Population Studies
A Journal of Demography

Routledge
Taylor & Francis Group

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rpst20

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To cite this article: Guido Alfani, Marco Bonetti & Mattia Fochesato (2023): Pandemics and socio-economic status. Evidence from the plague of 1630 in northern Italy, Population Studies, DOI: 10.1080/00324728.2023.2197412

To link to this article: https://doi.org/10.1080/00324728.2023.2197412

Published online: 10 May 2023.

Population Studies, 2023
https://doi.org/10.1080/00324728.2023.2197412

Pandemics and socio-economic status. Evidence from the plague of 1630 in northern Italy

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*This paper investigates the biological, socio-economic, and institutional factors shaping the individual risk of death during a major pre-industrial epidemic. We use a micro-demographic database for an Italian city (Carmagnola) during the 1630 plague to explore in detail the survival dynamics of the population admitted to the isolation hospital (*lazzaretto*). We develop a theoretical model of admissions to the* lazzaretto*, for better interpretation of the observational data. We explore how age and sex shaped the individual risk of death, and we provide a one-of-a-kind study of the impact of socio-economic status. We report an inversion of the normal mortality gradient by status for those interned at the* lazzaretto*. The rich enjoyed a greater ability to make decisions about their hospitalization, but this backfired. Instead, the poor sent to the* lazzaretto *faced a relatively low risk of death because they enjoyed better conditions than they would have experienced outside the hospital.*

Supplementary material for this article is available at: http://dx.doi.org/10.1080/00324728.2023.2197412

Keywords: pandemics; plague; historical demography; mortality crises; survival; poverty; health inequality; seventeenth century; Italy

[Submitted September 2021; Final version accepted November 2022]

Introduction

Among the great pandemics of the past, those caused by plague undoubtedly occupy a special position. The Black Death, which affected Europe and the Mediterranean during 1347–52, led to the highest mortality rates ever recorded in the area: in the range of 35–60 per cent, with about 50 million victims (Alfani and Murphy 2017, p. 316). To these we should add difficult-to-estimate victims in the Middle East, other parts of Asia, and probably sub-Saharan Africa (Green 2015, 2018). This event had enduring consequences, as the return of plague to Europe in 1347 after many centuries of absence led to a dramatic change in the demographic regime, which came to be characterized by relatively high mortality as a result of recurring plague outbreaks (Livi Bacci 2007). In most of Europe, this seems to have had positive economic consequences in the long run, providing a sort of relief to Malthusian constraints (Clark 2007; Fochesato 2018; Jedwab et al. 2022).

Notwithstanding the central role played by plague in pre-transitional demography, after a first phase of interest in the 1970s and 1980s (Biraben 1975; Del Panta 1980; Slack 1985), historical demographers seemed to lose interest in the plague for many decades, possibly partly because of the intrinsic difficulty of producing for medieval and early modern times the kind of data required by modern micro-demographic techniques. The situation has now begun to change, with the publication of a few micro-data-based works which have explored topics such as the geographic and seasonal patterns of the spread of plague within cities (Galanaud et al. 2015; Cummins et al. 2016; Henderson 2019) and the age and sex structure of mortality (Manfredini et al. 2002; Séguy et al. 2006; Curtis and Roosen 2017; Alfani and Bonetti 2019), even making some inroads into thorny issues such as the methods of transmission of the infection (Whittles and Didelot 2016; Alfani and Bonetti 2019). Additional insights have been provided by palaeo-archaeological research (DeWitte and Wood 2008; Barbiera and Dalla-Zuanna 2009; DeWitte 2009, 2015). Finally, palaeobiology is contributing greatly to a better understanding of the origin and spread of the different plague waves that affected Europe in medieval and early modern times (for a synthesis, see Green 2020; Guellil et al. 2020).

And yet, many aspects of the great plague epidemics of the past remain largely unknown. Paradoxically, this is especially the case for early modern plagues, even though we have vastly superior documentation for these later episodes compared with the Black Death. Particularly for the seventeenth century, when much of Europe (especially the South) was affected by what were probably the worst plagues since the 1347–52 pandemic (Biraben 1975; Alfani 2013a), it is possible to produce fairly sophisticated demographic and epidemiological analyses, as shown by Alfani and Bonetti (2019). This paper moves further: by making use of the exceptional documentation available for the city of Carmagnola in north-western Italy and its plague isolation hospital during the 1630 plague, it sets out to investigate two questions that have long remained unanswered: (1) How did individual chances of survival depend on socio-economic status (SES)? and (2) What was the impact on survival of medical treatment and hospitalization, whose specific dynamics—as we show—were themselves influenced by SES?

Historical context, data, and approach

During the seventeenth century, Europe was affected by the worst plagues since the Black Death. The first of these major epidemics likely started in northern Europe in 1623 then spread to other areas, becoming more severe as it moved southwards. By 1628–29, a large span of land from Bavaria and Switzerland, through southern France, and reaching into the Pyrenees area was infected. In much of Germany, the spread of plague was facilitated by the movement of armies involved in the exceptionally destructive Thirty Years' War (1618–48). The demographic catastrophe that ensued was the combined result of war, famine, and plague (Eckert 1996; Alfani 2013a). Until 1629, Italy seemed to be a lucky exception: probably also thanks to the action of its public health authorities, which at that time were the most effective in Europe. Indeed, by the start of the seventeenth century they had managed to make Italy plague free.

After centuries of experimentation and advances in fighting the plague, interventions by Italian public health authorities had become multilayered and included (moving from the territorially broader to the narrower): (1) between states: rigid health controls at political boundaries, mountain passes, and marine and river harbours; (2) within states: isolation of infected cities or entire territories by means of sanitary cordons; and (3) within cities: limitations to human contact by a range of temporary restrictions to freedom of movement, as well as quarantines and internment of the infected (and usually co-residents, under suspicion of infection) in specialized institutions, the *lazzaretti* (isolation hospitals) (Cipolla 1976, 1981; Cohn 2010a; Henderson 2013, 2020; Alfani and Murphy 2017). Many of the interventions applied to fighting pandemics today are directly descended from those first developed for fighting the plague.

It seems too optimistic to presume that the Italian health authorities could have prevented the infection from spreading to the Peninsula indefinitely. In any case, subsequent historical developments made this impossible, as in late 1629 German and French armies crossed the Alps to participate in the War of the Mantuan Succession, carrying with them the plague. During the following year, the epidemic covered most of the north plus Tuscany, which was affected relatively mildly. In northern Italy, the overall mortality rate was 30–35 per cent, leading to about two million victims (Alfani 2013a, p. 411). Due to its position close to the mouth of the Susa Valley (from where the French had invaded and towards which the Spanish armies allied to the local rulers, the Dukes of Savoy, converged), the authorities of Carmagnola were well aware of the risk of plague. By 1 January 1630 the city council had already appointed two 'intelligent and expert people' ('*due persone d'intelligenza et esperienza*'; *Ordinati* of Carmagnola, quoted in Abrate 1972, p. 72) to the position of public health officials with the authority to monitor the situation constantly and take all measures deemed necessary to prevent the plague from entering the city. The newly appointed officials immediately established a sanitary cordon to protect Carmagnola and positioned armed guards at all points of access, to check whether incoming visitors held a proper health certificate and to forbid in any circumstance the entry of people from cities or territories placed under a formal ban or simply suspected of being infected. The list of these 'banned' places was kept constantly updated in coordination with the *Magistrato sopra la Sanità* (the central health authority of the state). In April, the public health board was strengthened by the appointment of four additional officials (Abrate 1972, pp. 74–6).

All this proved to be in vain, as from late April the plague was present in the city. In his memoirs, Giovan Battista Gregorio, a hatmaker who claimed that his household had been first to be infected, hinted that the plague might originally have been brought to Carmagnola by the army of the Duke of Savoy, which had been quartered there. Together with his family, Gregorio was promptly moved to the newly built *lazzaretto*: a temporary structure beyond the city walls, incorporating a convent around which wooden huts (*capanne*) for the patients were built. This was, for the standards of the time (when only major cities such as Florence, Milan, and Venice had a permanent plague isolation hospital), a rather well-developed structure (compared e.g. with that of the nearby city of Ivrea during the plague of 1585; Alfani 2013b, pp. 96–9). Good-quality care was provided (see later), and consequently it seems appropriate to refer to admission as a kind of 'hospitalization'. Gregorio's testimony is confirmed by a list of those admitted to the *lazzaretto*: he and his family were the first to be recorded, on 3 May 1630 (see Section 1, supplementary material (SM hereafter) for additional information about the functioning of the plague isolation hospital). In the following weeks the contagion spread rapidly (Figure 1), with the situation spiralling out of control from June, causing the city to be placed under a formal ban from early July (Archival Source AS1). The epidemic reached a peak in August and slowly declined thereafter, especially from the beginning of winter. The plague seemed to resurge in spring 1631, but luckily after May it died out, as shown by the trend in admissions to the *lazzaretto*. Overall, this seasonal pattern matches that reported for other northern Italian communities (Manfredini et al. 2002; Alfani and Bonetti 2019).

On the eve of the epidemic, Carmagnola's 7,600 inhabitants represented quite a sizeable population in this part of Italy at the time: Turin, the capital of the Sabaudian State, was home to no more than 25,000 people. In Carmagnola, the plague caused 1,885 deaths (based on a list drafted at the end of the crisis), equal to a mortality rate of 244 per 1,000. This is significantly below the estimate for northern Italy as a whole, but in line with that reported for other cities in the same region (cf. Alfani and Percoco 2019). During the epidemic, 1,583 people were admitted to the *lazzaretto*, based on a rare and precious source (AS2) that provides us with the name and sex of all patients (clustered by household), the date of their internment and its length in days, and the overall cost borne for their care. This was a fixed rate of 2.5 *fiorini* per day without distinction by age or social status, hence its informative content is captured simply by length of internment. The outcome of the treatment can be obtained by nominative linkage of this source with the aforementioned list of all plague victims. Deaths at the *lazzaretto* numbered 443 (216 males and 227 females), about 28 per cent of those interned: surprisingly low considering that those hospitalized were either infected or known to have been exposed directly to infection. This suggests that living conditions and the level of care at the *lazzaretto* were relatively good, as confirmed by our in-depth analyses. Compared with other cases for which we have information, Carmagnola stands out, as about 55 per cent of those interned at Florence's *lazzaretto* in 1630–31 died, and similarly in other Tuscan cities, while during the 1575–77 plague about 50 per cent of the patients in Padua's *lazzaretto* died, as did up to 73 per cent of those interned in Venice (Stevens Crawshaw 2012, pp. 190–1; Henderson 2019, p. 209). Similar figures have been reported for plague isolation hospitals in the Low Countries during the seventeenth century (Curtis and Han 2021, p. 60). These figures, however, need to be interpreted with care, as they do not only reflect conditions within the *lazzaretto* but also the status of patients at the time of internment. According to our estimates, the absolute majority of those sent to the *lazzaretto* in Carmagnola entered it healthy, lowering the overall mortality rate (as not all became infected thereafter), but this kind of practice would have been impossible to follow in bigger cities, where a larger proportion of the plague isolation hospitals' capacity had to be reserved for those actually sick (see e.g. Henderson 2019, 2020).

Although the records of those sent to the *lazzaretto* are rare and interesting in themselves, they do not provide us with the kind of micro-demographic data required for any deeper exploration of the factors shaping survival among those hospitalized. This information could be obtained only by nominative linkage of additional historical sources, a demanding procedure given the character of the archival documentation available. Fortunately, a strong starting point was available: the database pieced together by Abrate (1972), who reconstructed the complete population structure by household, age, sex, and neighbourhood based on a list (*boccatico*) of all 'mouths' residing in the city (used

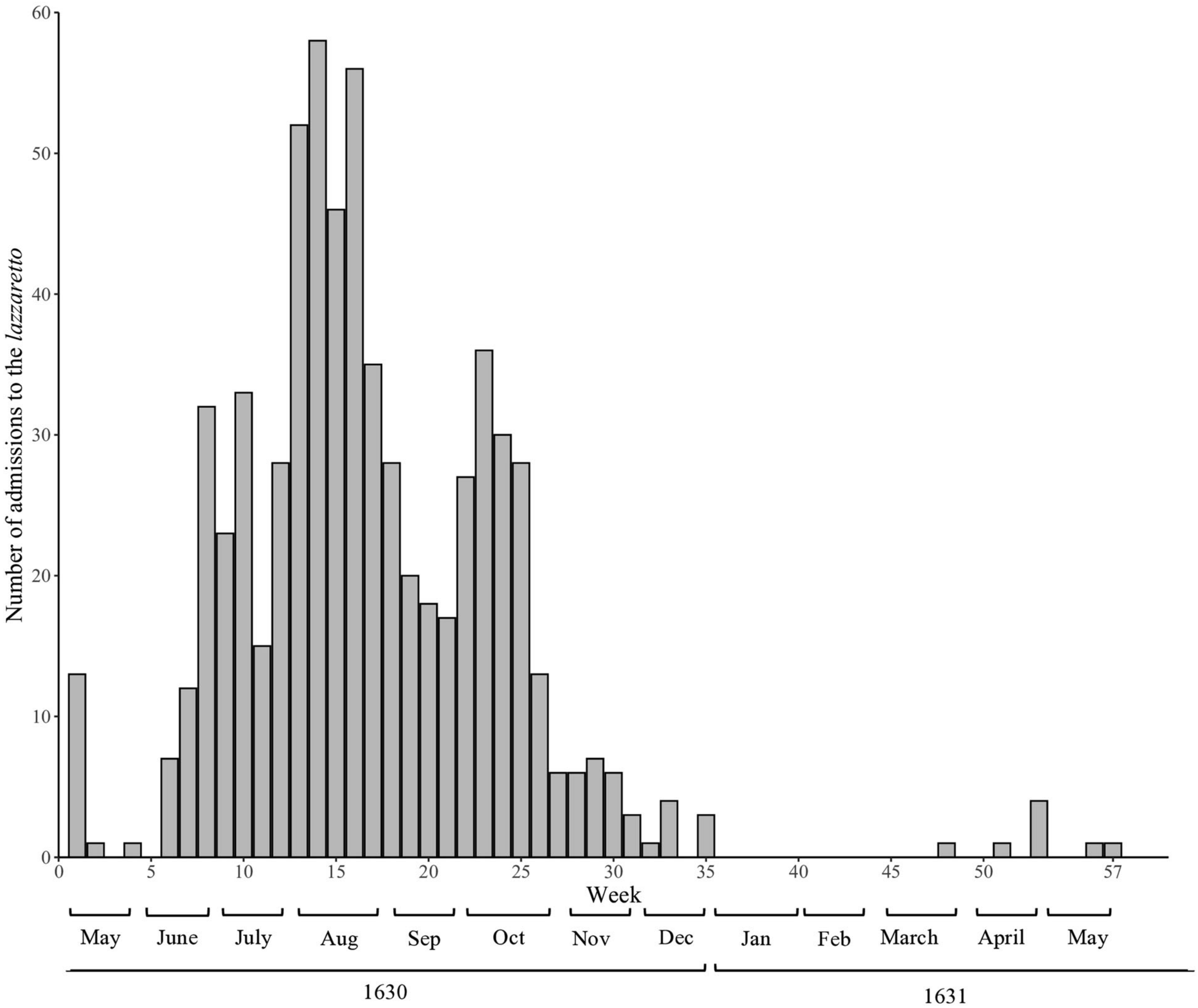


Figure 1 Weekly admissions to the *lazzaretto*: Carmagnola 1630–31
Note: Week 1 begins on 3 May 1630; week 57 ends on 5 June 1631.
Source: See Historical context, data, and methods section; and replication package (Note 3).

for poll tax collection) (AS3). Six neighbourhoods were distinguished: the area within the city walls (*dentro*), three distinct urban areas (*borghi*) physically located immediately outside the walls (Moneta, San Giovanni, and Santa Maria), and two clusters of rural houses located at some distance from the main settlement (*cascine* di Santa Maria and *cascine* di Moneta). To the resulting individual-level information, Abrate added SES, defined at the household level and based on an extraordinary tax on the estimated total income of each household head that was imposed on all those recorded in the *boccatico*. This rather exceptional source distinguished between heads from five income classes. The first three included the wealthiest individuals, such as large and medium landowners, merchants, public officials, and the main artisans. The fourth class included small landowners, most artisans, and lower merchants. The fifth included daily labourers and lesser artisans. To these, a sixth class was added: those who were deemed too poor to pay anything (Abrate 1972, pp. 19–53).

Abrate linked the complete population structure in 1621 to the records of those interned at the *lazzaretto* and to the list of all plague deaths, publishing as a printed appendix the complete details (as just defined) of all individuals who either died of the plague (inside or outside the *lazzaretto*) or were interned at the *lazzaretto* and survived. This procedure has two clear limitations: first, as Abrate did not adjust the 1621 population structure to reflect that of 1630 more precisely by taking into account the vital events (baptisms and burials) that had occurred in between, any direct estimate of mortality rates by age, sex, or other variable will suffer from some degree of imprecision unless calculated only on the hospitalized population, whose complete structure is known (see later and Table S1 (SM, Section 2)). Second, the method and sources that he used do not allow us to identify the exact age of those born after 1621 who died during the plague, so they are simply categorized as '≤10 years'. Finally, probably for reasons of space, Abrate failed to publish the details of individuals who survived the plague without ever being sent to the *lazzaretto*.

Although the choices made by Abrate did result in information allowing us to explore in unprecedented depth the survival process characterizing the *lazzaretto*, they also posed specific challenges which required the development of an ad-hoc approach; however, this approach could be usefully adapted to other cases where similar information constraints apply. Additionally, after digitizing Abrate's database, we performed systematic tests of information coherence and consistency, which led us to identify many probable errors. Because of this, we resorted to double-checking his data against the original archival sources, which led us to apply significant amendments. Our database, then, is a refined and augmented version of the original. Table 1 summarizes some key descriptive statistics.

As our main focus was the importance of SES and hospitalization in determining individual chances of survival, we divided our analyses into two parts. First, we studied the process of admission to the *lazzaretto*. We began by analysing the distribution of households by size (a key variable to determine the individual, household-specific risk of being sent to the *lazzaretto*), and we identified macro groups (social and geographic) that correctly captured the observed heterogeneity in household size. We then developed a theoretical model for how households were selected to be sent to the *lazzaretto*. Divergence between observed household sizes for the admitted households and those predicted by the theoretical model is potentially informative of otherwise unobservable differential behaviours, particularly the (probable) tendency for the richest to try to avoid internment to the *lazzaretto*, with possible consequences in terms of survival.

In the second part of our analysis, we studied the outcome of internment (death or survival) among the admitted. As we could not directly observe the health status of individuals (infected or not) when they were sent to the *lazzaretto*, we introduced some reasonable assumptions to impute their initial health status based on subsequent developments at the individual level. While such classification has the drawback of being based on the outcome, it did allow us to explore the factors determining individual chances of surviving the *lazzaretto*. Regarding internment, the general rule was that whenever an infected person was found, they and their entire household were moved to the *lazzaretto*. Although internment might have had a positive impact on individual chances of survival, the experience was surely not considered very desirable, particularly among the better off. Although levels of healthcare and hygiene maintained at Italian *lazzaretti* were relatively high (Stevens Crawshaw 2012; Henderson 2019), the one set up in Carmagnola was a temporary structure, lacking the comforts to which the rich were accustomed and also presenting growing problems with heating as the season progressed (Abrate 1972, pp. 103–4). It seems reasonable to conclude that the local elite tried to avoid internment, using their economic and political leverage to this end. This seems to have resulted in relatively late hospitalization, leading to higher fatality rates for them and their families.

Analysis of the process of admission of a household to the *lazzaretto*

We begin by exploring the process that led individuals to be admitted to the *lazzaretto*. We first describe, under suitable assumptions, how household size affected the probability of hospitalization of each of its members. We assume that when a single member became infected, the entire household was interned. As a second step, we model household size through a Poisson regression model, and we use additional data to estimate the associated parameters. We then use those results to build homogeneous groups of fiscal classes and neighbourhoods. Lastly, within such groups, we examine the model-predicted household sizes of admitted households and compare them with the observed household sizes for the same groups. From such comparison we draw some interesting conclusions on the process of admission itself.

We can assume that household sizes do not vary due to causes other than the plague during the period of interest. We study the effect of household size on the probability that a household is spared by the infection.

We assume that the number $N = 1 + X$ of members in a household is such that X follows a Poisson distribution with parameter $\lambda > 0$, that is:

$$p_X(x) = P(X = x) = \frac{e^{-\lambda}\,\lambda^x}{x!},\ x\{1,\ 2,\ \ldots\}, \qquad (1)$$

Table 1 Descriptive statistics by neighbourhood, Carmagnola, 1630–31

	Neighbourhood							
	Dentro (A)	Moneta (B)	San Giovanni (C)	Santa Maria (D)	Cascine di Santa Maria (E)	Cascine di Moneta (F)	Unknown	All
Total population	378 (26.70)	314 (22.17)	231 (16.31)	277 (19.56)	43 (3.04)	160 (11.30)	13 (0.92)	1,416
Sex								
Female	206 (54.50)	172 (54.62)	128 (55.41)	150 (54.78)	26 (60.46)	93 (58.12)	4 (30.77)	779 (55.01)
Male	172 (45.50)	142 (45.38)	103 (44.59)	127 (45.22)	17 (39.54)	67 (41.88)	9 (69.23)	637 (44.99)
Fiscal group								
1	16 (4.23)	5 (1.59)	0 (0.00)	2 (0.72)	0 (0.00)	18 (11.25)	0 (0.00)	41 (2.89)
2	48 (12.70)	19 (6.05)	7 (3.03)	6 (2.17)	8 (18.60)	33 (20.62)	0 (0.00)	121 (8.55)
3	40 (10.58)	40 (12.74)	60 (25.97)	24 (8.66)	17 (39.54)	37 (23.13)	0 (0.00)	218 (15.40)
4	125 (33.07)	62 (19.75)	65 (28.14)	59 (21.30)	7 (16.28)	45 (28.13)	0 (0.00)	363 (25.63)
5	123 (32.54)	160 (50.96)	79 (34.20)	162 (58.48)	10 (23.26)	25 (15.62)	0 (0.00)	559 (39.48)
6	21 (5.56)	28 (8.91)	20 (8.66)	24 (8.67)	1 (2.32)	2 (1.25)	0 (0.00)	96 (6.78)
Exempt	4 (1.06)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.28)
Unknown	1 (0.26)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	13 (100.00)	14 (0.99)
Age								
N individuals aged ≤10 years	88 (23.28)	62 (19.75)	50 (21.65)	60 (21.66)	4 (9.30)	26 (16.25)	1 (7.69)	291 (20.55)
N individuals aged 11–89 years	273 (72.22)	248 (78.98)	181 (78.35)	216 (77.98)	39 (90.70)	131 (81.88)	2 (15.38)	1,090 (76.98)
N individuals with missing age	17 (4.50)	4 (1.27)	0 (0.00)	1 (0.36)	0	3 (1.88)	10 (76.92)	35 (2.47)
Mean age (SD)[1]	33.41 (17.17)	35.54 (19.08)	35.33 (18.00)	32.79 (17.15)	32.46 (18.73)	31.42 (16.52)	27.00 (19.79)	33.81 (17.75)
Median age[1]	31	34	34	31	25	29	27	31

[1]Mean and median values of age exclude those of unknown age and children aged ≤10 years. SD is the standard deviation.

Notes: Table shows the distribution by sex, fiscal group, and age of the 1,416 individuals identified through the linkage across the historical sources described in the text. These include patients admitted to the *lazzaretto* (who died or were discharged) and those who died at home. Percentage values (by neighbourhood) are in parentheses.

Source: See Historical context, data, and methods section; and replication package (Note 3).

where '1' refers to the head of household. We have:

$$p_N(n) = P(N = n) = P(X = n - 1) = p_X(n-1) = \frac{e^{-\lambda}\,\lambda^{n-1}}{(n-1)!} \quad (2)$$

for $n = 1, 2, \ldots$. Note that the expected value of N is $E(N) = 1 + \lambda$.

Now, consider a fixed probability $p > 0$ that a randomly selected individual, regardless of age or other characteristics, becomes infected in a household containing no infected individuals. We assume *independence* of the events that individuals from the same household become infected based on the fact that no infected individuals exist in the household (yet).

The probability that all individuals in a household of size n (≥ 1) are spared by the disease is then equal to $(1-p)^n$, and the probability that a randomly selected household (*HH* in equations) is spared by infection is:

$$P(HH\ spared) = (1-p)e^{-\lambda p} \quad (3)$$

which, as expected, decreases in λ for fixed p. See Section 3 (SM) for additional details.

We now turn to the estimation of λ for specific subpopulations, starting from data reported in aggregated form by Abrate (1972, p. 23). These refer to the average *number of children* (including adult children) observed for each of the 36 combinations of neighbourhood and fiscal class. We develop a Poisson model for predicting the number of children in households in each fiscal class/neighbourhood combination (details in Section 4, SM). The model selection procedure establishes significantly different predictions across two geographic areas of residence. The first includes the neighbourhoods of *dentro*, *moneta*, and *cascine* di Santa Maria (from now on referred as A-B-E); the second includes the neighbourhoods of San Giovanni, Santa Maria, and *cascine* di Moneta (from now on referred as C-D-F). A feature distinguishing neighbourhoods A-B-E from C-D-F is that the first cluster includes the urban area within the walls, with more spatially concentrated houses and, on average, smaller households. Significantly different predictions are also established across four groups of fiscal classes (1-2-3 combined, 4, 5, and 6). Within each of the eight combinations of clusters of neighbourhoods and fiscal groups, the prediction is assumed to be homogeneous. Table S5 (SM) compares the predicted average numbers with the observed averages.

Now we turn to the total number of household members. The total size of a household is given by:

$$\text{Total HH size} = 1(\text{household head}) + \text{children} + \text{servants} + \text{others(non-servants)}, \quad (4)$$

where the last group includes spouses and other relatives. Note that more than one family could live in the same household. We assume that all counts (beyond the head of household) follow a Poisson distribution and are independent, meaning that the total household size is also Poisson distributed. We estimate the average number of servants for fiscal groups 1–5 to be 0.25, based on the *lazzaretto* records and considering that for these fiscal groups we did not find significant differences in the number of servants. As no servants were observed in households belonging to fiscal group 6 (the poorest), we set that estimate to 0. We estimate the average number of other individuals (non-servants) to be 1.37, for consistency with the observed size of the groups of co-residents. For example, the estimated average size for a household residing in neighbourhoods A-B-E and belonging to fiscal group 5 (where the estimated average number of children is 1.483) is: $1 + 1.483 + (0.25 + 1.37) = 4.103$.

The resulting model-based averages are computed within each combination of neighbourhood and fiscal group, as shown in Table 2 (and Figure S3, SM). The table also shows the predicted vs observed proportions of households admitted. Figure 2 shows graphically the observed and estimated proportions admitted for the eight groups (and marginally for the four fiscal groups). Overall, the estimated proportions capture the observed trend well, suggesting the model fit is reasonably good. Only for fiscal group 6 (that with the smallest households) is the proportion of households admitted to the *lazzaretto* much smaller than that predicted by our model. This is probably because one-person households, when infected, were *not* usually brought to the *lazzaretto*, as many such individuals, without any support from co-residents, were found dead in their homes.

We now compare the model-predicted sizes of admitted households with the observed number of household members in the *lazzaretto* (with the addition of those members who died at home). In Section 3 (SM) we obtain the distribution of household size among households admitted to the *lazzaretto*, assuming that all members of a household were transferred to the *lazzaretto* as soon as one became infected, to reflect public health policies of the time. In addition, we obtain the expression of

Table 2 Summary of model results comparing the predicted and the observed proportions of households admitted to the *lazzaretto* within each combination of geographic area and fiscal group, and marginally for the four fiscal groups: Carmagnola, 1630–31

Geographic area	Fiscal group	*N* households[1]	Observed average number children[2]	Estimated average number children	Other members[3]	Estimated average household size[4]	Estimated rate of admission (household)[5]	*N* admissions	Observed rate of admissions (household)
A-B-E	1-2-3	109	2.676	2.597	1.62	5.217	0.326	36	0.330
	4	181	2.161	2.033	1.62	4.653	0.297	41	0.226
	5	222	1.368	1.483	1.62	4.103	0.267	73	0.328
	6	143	0.998	1.053	1.37	3.423	0.229	15	0.104
C-D-F	1-2-3	116	3.094	3.172	1.62	5.792	0.354	47	0.405
	4	145	2.319	2.483	1.62	5.103	0.320	46	0.317
	5	225	1.922	1.812	1.62	4.432	0.285	72	0.320
	6	92	1.370	1.287	1.37	3.657	0.242	15	0.054
Total (population-weighted average)	1-2-3	225	2.890	2.893	1.62	5.513	0.359	83	0.364
	4	326	2.230	2.233	1.62	4.853	0.324	87	0.266
	5	447	1.640	1.649	1.62	4.269	0.292	145	0.324
	6	235	1.130	1.145	1.37	3.515	0.248	30	0.127

[1]The observed number of households is from Abrate (1972, p. 23).
[2]The observed average number of children is from Abrate (1972, p. 23).
[3]Average number of servants and other household members in addition to children and the head of household. Note that for all fiscal groups, except fiscal group 6, the average number of servants (0.25) is added to the average number of other household members (1.37); see discussion in the main text.
[4]Estimates include the head of household.
[5]Based on estimated average household size, but using the observed average numbers for children yields almost identical results ($p = 0.075$).
Note: Predictions are based on $p = 0.075$.
Source: As for Table 1.

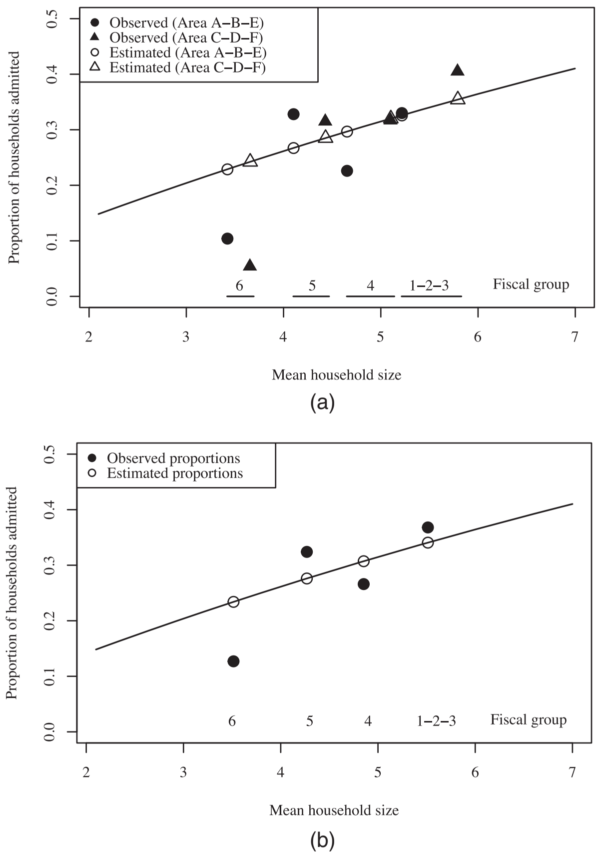


Figure 2 Observed and predicted proportions of households admitted by (a) fiscal group and geographic area; and (b) fiscal group only: Carmagnola 1630–31
Note: Calibrated value $p = 0.075$.
Source: As for Figure 1.

average size of households admitted to the *lazzaretto*. These calculations show that, as expected, the probability of admission rises with household size, and therefore, households admitted to the *lazzaretto* tend to be larger on average than those not admitted (Table 3). In Table 3 we also compare observed average household size with predicted average household size for admitted households, for each combination of neighbourhood and fiscal class.

While the observed proportions of households admitted seem to be compatible (except for the smallest households) with the model predictions in Table 2, the average household size is smaller than expected if indeed the entire household was admitted when the first infected individual was reported. This suggests that in practice, not all members of the infected household were transferred to the *lazzaretto* (or had died at home); some were left behind. This effect is largest for fiscal groups 1-2-3 and 4 in area C-D-F, and smallest for fiscal group 6 in both areas.

One reason for leaving some household members behind might have been the availability of space to quarantine them at home. This would be consistent with the larger gaps between the observed and estimated household sizes in the C-D-F area, which includes the less densely populated neighbourhoods where the largest households were usually located. Another reason for leaving some household members behind could be resistance to being brought to the *lazzaretto*, perceived as a dangerous and unpleasant place. Richer households might have had more leverage in convincing the authorities to make exceptions and leave at home some household members with no sign of illness. This hypothesis is consistent with the observed differences in Table 3, as the greatest differences between observations and predictions concern the richest households in C-D-F: the difference is equal to 3.48 for fiscal group 1-2-3 and declines monotonically with wealth reaching 1.82 for group 6. This view is seemingly confirmed by the lag between admission to the *lazzaretto* of individuals from the same household, which is way shorter for the poorest strata (Table 4), and by the observation that when focusing on children only, those from wealthier households were less likely to

Table 3 Comparison of predicted and observed average household sizes of admitted households, by fiscal group and geographic area: Carmagnola, 1630–31

Geographic area	Fiscal group	*N* households	Estimated average household size[1]	Estimated average household size (with observed rates)[2]	Estimated average household size in admitted household[3]	Observed average household size in admitted household[4]	Difference (observed–estimated)
A-B-E	1-2-3	109	5.217	5.296	5.870	3.860	−2.010
	4	181	4.653	4.781	5.300	3.000	−2.300
	5	222	4.103	3.988	4.740	2.710	−2.030
	6	143	3.423	3.368	4.040	2.660	−1.380
C-D-F	1-2-3	116	5.792	5.714	6.450	2.970	−3.480
	4	145	5.102	4.939	5.760	2.450	−3.310
	5	225	4.432	4.542	5.080	2.750	−2.330
	6	92	3.657	3.740	4.280	2.460	−1.820

[1]Uses predicted averages for children from the Poisson model; includes the head of household.
[2]Uses observed averages for children; includes the head of household.
[3]Computed from estimated average household size using $p = 0.075$.
[4]Includes individuals dying at home.
Source: As for Table 1.

be interned in the *lazzaretto* compared with those from poorer households (Table S8, SM). These conclusions are relevant for our later interpretation of the outcome of hospitalization.

Analysis of the outcomes after admission to the *lazzaretto*

Reconstruction of the patient's condition at admission

For each individual who entered the *lazzaretto*, we know their socio-economic and demographic characteristics, how long they remained in the *lazzaretto*, and whether they survived (the only possible outcomes of hospitalization were death or discharge in healthy condition). But we do not know whether individuals entered sick or healthy, nor whether they became infected inside or outside the *lazzaretto*. To illuminate these aspects, which are crucial for analysing the individual probability of survival of those hospitalized, we exploit the historical information about disease history (progression across stages) for this plague and the observed distribution of length of hospitalization combined with the outcome (death or discharge). Based on available historical information, we know that the disease often developed very rapidly, resulting in death within the first 8–10 days after infection. After this

Table 4 Average lag between first and last entry to the *lazzaretto* of household members, by geographic area and fiscal group: Carmagnola, 1630–31

Geographic area	Fiscal group	Average lag in days between first and last entry by household with at least two members admitted in the *lazzaretto*
A-B-E	1-2-3	18.58 (32.50)
	4	7.97 (21.12)
	5	8.41 (24.56)
	6	3.93 (14.96)
C-D-F	1-2-3	9.55 (23.77)
	4	6.48 (19.76)
	5	10.33 (30.99)
	6	0.00 (0.00)

Notes: The table shows, for each combination of cluster of neighbourhoods and fiscal group, the average lag between admission to the *lazzaretto* of the first and last household member, computed across households where at least two members were admitted. Standard deviations are shown in parentheses.
Source: As for Table 1.

phase, the probability of surviving increased and the individual could recover, although needing a long convalescence (Abrate 1972, p. 65).

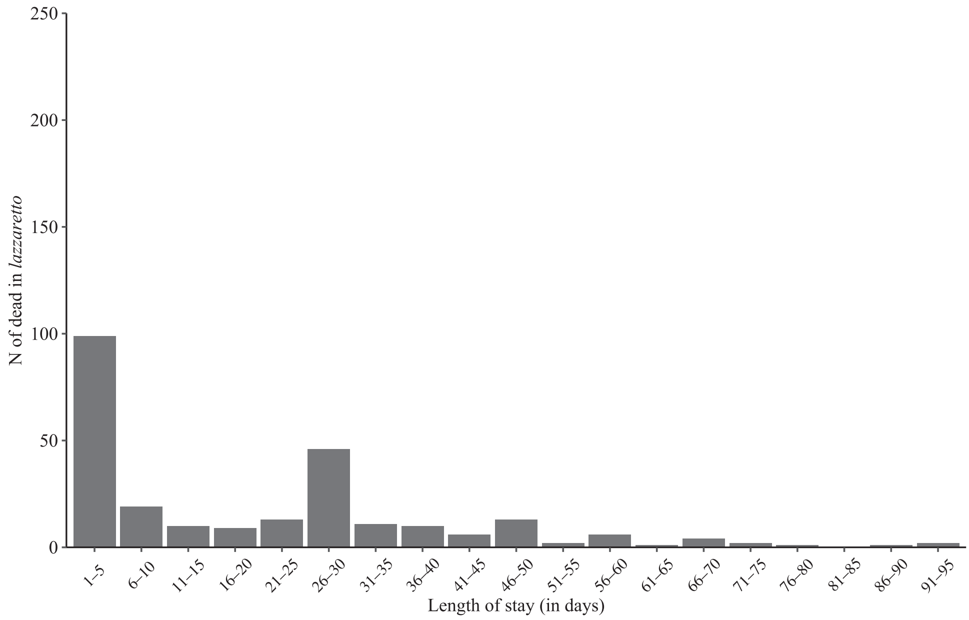
Among the patients admitted to the *lazzaretto*, we observe five groups (shown graphically in Figure 3):

- 49 per cent of the admitted individuals who survived were hospitalized for exactly 30 days (Figure 3(b)). This corresponds to the full length of the mandated quarantine period. Indeed, the *lazzaretto* was compelled to discharge a patient who had never shown any sign of illness at the exact end of the quarantine period, as clarified in an order sent by the *Magistrato sopra la Sanità* to the Carmagnola government dated 9 July 1630 (AS4). So we can reasonably assume that those who spent exactly 30 days at the *lazzaretto* had been admitted healthy and never developed symptoms, as illness would have either extended the length of their stay (diseased period plus 30 days of quarantine following recovery) or led to death. An additional 11 per cent of the admitted individuals who survived were discharged before the minimum period of quarantine.
- 76 per cent of those who died in the *lazzaretto* passed away within 30 days of entry (Figure 3 (a)). The distribution of length of stay in this group resembles the probability of dying after infection as described by the historical sources: most died in the first 10 days from internment, and longer periods of hospitalization before death were relatively rare. We conclude that these individuals were likely diseased when they entered the *lazzaretto*.
- Between the 40th and 50th day after admission, we observe a substantial number of individuals being discharged. We conjecture that these patients were diseased when admitted. They needed some days to recover from symptoms, assumed to be at most 20 days (recall that the conditional probability of dying, having survived the first 8–10 days of disease, was extremely low). After recovery, they were quarantined in the *lazzaretto* for an additional 30 days. This leads to the observed discharges after 40–50 days (10–20 days to recover plus 30 days of post-recovery quarantine).
- We observe two additional groups of individuals: those who died after the 30th day from admission and those who were discharged after more than 50 days from entry. Assuming the standard disease progression, we conclude that members of both groups were admitted healthy but were infected while at the *lazzaretto*. Those in the first group died, whereas those in the second were infected during their quarantine period (say, at least one day after admission), recovered in the following 20 days, and then suffered an additional quarantine of 30 days.

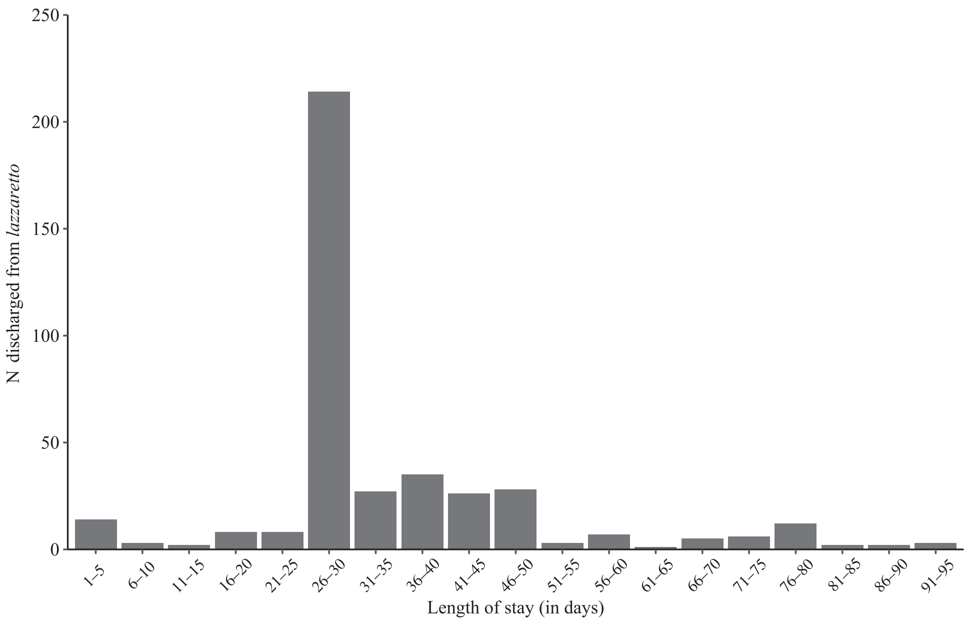
We use the patterns observed here to assign all those admitted to the *lazzaretto* to one of these five types (see Section 6, SM, for tests of sensitivity to the 30- and 50-day thresholds). Note that this classification is not based on other observed explanatory variables (sex, age, neighbourhood), hence it can enter the regression analysis as an additional variable. Table 5 reports the main characteristics of each type and shows their joint distributions with a series of explanatory variables. For completeness we also list two types of individuals who did not enter the *lazzaretto* (types 6 and 7). Finally, we observe that a substantial number of deaths, 42 (21 per cent of the deaths occurring within the first 30 days of stay), were registered on the exact 30th day from entrance. We suspect a process of day heaping: these deaths, which had likely occurred over the previous 29 days, seem to have been registered together with the recording of the discharge of another household member who had survived the quarantine. We redistribute them across the previous 29 days following the observed frequency distribution of times until death. This puts most deaths within a few days from admission, which seems reasonable due to the disease progression. This does not impact our regression analyses, as we do not exploit time-to-death information.

Probability of surviving and being discharged

We test the probability of being discharged from the *lazzaretto* as a function of the condition of the patients hospitalized, using the information on the patient's condition at admission (sick or healthy) as summarized in Table 5 and a series of potential determinants of the hospitalization outcome: SES, biological sex, age, and area of residence. We restrict the data set to the 677 individuals who entered the *lazzaretto*. We further exclude seven individuals without an identifiable SES, leaving a data set of 670. Of these, 44 per cent entered healthy and survived, while 17 per cent entered diseased and



(a) Individuals who died in the *lazzaretto*



(b) Individuals who survived and were discharged

Figure 3 Distribution of length of stay in the *lazzaretto*: Carmagnola 1630–31
Notes: This figure shows the distribution of length of stay of patients who: (a) died; and (b) survived and were discharged from the *lazzaretto*. The bin width is five days. For ease of visualization, we exclude the small fraction of cases who stayed in the *lazzaretto* for more than 100 days (2.4 per cent of patients); these are, however, included in all the subsequent analyses.
Source: As for Figure 1.

survived (the Pearson's χ^2 test between the two group is 81.842 with one degree of freedom and *p*-value < 0.001). The remaining 39 per cent died in the *lazzaretto*.

To test the effect of hospitalization on the probability of surviving the *lazzaretto*, we define the following variable:

$$y_i = \begin{cases} 1 & \text{if the } i\text{th individual survived and was discharged} \\ 0 & \text{if the } i\text{th individual died in the } \textit{lazzaretto}, \end{cases} \quad (5)$$

Table 5 Distribution of types (condition on entry and outcome) in the data set, by age, sex, and fiscal status: Carmagnola, 1630–31

		Type							
Outcome		1 Death	2 Survival	3 Survival	4 Death	5 Survival	6 Death	7 Death	
Length of stay in *lazzaretto* (days)		≤30	31–50	≤30	>30	>50	0	0	
Classification		Entered sick and died in the *lazzaretto*	Entered sick and recovered	Entered healthy and survived	Entered healthy, became sick in the *lazzaretto*, and died	Entered healthy, became sick in the *lazzaretto,* and recovered	Died at home (family admitted)	Died at home (family not admitted)[1]	Total—all types
Total number of cases (percentage of total)		198 (14.02)	116 (8.22)	251 (17.78)	63 (4.46)	49 (3.47)	311 (22.02)	424 (30.03)	1,412
Age group	≤10	42 (14.53)	34 (11.76%)	72 (24.91)	16 (5.54)	15 (5.19)	52 (17.99)	58 (20.07)	289
	11–20	41 (12.28)	31 (9.28)	65 (19.46)	10 (2.99)	9 (2.69)	74 (22.16)	104 (31.14)	334
	21–30	31 (15.82)	16 (8.16)	32 (16.33)	9 (4.59)	8 (4.08)	41 (20.92)	59 (30.10)	196
	31–40	22 (12.15)	13 (7.18)	23 (12.71)	11 (6.08)	7 (3.87)	37 (20.44)	68 (37.57)	181
	41–50	26 (15.20)	11 (6.43)	23 (13.45)	9 (5.26)	7 (4.09)	43 (25.15)	52 (30.41)	171
	51–60	13 (11.30)	6 (5.22)	18 (15.65)	3 (2.61)	1 (0.87)	33 (28.70)	41 (35.65)	115
	60+	17 (18.68)	4 (4.40)	9 (9.89)	4 (4.40)	1 (1.09)	30 (32.97)	26 (28.57)	91
	NA	6 (17.14)	1 (2.86)	9 (25.71)	1 (2.86)	1 (2.86)	1 (2.86)	16 (45.71)	35
Sex	Female	106 (13.62)	72 (9.25)	142 (18.25)	45 (5.78)	30 (3.86)	158 (20.31)	225 (28.92)	778
	Male	92 (14.51)	44 (6.94)	109 (17.19)	18 (2.84)	19 (3.00)	153 (24.13)	199 (31.39)	634
Fiscal group	1-2-3	50 (13.19)	23 (6.07)	71 (18.73)	16 (4.22)	10 (2.64)	105 (27.70)	104 (27.44)	379

(*Continued*)

Table 5 Continued.

	Type							
	1	2	3	4	5	6	7	
Outcome	Death	Survival	Survival	Death	Survival	Death	Death	
Length of stay in *lazzaretto* (days)	≤30	31–50	≤30	>30	>50	0	0	
Classification	Entered sick and died in the *lazzaretto*	Entered sick and recovered	Entered healthy and survived	Entered healthy, became sick in the *lazzaretto*, and died	Entered healthy, became sick in the *lazzaretto,* and recovered	Died at home (family admitted)	Died at home (family not admitted)[1]	Total—all types
4	36 (9.92)	28 (7.71)	60 (16.53)	16 (4.41)	9 (2.48)	87 (23.97)	127 (34.99)	363
5	100 (17.99)	50 (8.99)	95 (17.09)	26 (4.68)	23 (4.14)	99 (17.81)	163 (29.32)	556
6	10 (10.42)	13 (13.54)	23 (23.96)	5 (5.21)	6 (6.25)	20 (20.83)	19 (19.79)	96
Exempt	0 (0.00)	1 (25.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (75.00)	4
Unknown	2 (14.29)	1 (7.14)	2 (14.29)	0 (0.00)	1 (7.14)	0 (0.00)	8 (57.14)	14

[1]Includes 12 individuals who died at home but we do not know the household they belonged to.
Notes: The top five rows show the type, the patient's condition on exit from the *lazzaretto*, their length of stay in the *lazzaretto*, the description of different cases assigned to the records, and the number of cases in the data set (with corresponding percentages in parentheses). The following rows show the distribution of types across age, sex, and fiscal groups (in Table S9, SM, we also show the distribution of types by neighbourhood). Percentage distributions are computed within age, sex, and fiscal groups. The Pearson's χ^2 test between males and female is 13.255 (with six degrees of freedom and p-value = 0.039). The Pearson's χ^2 test between fiscal groups 1-2-3, 4, and 5 only is 43.031 (with 18 degrees of freedom and p-value = 0.001).
Source: As for Table 1.

which can take the values '1' and '0' with probabilities π_i and $1 - \pi_i$, respectively. We model the probability of survival, π_I, through a logistic regression model. Among the covariates we include variables capturing, for each individual *i*, their condition at entrance (healthy or sick), age, sex, fiscal group, and geographic area. We maintain the same grouping by fiscal class and neighbourhood used in the previous section, for consistency and because we expect structural differences across all households to be replicated within the *lazzaretto*. We test the effect of age, modelling it as both an ungrouped and grouped variable. Given the right-skewed distribution of age across the population (Figure S4, SM), we also explore a logarithmic transformation of age without observing changes in our conclusions. We use the Akaike Information Criteria within a forward and backward variable selection procedure for preliminary model selection. We then proceed with a series of likelihood ratio tests to identify a robust and significant final model. We prune some interaction terms which are difficult to interpret (shown in Section 7, SM). The final model is Model (5) in Table 6. For completeness, the table also shows the results of alternative specifications.

As Table 6 shows, being admitted healthy greatly increases the individual chances of surviving internment at the *lazzaretto* and being discharged. Men suffer from a slight disadvantage, and the general chances of survival decrease with age. However, modelling age as a grouped variable (Model (3)) allows us to highlight those who were at greatest risk of dying of the plague: adults aged 41–50 (for the over-60s, we can presume that also other causes of death might have played an important role). A concern might arise from the fact that our analyses are implemented on a mixture of individuals who caught the plague before/after their admission to the *lazzaretto* and those who likely never caught the plague. Consequently, in Table 7 we restrict the analysis to the individuals who did become infected at some point (types 1, 2, 4, and 5). While we lose the ability to detect the overall effect of condition at entrance and the sample size is reduced by 37 per cent, the impact of SES becomes more significant. Of particular note is the case of the poor (fiscal class 6), who appear to have enjoyed better chances of surviving the plague compared with all other groups. Sex becomes non-significant, suggesting that the observed differences in survival between men and women were due to differential exposure to the risk of infection and not to biological factors per se.

Discussion

Our results can be usefully placed in the broader context of the literature on mortality by SES in both pre-industrial and modern pandemics, as well as the more specialized literature about factors affecting plague mortality more generally. Regarding the latter, many studies have explored the biological factors shaping mortality. Overall, the case of Carmagnola confirms the position prevalent in the literature that plague affected both sexes similarly. This was the case, for example, in a range of sixteenth- and seventeenth-century plagues in England (Bradley 1977; Schofield 1977; Scott and Duncan 2001; Whittles and Didelot 2016) and Italy (Del Panta 1980; Alfani and Bonetti 2019). Also, during the fourteenth-century Black Death and the early plagues that followed, biological sex does not appear to have significantly affected the chances of survival, based on skeletal sources (DeWitte 2009), although a recent study of the southern Netherlands reported some over-representation of women among plague victims in the same period (Curtis and Roosen 2017), and this situation seems to have persisted in early modern times (Curtis and Han 2021). Interestingly, a study of six plagues occurring in Milan between 1452 and 1523 reported a similar disadvantage for women but attributed it to the high prevalence of poor widows and immigrant women in some of the most overcrowded parts of the city, where infection might have spread more easily (Alfani and Cohn 2007). Also, in Carmagnola's *lazzaretto*, differences in exposure to the risk of infection based on gender roles mattered, as we find a higher chance of survival for males interned healthy compared with females interned healthy ($p \leq 0.01$). This hints at differential treatment within the hospital: either an inferior level of care given to women or some sort of participation by healthy women in the daily activities of the institution, possibly involving care for the sick, which might have led to a higher risk of infection and higher mortality for non-biological reasons. Some support for the second interpretation, which we believe is the stronger, comes from a range of studies providing evidence that during epidemics certain practical tasks were women's responsibility, leading to a higher risk of infection (for a synthesis, see Curtis and Han 2021, pp. 66–7). Women are also known to have worked as servants, and even as practitioners, in Italian early modern *lazzaretti* (Stevens Crawshaw 2012, pp. 133–4, 161–2), and these workers might have sought some help from interned women who looked healthy.

Table 6 Logistic analysis of the probability of surviving the *lazzaretto*: Carmagnola, 1630–31

		Model				
		(1)	(2)	(3)	(4)	(5)
Intercept		−0.576***	−0.149	−0.338	−0.478**	−0.041
		(−1.000; −0.150)	(−0.643; 0.346)	(−0.864; 0.188)	(−0.884; −0.071)	(−0.513; 0.429)
Condition at entrance	Diseased	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	Healthy	2.074***	2.074***	2.074 ***	1.656***	1.660***
		(1.660; 2.490)	(1.660; 2.490)	(1.660; 2.490)	(1.160; 2.150)	(1.160; 2.160)
Sex	Female	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	Male	0.023	0.016	−0.005	−0.393*	−0.399*
		(−0.330; 0.337)	(−0.338; 0.370)	(−0.364; 0.353)	(−0.876; 0.088)	(−0.876; 0.075)
Fiscal group	5	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	1-2-3	0.044	0.058	0.070	0.057	0.072
		(−0.428; 0.516)	(−0.411, 0.528)	(−0.399; 0.540)	(−0.415; 0.531)	(−0.396; 0.541)
	4	0.253	0.277	0.287	0.243	0.260
		(−0.268; 0.774)	(−0.260; 0.813)	(−0.246; 0.820)	(−0.281; 0.767)	(−0.278; 0.799)
	6	0.678	0.714	0.716	0.648*	0.724*
		(−0.558; 0.235)	(−0.178; 1.610)	(−0.177; 1.610)	(−0.165; 1.530)	(−0.166; 1.610)
Geographic area	A-B-E	*Ref*	*Ref*	*Ref*	–	–
	C-D-F	−0.161	−0.151	−0.142	–	–
		(−0.558; 0.235)	(−0.548; 0.247)	(−0.540; 0.256)		
Age		–	−0.016***	–	–	−0.016***
			(−0.026; −0.006)			(−0.026; −0.006)
Age group	≤10	–	–	*Ref*	–	–
	11–20	–	–	0.069	–	–
				(−0.436; 0.574)		
	21–30	–	–	−0.366	–	–
				(−0.956; 0.224)		
	31–40	–	–	−0.516	–	–
				(−1.160; 0.130)		
	41–50	–	–	−0.641**	–	–
				(−1.300; −0.019)		
	51–60	–	–	−0.273	–	–
				(−1.100; 0.556)		
	>60	–	–	−1.051***	–	–
				(−1.860; −0.242)		
Condition at entrance × Sex	Healthy × Male	–	–	–	1.039***	1.036 ***
					(0.257; 1.820)	(0.261; 1.810)
Sample size		655	655	655	655	655
Wald χ^2 test (df)		128.4 (6)	131.5 (7)	132.4 (12)	129.6 (6)	132.6 (7)

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Notes: The dependent variable is the probability of being discharged from the *lazzaretto*. Models (1), (2), and (3) include only main effects. Models (4) and (5) include the interaction effect chosen on the basis of model selection, with (5) being the best model and (4) a version of it without age. Ref indicates the reference category; df are the degrees of freedom. The 95 per cent confidence intervals are based on standard errors clustered at the household level (following Abadie et al. 2017) and are shown in parentheses.

Source: As for Table 1.

Regarding age, our study provides support to the recent reassessment of age-specific risk of death based on the case study of Nonantola, also in northern Italy and affected by the 1629–30 plague (Alfani and Bonetti 2019). In Carmagnola, plague seems to have affected adults in a particularly severe way, starting with the 41–50 age group (Table 6). In Nonantola, the risk of death peaked around ages 40–60. Our study and that of Nonantola are unique in being grounded in a complete reconstruction of the age and sex structure of the population at risk (although in our case, for the hospitalized population only), which allows us to overcome a systematic fault in earlier studies, which used the method of excess mortality and thus could not distinguish between the simple age distribution of observed deaths and the age-specific mortality rates. As a consequence, those studies argued for young adults being worst affected (with a peak in the 11–20 age group: see Manfredini et al. 2002; Alfani and Cohn 2007), whereas in fact young adults suffered a *lower* risk of death compared with older groups and were

Table 7 Logistic analysis of the probability of surviving the *lazzaretto* among infected patients only: Carmagnola, 1630–31

		Model				
		(1)	(2)	(3)	(4)	(5)
Intercept		−0.402* (−0.842; 0.036)	0.083 (−0.456; 0.623)	−0.110 (−0.626; 0.405)	−0.442** (−0.869; −0.015)	0.033 (−0.454; 0.520)
Condition at entrance	Diseased	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	Healthy[1]	0.249* (−0.258; 0.757)	0.239 (−0.266; 0.744)	0.230 (−0.234; 0.694)	−0.042 (−0.623; 0.538)	−0.012 (−0.597; 0.571)
Sex	Female	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	Male	−0.201 (−0.614; 0.212)	−0.238 (−0.652; 0.175)	−0.243 (−0.656; 0.171)	−0.393 (−0.878; 0.090)	−0.400 (−0.881; 0.079)
Fiscal group	5	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
	1-2-3	−0.094 (−0.624; 0.436)	−0.102 (−0.633; 0.430)	−0.067 (−0.596; 0.461)	−0.087 (−0.613; 0.438)	−0.097 (−0.615; 0.420)
	4	0.225 (−0.327; 0.777)	0.230 (−0.336; 0.796)	0.254 (−0.283; 0.791)	0.193 (−0.363; 0.750)	0.198 (−0.334; 0.732)
	6	0.780* (−0.049; 1.610)	0.809* (−0.034; 1.650)	0.847** (0.062; 1.630)	0.765* (−0.048; 1.580)	0.792** (−0.016; 1.570)
Geographic area	A-B-E	*Ref*	*Ref*	*Ref*	–	–
	C-D-F	−0.267 (−0.699; 0.165)	−0.243 (−0.675; 0.189)	−0.243 (−0.651; 0.164)	–	–
Age		–	−0.018*** (−0.029; −0.006)	–	–	−0.017*** (−0.029; 0.006)
Age group	≤10	–	–	*Ref*	–	–
	11–20	–	–	−0.078 (−0.671; 0.516)	–	–
	21–30	–	–	−0.400 (−1.060; 0.258)	–	–
	31–40	–	–	−0.371 (−1.060; 0.317)	–	–
	41–50	–	–	−0.511 (−1.230; 0.127)	–	–
	51–60	–	–	−0.683 (−1.630; 0.268)	–	–
	>60	–	–	−1.284** (−2.300; −0.265)	–	–
Condition at entrance × Sex	Healthy × Male	–	–	–	0.774 (−0.241; 1.790)	0.662 (−0.279; 1.600)
Sample size		414	414	414	414	414
Wald χ^2 test (df)		9.1 (6)	17.2 (7)	17.1 (12)	9.9 (6)	17.7 (7)

$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

[1]The 'healthy' in this table include only those who were admitted to the *lazzaretto* and became infected while interned. Consequently, the variable does not reflect the overall effect of condition at entry, for which the results in Table 6 should be considered instead.

Notes: The dependent variable is the probability of being discharged from the *lazzaretto*. Models (1), (2), and (3) include only main effects. Models (4) and (5) include the interaction effect chosen on the basis of model selection, with (5) being the best model and (4) a version of it without age. Ref indicates the reference category; df are the degrees of freedom. The 95 per cent confidence intervals are based on standard errors clustered at the household level and are shown in parentheses.

Source: As for Table 1.

particularly abundant among those who died simply because their cohorts were much larger. Indeed, our more refined analysis of Carmagnola's data contradicts that of Abrate (1972), who fell into the trap just described, working on excess mortality. In another respect, however, our study is in agreement with all the literature discussed so far: the very young (ages ≤10) were affected relatively lightly by the plague.

Regarding SES, the consensus among historians is that by the end of the Middle Ages, plague had acquired a clear social connotation, becoming a disease affecting the poor preferentially (Slack 1985; Cohn 2010b; Alfani 2013b). This view finds support in the medical treatises of the time, which systematically advised the expulsion or at least isolation of beggars and vagrants from the city at the first suspicion of plague, to preserve public health (Cohn 2010a). Empirical attempts at testing this social connotation of plague, however, remain scattered, basically due to the difficulty of categorizing individuals by SES. In their study of Nonantola, Alfani and Bonetti (2019) managed to distinguish the overall population into two broad classes with different statuses (a ‘high’ class comprising all those belonging to households whose head was given a title, e.g. *messere* or gentleman, and a ‘low’ class comprising everybody else), but this distinction proved non-significant. While this might reflect a somewhat limited status differential in mortality caused by the 1630 plague (see later), it is undoubtedly possible that the categorization used was too rough to capture existing differences. Other studies using individual-level information were even less precise in assigning status, usually resorting simply to making reasonable inferences based on urban areas, which were affected more severely. For example, Cummins et al. (2016) in their analysis of the string of plagues that affected London during 1560–1665 reported that the first outbreaks almost invariably started in the poorest parts of the city, whereas the richest parishes tended to be relatively spared. Similar conclusions were reached by Galanaud et al. (2015) for the French city of Dijon during the plagues of 1400 and 1428, and by Cohn and Alfani (2007) for Milan in 1523. All these data-driven studies confirm the qualitative assertions made by early modern Italian plague treatises based on direct experience: for example, ‘For Piedmont’s plague of 1599–1600 [the doctor] Roffredi identified Turin’s victims as concentrated in “the city’s vilest neighbourhoods”, where leather-workers, grooms, stable boys, working girls […], the lowest of the whores […], and the meanest of the plebs resided’ (Cohn 2010a, p. 214).

Although the overall evidence that late medieval and early modern plague had a social connotation is quite strong, given the extremely high mortality rates for the 1629–30 epidemic in northern Italy (35 per cent on average) it is clear that a part of the elite also died. We have an indication of this in the large proportions of members of city councils who died in service (Alfani and Percoco 2019, p. 1184). As a consequence, the socio-economic gradient in the risk of death might have been somewhat reduced to begin with. Similarly, for Carmagnola, Abrate (1972, p. 87) held that ‘plague struck blindly, with no respect towards the rich and the powerful who admittedly, however, had not fled’ (our translation). An interesting detail is that the first two people appointed as public health officials and charged with organizing the city defences against the plague were the richest citizens of Carmagnola: Ottavio Maghino and Francesco Albertino. This spirit of service might have exposed at least some members of the elite (and their families) to an exceptionally high risk of infection and death. For example, Maghino’s household suffered four plague deaths: Maghino himself, his wife, and two servants.

While the commitment of the elite to fighting the plague helps to explain the apparent lack of a socio-economic gradient in overall mortality, among those sent to the *lazzaretto* the poor seem to have run a lower risk of death compared with all other segments of the population ($p < 0.05$ or < 0.1 in most models in Tables 6 and 7). To solve this apparent paradox, we must consider that one of the mechanisms through which SES affects survival is by modifying access to healthcare. During a pre-industrial plague epidemic, while forced hospitalization of the poor was common practice, the richest seem to have had some opportunity to opt out of hospitalization, which they might have attempted out of simple fear of the *lazzaretto*. We have evidence of this from the average size of the groups of co-residents brought to the *lazzaretto*, which is markedly smaller for the richest fiscal classes than we would expect based on our probabilistic model. As this discriminatory practice was not officially sanctioned by law or by the public health authorities, it did not leave any trace in the available historical sources. Some evidence comes from the lag between the hospitalization of different members of the same household: while those belonging to households from the low and middle strata of society were usually all interned on the same day, members of households higher up the social ladder were often admitted with a lag between them. As chances of survival at the *lazzaretto* were actually rather good, the fact that the richest groups used their political leverage to avoid treatment there might have increased their overall susceptibility to dying of plague, possibly because proper medical treatment was administered late or because they became sick at home with nobody to help, compromising their health status *prior* to hospitalization.

The inversion of the usual socio-economic gradient in mortality observed at the *lazzaretto*, however, is a two-sided phenomenon: not only did the rich experience a disadvantage in survival (a possible result of their own choices) but the poor enjoyed relatively good chances of survival compared with all other strata of society. A crucial factor was access to food of adequate quality and quantity. The authors of early modern plague treatises from the late sixteenth century onwards insisted that during plagues, the poor, if left without assistance, risked dying because they were forced to eat corrupted or otherwise unhealthy food and in insufficient quantities (Cohn 2010a, pp. 211–5). But within the *lazzaretto*, provision of food and drinking water was guaranteed to all patients. This satisfied medical recommendations regarding treatment of those infected, as well as religious recommendations to provide charity to the needy (Cohn 2010a; Stevens Crawshaw 2012; Henderson 2019). When we refer to the hospitalized poor, we must not forget that the 'unworthy' poor (e.g. beggars) were expelled from cities at the first fear of contagion and probably died en masse. Related to this, we must also consider that those poor deemed worthy of assistance were nevertheless perceived as possible plague-spreaders: hence they tended to be sent more promptly (even, to some degree, preventively) to the *lazzaretto*. In some settings this made them more susceptible to infection (Alfani and Murphy 2017, p. 329) but not in Carmagnola. Surviving documentation suggests that availability of space at the *lazzaretto* was not a problem there, at least during the summer when the epidemic peaked. So it can be reasonably conjectured that while interned, the poor were able to isolate themselves better than in their crowded homes. More generally, efficient isolation at the *lazzaretto*, itself dependent on sufficient availability of space, might explain the relatively low overall mortality rates experienced by those interned there in comparison with *lazzaretti* in other cities during the same epidemic (a relatively limited spread of infection, as suggested by the lower overall mortality in Carmagnola compared with elsewhere, might also have helped to avoid straining the infrastructure). This is probably why mortality rates among those interned were only slightly higher than among the total population of Carmagnola.

The lack of a clear socio-economic gradient in mortality, while reflecting reports for some other parts of northern Italy during the 1630 plague, cannot be generalized to other plagues or other world areas. Early modern plague did tend to affect the poor more than the rich, and the same is true for subsequent pandemics. The cholera pandemics of the nineteenth century are a particularly good example (Snowden 2019; Alfani 2022). But also in the case of infections with very different kinds of transmission, the poor have been reported to suffer a higher risk of death. This was the case for the Spanish influenza of 1918–19 in Sweden (Karlsson et al. 2014, p. 6; Bengtsson et al. 2018; Mamelund and Dimka 2021). The same situation has been replicated during the Covid-19 pandemic: poverty has been put forward as a major explanator for differences in individual risk of Covid-19 death, often in association with other factors (e.g. ethnicity, race) and especially in countries where access to public health remains uneven across society (for the US, see Brown and Ravallion 2020; Zalla et al. 2021; for Europe, see Decostier et al. 2020; Williamson et al. 2020; Mamelund and Dimka 2021).

Concluding remarks

This paper has provided the first ever micro-demographic study of the probabilities of survival for a population of patients of an early modern isolation hospital during a major plague. Although the data set we used to study the Italian city of Carmagnola in 1630 is currently unique regarding the number of individual-level variables and their quality (with the information for SES standing out for being exceptionally good), we can expect a comparable set of historical sources to exist elsewhere and consequently, the novel statistical approach that we developed could be applied to similar studies in future. We found that biological sex did not affect probability of survival, except for women interned healthy, who were presumably required to help with the daily activities of the *lazzaretto* and so experienced a greater risk of infection and death. Regarding age, we confirmed the results of recent micro-demographic research which argued for the risk of dying of plague increasing with age, in contrast to earlier studies which, based on simple excess-mortality methods, had argued that plague affected mostly young adults. Our most innovative results concerned the effect of SES: we found that at the *lazzaretto*, the poorest strata experienced better chances of survival and the richest lower chances of survival compared with all others. This contrasts with the generally stable connection between poverty and epidemics across history (with the poor suffering more than others), which comes across rather clearly from the historical–epidemiological literature. So it seems proper to focus briefly on what insights our study might offer for understanding the most recent crisis, because in Carmagnola, the poor as a group managed to *escape* their apparent destiny to be the main victims.

In an epoch and area characterized by high inequalities in access to economic resources (such as seventeenth-century northern Italy; Alfani 2015, 2021), an important factor in determining how the poor fared during a major epidemic seems to have been the availability of good-quality healthcare, provided universally and for free by public institutions. This seems to have eroded potential differentials in survival by SES, a process to which the rich also contributed according to our hypothesis that they tried to avoid hospitalization (and that this backfired). This speaks directly to current debates in western countries, as in many, the disproportionate impact of Covid-19 on the poorest and most fragile strata, not only in terms of mortality but also of relative economic damage, has led to concerns across society. From this perspective, uneven access to healthcare is coming under closer scrutiny. Finally, during the 1630 plague, trying to improve the conditions of the poor seems to have been a means of limiting the effects of the pandemic across society. The same conclusion can be reached even more clearly if we consider the case of cholera: this great pandemic scare of the nineteenth century provided the crucial political stimulus to improve the living conditions of the poorest residents of cities significantly, with lasting effects in terms of a rebalancing of general status-based health differentials (Alfani 2022). At least from this point of view, we can only hope that history will repeat itself.

Notes

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4 There are no funders to report.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Archival sources

AS1. Letter of the representative of the *Magistrato sopra la Sanità* dated 16 July 1630. Archivio Storico Comunale di Carmagnola, Sanità Pubblica—Malattie Infettive, fas. 1.

AS2. *Individui stati condotti al Lazzaretto* [*Individuals who have been brought to the Lazzaretto*]. Archivio Storico Comunale di Carmagnola, Sanità Pubblica—Malattie Infettive, fas. 1.

AS3. *Consegna di tutti li capi di casa si di carmagnola che vi habitanti* [*Declaration of all the household heads from Carmagnola or who have residence there*]. Archivio Storico Comunale di Torino, Camera dei conti di Piemonte, art. 531, mazzo 4, Fasc. 26, 1621.

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