend from the first registered Covid-19 case in the province, and date and province fixed effects. Regression based on daily data for 106 Italian provinces between the 25^{th} of February and the 3^{rd} of May 2020. Observations weighted by the population in the province at the start of 2020. Confidence intervals at 95% based on standard errors clustered at the province level reported.