The Grey Zone
How Not Imposing a Strict Lockdown at the Beginning of a Pandemic Can Cost Many Lives

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Barcelona, August 28 2023
The Grey Zone
On February 23 2020, the Italian government ordered its military police to seal the borders and declared a Red Zone around 10 municipalities of the province of Lodi in the Lombardy Region.
On the same day, a patient tested positive at the hospital of Alzano Lombardo, a town in the Serio Valley, Bergamo, 60 miles away from Lodi.

On February 28, the province of Bergamo reported 103 positive Covid-19 cases. The government’s scientific committee did not advise in favor of a Red Zone nor did Lombardy health officials.

Confindustria Bergamo, the province industrial association, posted a video titled "Bergamo is running".
The Grey Zone

On March 3, the government’s scientific committee proposed a Red Zone in the Serio Valley around Nembro and Alzano Lombardo.

On March 4, the military police was ready to seal the borders and turn the area into a Red Zone. But nothing happened. No Red Zone was ever declared.
The Serio Valley

Number of people infected per municipality (grouped together in inhabited centers)

- 1-15
- 16-30
- 31-60

Limit of territorial zones 8 and 9

AMBITO 8 (18 municipalities)

AMBITO 9 (20 municipalities)

Data: cumulative survey from February 24 to April 14, 2020
Laboratory: C31 (Biolife Project), University of Bergamo
Source: Italian National Institute of Health; Types of ISTAT regulations.
The Grey Zone

Timeline of public policy measures adopted to contain the first wave of the pandemic.

Feb-23-2020

Red Zones
- Red Zone’s borders sealed by the army;
- Stop to all non-essential economic activities;
- Stop to schools and universities;
- No entry or exit from Red Zones;
- Stop to all non-essential public transports;

Mar-05-2020

First partial Lockdown
- Stop to schools and universities;

Mar-12-2020

Second partial Lockdown
- Stop to schools and universities;
- Stop to all commercial activities;

Mar-23-2020

Full Lockdown
- Stop to schools and universities;
- Stop to all non-essential economic activities;
- No entry or exit from the municipality of residence;
- Stop to all non-essential public transports;

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In the absence of mass screening and aggressive contact tracing, the timely set up of a Red Zone has been recognized as one of the most effective Non Pharmaceutical Interventions (NPIs) to contain the spread of Covid-19 cases, to prevent hospitals from being overwhelmed, and to potentially limit the number of deaths (Fagiuoli et al., 2020; Signorelli et al., 2020) this seems to be also the conclusion of Chernozhukov’s paper cited below and another theoretical paper by Acemoglu, Chernozhukov and other two. Previous studies using counterfactual analysis have shown that strict initial lockdown measures played an important role in limiting the spread of the Covid-19 infection. Fang et al. (2020) showed that the lockdown in Wuhan, enacted on January 23, 2020 decreased the number of positive cases by 64.8 percent in the 347 Chinese cities outside Hubei province, and by 52.64 percent in the 16 non-Wuhan cities inside Hubei. Cho (2020) showed that the number of deaths in Sweden would have been reduced between 23 and 30 percent had Sweden implemented those policies. In addition, the impact of NPIs becomes visible with a time lag of around 5 weeks as individuals adjust their behavior in response to the policies. Using a dynamic causal model for the effect of NPIs in the United States Chernozhukov et al. (2021) found that both policies and information on transmission risks are important determinants of Covid-19 deaths and that a change in policies explains a large fraction of observed voluntary changes in social distancing. Flaxman et al. (2020) find that major NPIs and lockdowns in particular have had a large effect in reducing transmission. Pifarré Crudu, Di Stefano, Mellace, Tiezzi.
Research Question

Would imposing a Red Zone in the Serio Valley have helped saving lives?
The paper in a nutshell

We estimate the causal effect of the (missed) adoption of a Red Zone in this area on daily excess mortality in 2020.

- We apply the Synthetic Control Methods (SCM) to a panel data at the municipality and daily level.

- We find that about two-thirds of the reported deaths could have been avoided had the government declared a Red Zone.

- We find similar results using the Augmented SCM and the Synthetic DiD.

- We show that, SCM, DiD, and similar methods implicitly restrict effect heterogeneity on the effect of the pandemic.

- We provide a way to empirically assess the credibility of this assumption in our setting.
In the absence of mass screening and aggressive contact tracing, the timely set up of a Red Zone has been recognized as one of the most effective Non Pharmaceutical Interventions (NPIs) (Acemoglu et al., 2021; Chernozhukov et al., 2021; Fagiuoli et al., 2020; Signorelli et al., 2020).

Previous studies using counterfactual analysis have shown that strict initial lockdown measures played an important role in limiting the spread of Covid-19 (Cerqueti et al., 2022; Chernozhukov et al., 2021; Cho, 2020; Fang et al., 2020; Flaxman, Mishra, Gandy et al., 2020).

Singh et al. (2021) suggest that the actual impact of NPI measures may depend on the characteristics of the groups that receive the treatment and ultimately on their compliance.
Identification strategy
Synthetic Control Method (Abadie et al. 2003 and later)

**Idea**: create a linear combination of control units that mimics what would have happened to the treated units in the absence of the intervention.

**Weights**: chosen to minimize the distance in the pre-intervention characteristics of the treated and of the synthetic control.

**Causal effect**: estimated as the difference between the observed outcome of the treated and of the synthetic control units in the post-intervention period.
Graphical illustration
Notation

We assume that

\[ Y_{jt}^{NP} = f_{jt} \text{ (no pandemic)}, \]
\[ Y_{jt}^{RZ} = \beta_{jt} + f_{jt} = \beta_{jt} + Y_{jt}^{NP} \text{ (Red Zone)}, \]
\[ Y_{jt}^{NRZ} = \beta_{jt} + \gamma_{jt} + f_{jt} = \gamma_{jt} + Y_{jt}^{RZ} \text{ (no Red Zone)}, \]

where \( f_{jt} \) are unobserved common components that determine the outcome \( Y \).
Implicit additional assumption

- Let unit 1 be one of the treated municipalities and units from 2 to \( J \) be municipalities that imposed a Red Zone.
- The effect of no implementing a red zone \( \gamma_{1t} \), we need that the SCM weights satisfy \( \sum_{j=2}^{J} \hat{w}_j f_{jt} = f_{1t} + o_p(1) \) as usual.
- In addition we need to assume that

\[
\sum_{j=2}^{J} \hat{w}_j \beta_{jt} = \beta_{1t} \text{ non-extreme pandemic effect (NEPE)}.
\]
Plausibility of NEPE

- We are able to control for many geographic, and socio-demographic characteristics that are believed to be the main determinants for the spread of the virus.
- All municipalities (except Vo’ Euganeo) are in the same region.
- Thus, we expect NEPE to be reasonably plausible.
- We use municipalities that were not immediately hit by the pandemic to further check the plausibility of NEPE.
Using non-affected municipalities

We can recover the total effect of the pandemic on our treated unit and on the Red Zone units (that received a positive weight) as

\[
\gamma_{1t} + \beta_{1t} \approx \gamma_{1t} + \beta_{1t} = Y_{1t} - \sum_{i=J+1}^{K} \hat{w}_i Y_{it}.
\]

\[
\beta_{jt} \approx \hat{\beta}_{jt} = Y_{jt} - \sum_{i=J+1}^{K} \tilde{w}_j^i Y_{it}, \quad j = 2, \ldots, J,
\]
Plausibility of NEPE

We can then estimate $\gamma_{1t}$ as

$$\tilde{\gamma}_{1t} = \gamma_{1t} + \beta_{1t} - \max_{j \in [2, \ldots, J], \hat{w}_j > 0} \hat{\beta}_{jt}$$

$$= \left( Y_{1t} - \sum_{i=J+1}^{K} \hat{w}_i Y_{it} \right) - \max_{j \in [2, \ldots, J], \hat{w}_j > 0} \left( Y_{jt} - \sum_{i=J+1}^{K} \tilde{w}_i^j Y_{it} \right).$$

Two interpretations of the quantity $\tilde{\gamma}_{1t}$:

1. If $\beta_{1t} < \max_{j \in [2, \ldots, J], \hat{w}_j > 0} \hat{\beta}_{jt}$, $\tilde{\gamma}_{1t}$ is a lower bound for $\gamma_{1t}$.

2. If $\beta_{1t} > \max_{j \in [2, \ldots, J], \hat{w}_j > 0} \hat{\beta}_{jt}$ a large $\tilde{\gamma}_{1t}$ indicates that $\gamma_{1t}$ should be large.
Using non-affected municipalities for inference

- Implementing a red zone does not completely stop the effect of the pandemic.

- Thus, we need to take into account that, in the post intervention period, the red-zone municipalities are still affected by the pandemic.

- We can use the non-affected municipalities to:
  1. Estimate the effect of the pandemic in each red-zone municipalities.
  2. As an alternative donor pool for the treated municipalities.

- The former together with our NEPE assumption allows us to estimate the effect of the pandemic the three municipalities in the Serio valley would have experienced under a red zone.

- The latter allows us to run the standard inference procedures after subtracting those effects by the respective outcomes.
Data
Data

Daily number of all-cause deaths from November 1st 2019 to October 30th 2020 on all Italian municipalities (ISTAT, Decessi anni 2011-2021).

**Treatment**: missed adoption of Red Zone.

**Outcome variable of interest**: cumulative daily excess mortality (difference between daily mortality and average mortality on the same day in the previous 8 years) at the municipality level.

**Pre-treatment period**: from November 1st 2019 to February 22nd 2020 (114 days).

**Post-treatment period**: from February 23d 2020 to October 30th 2020.

**Treated units**: Albino, Nembro and Alzano Lombardo in the province of Bergamo.
Main donor pool: 10 municipalities in the province of Lodi, where a Red Zone was implemented from February 23 to March 23 2020, and Vo’ Euganeo in the province of Padova.

Extra donor pool: 39 municipalities in Lombardy with comparable population size and with a distance from Codogno (the centre of the Red Zone) and Albino (the centre of the Serio Valley) greater than 60 km and 50 minutes drivetime.
Donor pools

[Map of the region showing Donor pools in Milano, Lodi, Piacenza, and Casalpusterlengo.]
## Covariates balance: red zone

### Red Zone

<table>
<thead>
<tr>
<th>Mortality, Demographic and Geographic variables</th>
<th>Albino</th>
<th>Alzano Lombardo</th>
<th>Nembro</th>
<th>Average of all donors ($n = 11$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Real</td>
<td>Synthetic</td>
<td>Real</td>
<td>Synthetic</td>
</tr>
<tr>
<td>- Cumulative excess mortality per 1,000 inhab.</td>
<td>-0.43</td>
<td>-0.37</td>
<td>-0.39</td>
<td>-0.34</td>
</tr>
<tr>
<td>- PM-10 (2019)</td>
<td>27.99</td>
<td>32.61</td>
<td>28.12</td>
<td>32.69</td>
</tr>
<tr>
<td>- Share of male population (2019)</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>- Share of population over 65 (2019)</td>
<td>0.21</td>
<td>0.22</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>- Share of population over 85 (2019)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>- Employees in manufacturing (2017)</td>
<td>2029.75</td>
<td>880.48</td>
<td>582.13</td>
<td>885.83</td>
</tr>
<tr>
<td>- Attraction index (2015)</td>
<td>32.63</td>
<td>33.20</td>
<td>30.13</td>
<td>29.99</td>
</tr>
<tr>
<td>- Population density (2019)</td>
<td>559.58</td>
<td>451.34</td>
<td>999.90</td>
<td>460.65</td>
</tr>
<tr>
<td>- Altimetric area</td>
<td>1.00</td>
<td>4.67</td>
<td>3.00</td>
<td>3.99</td>
</tr>
<tr>
<td>- Distance from the closest hospital</td>
<td>8100.20</td>
<td>6996.11</td>
<td>0.00</td>
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<td>- Distance from the second closest hospital</td>
<td>14647.63</td>
<td>13474.50</td>
<td>7087.21</td>
<td>12188.25</td>
</tr>
</tbody>
</table>
## Covariates balance: non-affected

<table>
<thead>
<tr>
<th>Mortality, Demographic and Geographical variables</th>
<th>Albino</th>
<th>Alzano Lombardo</th>
<th>Nembro</th>
<th>Average of all donors (n = 39)</th>
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<tr>
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<td>0.49</td>
<td>0.50</td>
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<tr>
<td>- Share of population over 65 (2019)</td>
<td>0.21</td>
<td>0.18</td>
<td>0.21</td>
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<tr>
<td>- Share of population over 85 (2019)</td>
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<td>- Employees in manufacturing (2017)</td>
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<td>- Attraction index (2015)</td>
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<tr>
<td>- Population density (2019)</td>
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<td>586.70</td>
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<td>- Altimetric area</td>
<td>1.00</td>
<td>4.57</td>
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<td>4.67</td>
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<tr>
<td>- Distance from the closest hospital</td>
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<td>7669.61</td>
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Weights: red zone

<table>
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<th>Donor pool (n = 11)</th>
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<td>0.503</td>
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<td>2  Bertonico</td>
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<tr>
<td>3  Casalpusterlengo</td>
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<tr>
<td>4  Castiglione d’Adda</td>
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<tr>
<td>5  Codogno</td>
<td>0.865</td>
<td>0.494</td>
<td>0.484</td>
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<td>6  Fombio</td>
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<td>7  Maleo</td>
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<td>0</td>
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<td>8  San Fiorano</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9  Somaglia</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 Terranova dei Passerini</td>
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</tr>
<tr>
<td>11 Castelgerundo</td>
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## Weights: non-affected

<table>
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<tr>
<th>Donor pool (n = 39)</th>
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<td>2 Caronno Pertusella</td>
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<td>3 Castellanza</td>
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<td>4 Fagnano Olona</td>
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<td>5 Lonate Pozzolo</td>
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<td>6 Luino</td>
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<td>7 Malnate</td>
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<td>8 Olgiate Olona</td>
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<td>0</td>
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<td>9 Samarate</td>
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<td>15 Arluno</td>
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<td>16 Busto Garolfo</td>
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<td>17 Canegrate</td>
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</tr>
<tr>
<td></td>
<td>Location</td>
<td>Weights: non-affected</td>
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<td>Casalmaggiore</td>
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<td>36</td>
<td>Porto Mantovano</td>
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<td>38</td>
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<td>0.002</td>
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<tr>
<td>39</td>
<td>Lentate sul Seveso</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>
Some Suggestive Trends

Excess mortality per 1,000 inhabitants

Days (from 1st November)

Excess mortality per 1,000 inhabitants

Cumulative excess mortality per 1,000 inhabitants

22nd February

23rd March

Nembro

Castiglione d'Adda

Maleo

Alzano Lombardo

Codogno

Fombio

San Fiorano

Casalpusterlengo

Somaglia

Bertonico

Terranova dei Passerini

Vo'

Castelgerundo

Crudu, Di Stefano, Mellace, Tiezzi
Some Suggestive Trends

Cumulative excess mortality per 1,000 inhabitants

Days (Nov. 1, 2019 – Oct. 31, 2020)

Not affected municipalities

February 22
March 23

Crudu, Di Stefano, Mellace, Tiezzi

The Grey Zone

Barcelona, August 28 2023
Results
Results: Albino

Trend in excess mortality

Days (Nov. 1, 2019 − Apr. 8, 2020)
Cumulative excess mortality per 1,000 inhabitants

Albino
Synthetic Albino (Not affected)
Synthetic Albino (Red zone)

Trend in excess mortality

Days (Nov. 1, 2019 − Oct. 31, 2020)
Cumulative excess mortality per 1,000 inhabitants

Albino
Synthetic Albino (Not affected)
Synthetic Albino (Red zone)
Results: Nembro

![Graph showing trend in excess mortality]

Days (Nov. 1, 2019 – Apr. 8, 2020)

Cumulative excess mortality per 1,000 inhabitants

- Nembro
- Synthetic Nembro (Not affected)
- Synthetic Nembro (Red zone)

February 22
March 23

![Graph showing trend in excess mortality]

Days (Nov. 1, 2019 – Oct. 31, 2020)

Cumulative excess mortality per 1,000 inhabitants

- Nembro
- Synthetic Nembro (Not affected)
- Synthetic Nembro (Red zone)

February 22
March 23

Crudu, Di Stefano, Mellace, Tiezzi
The Grey Zone
Barcelona, August 28 2023
### Results: treatment effects

<table>
<thead>
<tr>
<th>Location</th>
<th>April 8, 2020</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albino (Red Zone)</td>
<td>4.27</td>
<td>4.61</td>
</tr>
<tr>
<td>Albino (not affected)</td>
<td>5.38</td>
<td>5.64</td>
</tr>
<tr>
<td>Alzano Lombardo (Red Zone)</td>
<td>4.91</td>
<td>5.35</td>
</tr>
<tr>
<td>Alzano Lombardo (not affected)</td>
<td>6.59</td>
<td>6.73</td>
</tr>
<tr>
<td>Nembro (Red Zone)</td>
<td>7.38</td>
<td>7.84</td>
</tr>
<tr>
<td>Nembro (not affected)</td>
<td>11.80</td>
<td>11.95</td>
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</tbody>
</table>
ASCM and SDiD
ASCM: Albino

Cumulative excess mortality per 1,000 inhabitants

Days (Nov. 1, 2019 - Apr. 8, 2020)

March 23
February 22

Cumulative excess mortality per 1,000 inhabitants

Days (Nov. 1, 2019 - Oct. 31, 2020)

March 23
February 22
ASCM: Nembro

Cumulative excess mortality per 1,000 inhabitants

- Nembro
- Synthetic Nembro

Days (Nov. 1, 2019 - Apr. 8, 2020)

March 23
February 22

Cumulative excess mortality per 1,000 inhabitants

- Nembro
- Synthetic Nembro

Days (Nov. 1, 2019 - Oct. 31, 2020)

March 23
February 22
SDiD: Albino

The Grey Zone

Barcelona, August 28 2023
SDiD: Nembro
Results: ASCM and SDiD estimates

<table>
<thead>
<tr>
<th></th>
<th>SCM</th>
<th>ASCM</th>
<th>SDID</th>
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</thead>
<tbody>
<tr>
<td>Albino</td>
<td>4.61</td>
<td>5.14</td>
<td>4.60</td>
</tr>
<tr>
<td>Alzano Lombardo</td>
<td>6.73</td>
<td>7.59</td>
<td>5.79</td>
</tr>
<tr>
<td>Nembro</td>
<td>7.84</td>
<td>6.91</td>
<td>5.13</td>
</tr>
</tbody>
</table>
Inference and robustness tests
Inference and robustness tests

- In-space placebo tests (RC1)
- Leave-one-out analysis (RC2)
- Restricting donor pool to Red Zone Lombardy municipalities (RC3)
- Backdating of the intervention (RC4)
- Using a different starting date (RC5)
Conclusion

- Timely adoption crucial for NPIs’ effectiveness.

- Introducing a Red Zone around the Serio Valley would have reduced the number of deaths by about two-thirds between March and April 2020.

- These results are robust to several standard checks and different methods.
Thank you for your attention
Placebo tests

Albino
Days (Nov. 1, 2019 − Oct. 31, 2020)
Gap in cumulative excess mortality per 1,000 inhabitants

Alzano
Days (Nov. 1, 2019 − Oct. 31, 2020)
Gap in cumulative excess mortality per 1,000 inhabitants

Nembro
Days (Nov. 1, 2019 − Apr. 8, 2020)
Gap in cumulative excess mortality per 1,000 inhabitants
Leave-one-out estimates

Trends in excess mortality

Days (Nov. 1, 2019 − Oct. 31, 2020)
Cumulative excess mortality per 1,000 inhabitants

Albino
Synthetic Albino (Red zone)
Synthetic Albino (leave-one-out)

February 22
March 23

Alzano
Synthetic Alzano (Red zone)
Synthetic Alzano (leave-one-out)

Nembro
Synthetic Nembro (Red zone)
Synthetic Nembro (leave-one-out)
Restricting donor pool to Red Zone lombardy municipalities

![Diagram of trends in excess mortality]

Days (Nov. 1, 2019 − Oct. 31, 2020)
Cumulative excess mortality per 1,000 inhabitants

- Alzano
- Synthetic Alzano (Red Zone restricted)
- Synthetic Alzano (Red zone)

February 22
March 23

![Diagram of trends in excess mortality]

Days (Nov. 1, 2019 − Oct. 31, 2020)
Cumulative excess mortality per 1,000 inhabitants

- Albino
- Synthetic Albino (Red Zone restricted)
- Synthetic Albino (Red zone)

February 22
March 23

![Diagram of trends in excess mortality]

Days (Nov. 1, 2019 − Oct. 31, 2020)
Cumulative excess mortality per 1,000 inhabitants

- Nembro
- Synthetic Nembro (Red Zone restricted)
- Synthetic Nembro (Red zone)

February 22
March 23

back

Crudu, Di Stefano, Mellace, Tiezzi

The Grey Zone

Barcelona, August 28 2023
Backdating treatment date to January 1, 2020

Trends in excess mortality: Albino and Synthetic Albino

Trends in excess mortality: Alzano and Synthetic Alzano

Trends in excess mortality: Nembro and Synthetic Nembro
Moving treatment date to January 1, 2020
Plausibility of NEPE

![Graphs showing cumulative excess mortality per 1,000 in each city over time.](image-url)