TECHNOLOGICAL PROGRESS AND HEALTH CONVERGENCE:
THE CASE OF PENICILLIN IN POST-WAR ITALY

Marcella Alsan
Vincenzo Atella
Jay Bhattacharya
Valentina Conti
Iván Mejía-Guevara
Grant Miller

ABSTRACT

Throughout history, technological progress has transformed population health, but the distributional effects of these gains are unclear. New substitutes for older, more expensive health technologies can produce convergence in population health outcomes, but may also be prone to "elite capture" leading to divergence. This paper studies the case of penicillin using detailed mortality statistics and exploiting its sharply-timed introduction in Italy after World War II. We find penicillin reduced both the mean and standard deviation of infectious diseases mortality, leading to substantial convergence across disparate regions of Italy. Our results do not appear to be confounded by competing risks or mortality patterns associated with World War II.

Marcella Alsan
Stanford Medical School
Center for Health Policy/PCOR
117 Encina Commons, Room 218
Stanford, CA 94304
and NBER
malsan@stanford.edu

Vincenzo Atella
University of Rome Tor Vergata
atella@uniroma2.it

Jay Bhattacharya
117 Encina Commons
CHP/PCOR
Stanford University
Stanford, CA 94305-6019
and NBER
jay@stanford.edu

Valentina Conti
Food and Agriculture Organization of
the United Nations
Viale delle Terme di Caracalla
Rome 00153
Italy
valentinaconti23@yahoo.it

Iván Mejía-Guevara
Center for Population Health Sciences
Stanford University
Stanford, CA 94305
imejia@stanford.edu

Grant Miller
CHP/PCOR
Stanford University
117 Encina Commons
Stanford, CA 94305-6019
and NBER
ngmiller@stanford.edu

I Introduction

Technological progress in medicine has been described as a leading explanation for the increase in post-World War II era (Davis 1956; Preston 1975; Easterlin 1999; Mokyr 2002; Acemoglu and Johnson 2007) and is often put forth as a solution to health challenges in developing countries. Yet technological progress can also have unintended consequences for the distribution of disease. If only elites can afford a health technology, or if a technology is a private good that might substitute for public good provision, such innovation could widen health disparities, at least initially (Mosca 1939; Olson 1965; Kremer and Willis 2016; Ashraf et al. 2016). Alternatively, "breakthrough" health technologies that are less expensive may supplant older, more expensive ones may encourage population health convergence.

In this paper, we analyze the effects of the introduction of penicillin, arguably one of the most important medical technologies of the twentieth century (Tomes 1990, 1998). Discovered to kill *Staphylococcus* bacteria by Alexander Fleming in 1928 – and successfully isolated and produced by Howard Florey, Ernst Chain, and Norman Heatley in 1939 – this new "miracle drug" quickly became the first-line treatment for pneumonia, diphtheria, syphilis, gonorrhea, scarlet fever, and other infectious diseases (Dowling 1977; Levy 1992).[1] Penicillin's achievements were preceded by those of sulfa agents, the first chemotherapy developed to fight infection and the subject of scholarship by Jayachandran, Lleras-Muney and Smith (2010), who find the introduction of sulfa drugs led to impressive reductions in maternal mortality and pneumonia deaths in the historical United States.[2]

We build off the Jayachandran et al. (2010) study in two ways: first, by exploring the role penicillin had on average mortality in Italy following its introduction by the United

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[1] *The Lancet* published a high-profile article in 1943 entitled "General and Local Administration of Penicillin," describing the effectiveness of penicillin in treating wounded soldiers in North Africa (Florey and Florey 1943). Some scholars estimate that penicillin saved at least 300,000 lives during the Second World War (Dowling 1977; Levy 1992; Ratcliff 1945).

[2] Conybeare (1948), Loudon (1988), and Mackenbach and Looman (1998) also provide suggestive evidence on the importance of antibiotics. By contrast, some studies suggest that penicillin did not have the dramatic effect commonly attributed to it (Hemminki and Paakkulainen (1976) studying Finland and Sweden, for example).

Nations in the aftermath of World War II, and second, and more generally, by documenting the effects of the technology on the *distribution* of mortality.[3] Some scholars suggest that the distribution of new technologies, even inexpensive ones, often benefit the elite first (Brenzel and Claquin 1994). Others suggest that more portable technologies which do not require large scale infrastructure investments are less prone to elite capture and have considerable potential to improve population health (Acemoglu and Robinson 2008; Mosca 1939; Olson 1965). For penicillin, this could be particularly true given that political decision-making often targeted expensive water and sanitation infrastructure – which can greatly reduce the spread of infectious diseases – towards more elite neighborhoods and communities (Bigatti 2014; Massarutto 2011; Picci 2002; Troesken 2004). Finally, technological progress may be "necessary" but not "sufficient" for health convergence – institutions may be critical to ensure benefits are distributed to those most in need.

To study the distributional consequences of the introduction of penicillin, we assemble a dataset of Italian vital records spanning much of the twentieth century (Atella, Francisci and Vecchi, 2017). We use these data to estimate the contribution of penicillin to infectious disease mortality decline in Italy during the twentieth century. Focusing on the years between 1924 and 1955, we first establish its average effect on mortality by interacting the sharp timing of penicillin introduction with causes of death sensitive to penicillin, controlling for time- and region-level effects as well as regional linear time trends. We then estimate penicillin's effect on the distribution of mortality in four ways: first, by analyzing changes in the age distribution of deaths over time, using Kolmogorov-Smirnov (KS) tests to detect significant differences in these distributions year-by-year; second, using our econometric approach akin to our framework for studying mean reductions in mortality rates, but testing for differential declines by initial level of infectious disease death rates; third, testing for β-convergence, following the literature on macroeconomic growth and economic convergence (Barro and Sala-i-Martin 1992); and, fourth, testing for σ-convergence by estimating the relationship

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[3]Sulfa drugs are distinct from beta-lactam antibiotics, of which penicillin is the first developed (Mandell, Douglas and Bennett 2010).

between penicillin introduction and changes in the standard deviation of regional mortality rates (Janssen et al. 2016).

We find sharply-timed reductions in penicillin-sensitive mortality rates across Italy that closely coincide with the introduction of penicillin in 1947. There are no trend differences between penicillin-sensitive and penicillin-insensitive diseases prior to 1947, and the subsequent decline of about 0.3 deaths per thousand annually represents a 66% reduction relative to the average rate of penicillin-sensitive deaths in earlier years. Then, using all four estimation approaches, we find clear evidence of mortality rate convergence across regions of Italy. Relative to years prior to 1947, the introduction of penicillin reduced the dispersion of penicillin-sensitive mortality rates across regions by 68%, explaining 40% of all-cause convergence over this period.

We also consider two important threats to the internal validity of our analyses. The first is competing risks. Because our estimation framework relies on comparisons between penicillin-sensitive and penicillin-insensitive diseases, reductions in penicillin-sensitive deaths could mechanically increase non-communicable disease (NCD) mortality as those benefitting from penicillin live long enough to suffer and die from non-infectious causes. We show that competing risks are not a threat in practice because the decline in penicillin sensitive death rates is present when examining a simple change over time (i.e. not making comparisons with NCDs). Furthermore, even when the sample time frame is limited to a very short window following pencillin's debut, thereby reducing the movement of infectious disease survivors into deaths due to non-infectious causes, we still find statistically significant and medically meaningful effects. The second issue is that penicillin was introduced shortly after the end of World War II. Infectious disease mortality rates commonly surge during wartime (Erdem et al. 2011; Zapor and Moran 2005), so their decline relative to non-infectious mortality rates could partly reflect the end of conflict and regression to the mean. However, our results are similar across areas with varying degrees of war-related destruction and are robust to excluding years 1943–1945 (the years of most intense conflict in Italy) from our estimation.

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The paper proceeds as follows. Section II provides historical background on public health in Italy and the introduction of penicillin, and Section III describes the construction of the dataset. Section IV focuses on the role of penicillin for mean reductions in mortality, and examines penicillin's contributions to population health convergence. Section V presents estimation results. Section VI considers competing risks and presents other robustness checks, and Section VII concludes.

II Background

II.A Early Efforts to Combat Infectious Disease Mortality in Italy

At the time of unification in 1861, life expectancy at birth in Italy was approximately 29 years, and the crude death rate was about 35 per 1,000 people (Atella, Francisci and Vecchi, 2017). In 1887, Francesco Crispi's government introduced the country's first sanitary reforms under the Crispi-Pagliani law.[4] However, infectious disease deaths in Italy did not begin to decline until the early twentieth century, which historians link to improvements in municipal hygiene under provisions of the law governing water quality and sanitation in urban areas (Giovannini 1996; Giuntini 1999; Pogliano 1984). During fascist rule (1920-1943), public health initiatives targeted the so-called "triple endemic diseases:" malaria, syphilis, and tuberculosis.[5]

Italy's nascent healthcare system and reforms often failed to reach its poorest members (Giovannini 1996; Giuntini 1999; Pogliano 1984).[6] Municipal authorities were responsible for providing healthcare to the indigent, yet in practice private charitable organizations

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[4]The establishment of a health system is interpreted by historians as one of the most important achievements of Italian "political and moral life" at the beginning of the new Kingdom [Croce (1928), cited in Cosmacini (2005), p. 345].

[5]The most important provisions focused on malaria were issued between 1923 and 1934 through a series of laws designed to arrive at a thorough land reclamation operation (*bonifica integrale*). The Consolidation Act on the reclamation of marshlands was approved with Royal Decree no. 3256 of 30 December 1923. Law no. 3134 of 24 December 1928, called the "Mussolini Law," granted financial resources to land reclamation and provided for integration regarding the supply of drinking water and the construction of rural buildings, hamlets, and roads.

[6]The law's principles of universalism became effective only in 1978, when the Italian National Health Service System (SSN) was established.

provided these services (Opere Pie, or "Pious Organizations").[7] A Royal Decree in 1884 established that private firms could invest in the water sector (Ermano and Massarutto 2012). Massarutto (2011) argues this decree and the ensuing privatization directed water supply towards the wealthy in urban areas. As late as the 1950s, only 52% of private houses in Italy received potable water (Doria 2010), and only 7% had all three utilities: potable water, adequate sanitation, and electricity (Barra Bagnasco 1996).[8]

Mortality rates in Italy declined on average during the early- to mid-1900s (see Figure 1), though wide regional health disparities in infectious disease mortality were prevalent at the beginning of this period (Figure 2, Panel A). Nationally, life expectancy at birth in Italy rose to 40-45 years – but varied by as much as 12 years across regions.[9] These regional disparities peaked in 1925-1930, remained high until WWII, and then declined sharply at the end of the war. Understanding whether the introduction of penicillin contributed to the compression of regional mortality rates is a central focus of this paper.

II.B The Advent of Penicillin in Italy

The supply of penicillin in Italy began in 1947 (Luzzi 2004). In its early stage of distribution (1945 and 1946) penicillin was available in Italy through international aid only, imported by the UNRRA (United Nations Relief and Rehabilitation Administration) channel and limited in quantity. At that time the black market was flourishing. Therefore, having enough money and connections, people could reach for the drug (the initial distribution of penicillin in Italy by the US Army started with the main intent of using it to treat the spreading of venereal

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[7]The "non-poor" generally used services provided by individual private-practice doctors (*medici libero-esercenti*) who made home visits.

[8]Until the end of WWII, national public spending for infrastructure was concentrated in the North. On public investments in water, a Royal Decree issued in 1884 created a dualism in the management of water services: water was public, but private companies could invest in the sector once awarded government licenses (Ermano 2012). As a result, water was largely provided to wealthy families in urban areas (Massarutto 2011). Although many subsequent laws governing water management were issued between 1861 and 1950, universalism in the water sector was not achieved until the late 1950s (Mantelli and Temporelli 2007). Modern water infrastructure in poorer southern regions was completed only in the late 1980s (Mantelli and Temporelli, 2007).

[9]During the 1920s the regional variation in life expectancy at birth was almost as large as that estimated for Indian states between 2011 and 2016 – ranging from 61.5 years in Madhya Pradesh to 77 years in Kerala (Ponnapalli et al., 2013).

diseases). To resolve this problem ENDIMEA (Ente Nazionale Distribuzione Medicinali agli Alleati) was established, which began its work on October 1st, 1944. Since January 1st, 1945, each provincial health office began to communicate to the General Directorate of Public Health (DGSP), within the Ministry of the Interior, estimates of the demand for medicines for the quarter. The DGSP, based on the requests and the availability of drugs, granted the drugs to the applicants, informing ENDIMEA to ship the product to the local private wholesalers. Once the wholesaler collected the drugs, he was responsible for the distribution of medicines to the Provincial Health Offices. The latter also had an obligation to follow the drug during the journey from the wholesaler warehouse to the pharmacies or hospitals, in order to prevent theft and illegal sales.[10]

Italian patients could receive the new drug free of charge if requested by their physicians. Provincial Health Offices were held accountable for any shortages of medicines, and pharmacists received a high margin for the sale of antibiotics, which discouraged the emergence of an underground market favoring the wealthy (Battini 1946; Luzzi 2004).

III Data

III.A Vital Statistics Data[11]

The Italian National Statistical Office (ISTAT) provides national vital statistics in annual Health Statistics Yearbooks (Annuario di Statistiche Sanitarie) starting from 1887. Vital statistics for years 1924-1955 were digitized at the region-year-cause of death level.[12]

Harmonizing Regions. ISTAT data provides death counts for Italy's regions over time.

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[10] The Italian health authorities were responsible for any shortages of medicines. In the spring of 1945 the drug became available via physician prescription, but only in the City Public Health Offices (Ufficio d'Igiene). In 1947, the pharmaceutical company "SPA Milan" became the first private Italian company to market antibiotics, selling Supercillin (in vials) and Prontocillin (tablets). A year later, the Anglo-American monopoly over penicillin was broken by Domenico Marotta, then-director of the *Istituto Superiore di Sanit*, who called Ernst Chain to lead the International Centre for Microbiological Chemistry in Rome.

[11]For a complete description of the vital statistics, see Appendix A.

[12]To the best of our knowledge, formal demographic analyses of the quality and completeness of Italy's historical mortality statistics have not been published. However, Italian vital statistics back to the nineteenth century are included in the Human Mortality Database (HMD), and data quality is a central criterion for HMD inclusion. http://www.mortality.org/. (Data documentation for Italy HMD available at: http://www.mortality.org/hmd/ITA/InputDB/ITAcom.pdf).

Due to changes in administrative regional borders over our period of investigation, we had to aggregate some regions. From 1924 until the end of WWII, Italy was organized into 18 administrative regions with only minor changes across region borders. The only exception was the establishment of Valle dAosta in September 1945. For this reason, to obtain a harmonized regional dataset from 1924 to 1954 we treat Piedmont and Valle dAosta as a single region. Thus, our sample includes the following 18 regions: Piedmont and Valle d'Aosta, Lombardy, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Liguria, Emilia Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzi and Molise, Campania, Apulia, Basilicata, Calabria, Sicily and Sardinia.[13]

Harmonizing Cause of Death. Officially, ISTAT assumed the responsibility of collecting mortality data at individual level only in 1930, following Law no. 2238 issued in December 1929. Previously, the statistical office was within the Ministry of Agriculture, Industry and Trade via *Indagine sulle cause di morte*. ISTAT collects this information using an official reporting format ("*Scheda di morte*") following international standards recommended by the World Health Organization (WHO). These individual death certificates consist of two parts. A general practitioner or coroner certifies the first part and ascribes cause. The "initial cause" – disease or trauma – is recorded, which may have led to additional complications but initiated a causal chain leading to death. Diagnostic codes are then assigned to each death using WHO International Classification of Diseases (ICD) criteria. The second part is completed by a municipal civil registrar and includes information about the demographic and social characteristics of the deceased.

Causes of death reported in Italy's vital records change over time. We therefore use categories that can be consistently identified and tracked across all study years, effectively adopting the classification used in 1956–1957 for all years of our analysis (1924–1955).[14] We

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[13]For sake of completeness, in December 1963 the region of Molise was established by splitting the "Abruzzi and Molise" into two distinct regions. This last change brought Italy to have the current administrative structure based on 20 regions.

[14]The 17 causes of death are the following: infective and parasitic diseases; tumors; allergic and endocrine glands diseases; blood and hematopoietic diseases; psychic and personality disorders; nervous system diseases; circulatory system diseases; respiratory system diseases; digestive system diseases; genitourinary system dis-

then classify each of these causes that can be consistently tracked over time according to whether or not it can be treated with penicillin. Ultimately, this process yields 79 penicillin-insensitive, 15 penicillin-sensitive, and 15 unclassified diseases.[15] In our analysis of cause-specific mortality we exclude unclassified deaths.

Constructing war related destruction indicator. We measure destruction related to World War II using the number of military and civilian deaths directly related to war causes at the regional level that occurred between 1940 and 1945 (ISTAT 1957).[16]

Constructing Rates. Finally, using death counts by region, year, and cause, we construct mortality rates using data on regional populations in Italy over time. Specifically, to create population denominators, we use regional population counts from Italy's decennial population censuses provided by ISTAT. For inter-censual years, population estimates accounting for births and deaths provides estimates of this population construction process using several sources of population data (Vecchi, 2017; see Appendix A for more details).[17]

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eases; complications of pregnancy; skin and tissue diseases; bones and locomotive organs diseases; congenital malformations; early childhood particular diseases; senility and pathologic states; accidents, traumatisms, and poisonings. The coding system adopted during years 1924–1955 has changed from the International Analytical Classification (IAC) to the ISTAT Intermediate Classification (IIC) adopted in subsequent years. Moreover, from 1958 onwards, there is a higher disaggregation of diseases with respect to years 1956–1957, due to the inclusion of new death-related causes.

[15]The list of "penicillin-sensitive" and "penicillin-insensitive" categories of death are reported in Appendix B.

[16]The war victims are quantified according to the region of actual death, delivering a space/time quantification of war conflicts. WWII severity indicator in Italy is provided by the official publication "Morti e dispersi per cause belliche negli anni 1940–45" (The dead and the missing due to war causes between 1940–1945) (ISTAT, 1957). The intensity of war destruction was quantified based at the median. Regions above-median conflict deaths are: Piedmont-Valle d'Aosta, Veneto, Friuli Venezia Giulia, Emilia Romagna, Toscana, Umbria, Marche, Lazio. Lombardy, Trentino Alto Adige, Abruzzi and Molise, Campania, Puglia, Basilicata, Campania, Sicilia, Sardegna. See Atella, Di Porto, and Kopinska (2017) for a detailed description of the data used. WWII-related death rates were then computed by dividing death county by the average regional population between 1940–1945.

[17]Population estimates were interpolated into age bins of 0–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, 71–75, and 76+ by using known population data for years 1921–1927, 1931–1936, 1943–1950, 1953, 1957, and 1959–1961. To estimate missing population data, we broke the age bins into separate individual age columns and assumed a uniform population distribution for each age within an age bin. We interpolated missing age-specific population by taking the current year's age-specific population and adding the previous year's age-specific mortality to get the previous year's age-specific population. We use the same methodology in the opposite direction by interpolating the age-specific population data of the subsequent year by taking the current year's age-specific population and subtracting the current year's population age-specific mortality. Afterwards, we re-aggregated the age columns into the original age bins for the population controls of our study.

Our final sample contains region-year-cause of death observations for years 1924–1959. Table 1 shows descriptive statistics on all-cause mortality for penicillin-sensitive and penicillin-insensitive diseases before and after penicillin introduction.

III.B Human Mortality Database (HMD) Data

We also use national-level data on age-specific deaths from the Human Mortality Database (HMD) in two ways (HMD 2017).[18] First, because the regional vital statistics do not contain information about deaths by age, precluding age-adjustment, we control for age-specific population counts.[19] Second, we directly examine changes in the age distribution of deaths over time as an alternative strategy for studying mortality convergence.

III.C Graphical Analysis

Mortality Decline by Cause. As Figure 1 shows, Italy's total mortality rate fell substantially between 1924 and 1955. However, this decline varied dramatically by cause – and in particular, by penicillin sensitivity. Panel A of Figure 2 shows that with the official introduction of penicillin in 1947, the decline in regional mortality rates for penicillin-sensitive causes accelerated sharply. Moreover, the variance in regional death rates sensitive to penicillin became markedly more compressed beginning in 1947, with substantial convergence occurring by the mid-1950s. Panel B of Figure 2 demonstrates regional mortality rates for non-infectious causes did not decline over the entire period – nor did their variance.[20]

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[18]National-level HMD estimates are constructed by HMD investigators using vital statistics, population censuses, and population estimates directly from ISTAT and from other researchers working on behalf of ISTAT. Death counts in the Italian vital statistics are based on the *de facto* population ("popolazione presente") until 1980 and on the *de jure* population ("popolazione residente") afterwards. Therefore, mortality rates before 1981 in the HMD are based on population estimates of the *de facto* population, calculated from census counts to consider this change in the coverage of vital statistics (Glei 2015). Death counts from the vital statistics are also adjusted both to include missing military deaths during World Wars I and II and to spatially redistribute deaths by age and calendar year (Jdanov et al. 2008). For the period 1937–51, intercensal survival methods are used to derive population estimates using pre- and post-war census counts (Jdanov et al. 2008).

[19]This data is also available online at:http://www.mortality.org/

[20]More work is required to address concerns about the confounding role of World War II given that infectious disease deaths often exceed direct casualties due to conflict (Erdem et al. 2011; Zapor and Moran 2005). We address this issue later in Section VI.B. Further, one might also argue that WWII has favored internal migration flows from poorer to richer regions, thus contributing to higher differentials among regional mortality rates. Atella, Deb and Kopinska (2019) show that the phenomenon of migration within Italian

Mortality Decline by Age. Figure 3 depicts the age distribution of period life table deaths in Italy for years between 1924 and 1955. The figure reveals substantial reductions in infant and child mortality over time (which are generally due to infectious causes, mostly penicillin-sensitive (Vercelli et al. 2014)). As a result, deaths appear to become more concentrated at older ages – a pattern consistent with convergence, although the timing of this compression is less readily evident (Section VI investigates this issue more closely).

Standard Deviation and Average Life Expectancy: Figure 4 shows both life expectancy at birth and the standard deviation of age at death across regions (a common indicator used in the literature to measure mortality convergence and lifespan inequality (Edwards and Tuljapurkar 2005; Gillespie et al. 2014)) by year. Life expectancy at birth increases from 51.5 in 1924 to 57.6 in 1939, declines abruptly during WWII until the 1943 Italian armistice, recovers quickly to its pre-war level, and continues to increase in the post-war years. The standard deviation of age at death declines little during the pre-war period (as life expectancy at birth is rising), remains relatively constant during WWII, and then declines precipitously beginning in the late 1940s (around the time that penicillin was introduced) and throughout the post-war period. This rapid decline beginning in the latter 1940s is suggestive of mortality convergence.

Standard Deviation by Cause: Figure 5 shows the standard deviation of regional death rates separately for the all-cause mortality rates, penicillin-sensitive mortality rates, and penicillin-insensitive mortality rates over time. Before WWII, the standard deviation trajectories of penicillin-sensitive and -insensitive mortality rates were similar. Both experience disruptions during the war period, but after 1947 the standard deviation of penicillin-sensitive mortality rates across regions converges, while the standard deviation of penicillin-insensitive mortality rate slightly diverges.

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regions began in earnest in 1951.

IV   Estimation

IV.A   Mortality Decline

Building on graphical evidence shown in Figures 2 and 4, our empirical strategy tests for sharply-timed differential trend breaks in penicillin-sensitive mortality rates (relative to penicillin-insensitive mortality rates) coincident with the introduction of penicillin in 1947. Specifically, we estimate:

$$(1) \qquad m_{ict} = \alpha + \gamma_i + \delta_t + \theta_c + \beta(I_t^{post} * Sensitive_c) + X_{it}\varphi + \gamma_i * t + \epsilon_{ict},$$

for regions i, causes of death c, and years t. m_{ict} is a region-cause-year specific death rate (specified both in level and natural log form). I_t^{post} is a dummy variable equal to one for observations in years 1947 or later, $Sensitive$ is a dummy variable for whether or not cause c is sensitive to penicillin, and X is a vector of covariates including interpolated population estimates in discrete age categories. We include year, region, and disease fixed effects, and our preferred specification also includes linear time trends interacted with region dummies. Standard errors are clustered by region, and we report p-values corresponding to block bootstrapped standard errors.[21]

We also assess the temporal dynamics of the introduction of penicillin by substituting a vector of year dummy variables for , I_t^{post} in Equation (1):

$$(2) \qquad m_{ict} = \alpha + \gamma_i + \delta_t + \theta_c + \sum_j \rho_j(Sensitive_c * I_t^j) + X_{it}\varphi + \gamma_i * t + \epsilon_{ict},$$

where I_t^j is a vector of j year dummy variables and all other variables are defined as before.

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[21]To assess the robustness of our results, we also estimate variants of specification (1), using both levels and log specifications and including region-specific linear time trends.

IV.B Mortality Convergence

To study mortality convergence at the national level, we first analyze changes in the distribution of age at death (Kannisto 2000; Fries 1980; Wilmoth and Horiuchi 1999). Specifically, we use Kolmogorov-Smirnov (K-S) tests to formally assess if the timing of statistically significant changes in the distribution of age at death coincides with the introduction of penicillin in 1947, comparing the distribution in each year between 1924-1954 with the last year in our sample, 1955.[22]

Second, we test for mortality convergence associated with the introduction of penicillin using an econometric framework similar to the one that we use for estimating mean reductions in penicillin-sensitive mortality rates. Specifically, we re-estimate Equation (1), stratifying by the pre-1947 level of both penicillin-sensitive mortality rates and overall regional mortality rates.

Third, we test for β-convergence, or convergence in levels of mortality rates, following the approach of Barro and Sala-i-Martin (1992) to study convergence in Gross Domestic Product (GDP) per capita across countries. This approach assesses if regions with higher pre-1947 penicillin-sensitive and -insensitive mortality rates converged towards regions with lower mortality rates by sub-periods (before and after the introduction of penicillin, 1929-1946 and 1947-1955). Specifically, we estimate:

$$(3) \qquad \frac{(m_{ict} - m_{ict_0})}{(t - t_0)} = \alpha + \gamma_i + \beta m_{ict_0} + \epsilon_{it}$$

where m_{ict} is the mortality rate in region i due to cause c in initial year t_0 ($t_0 = 1924$ for the first sub-period, and $t_0 = 1947$ for the second sub-period) and β is the parameter of interest.

Finally, we test for σ-convergence, or convergence in the standard deviation of mortality

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[22]A two-sample Kolmogorov-Smirnov statistic is used to test whether two empirical one-dimensional distribution functions $(F_m(x), G_n(x))$ differ from each other. The KS statistic is defined by the formula $D_{mn} = sup_x \mid F_m(x) - G_n(x) \mid$. The null hypothesis that the two samples come from the same distribution is rejected, at the level of significance α, when $D_{mn} > c(\alpha)\sqrt{\frac{m+n}{mn}}$, where $c(\alpha) = \sqrt{-\frac{1}{2}ln(\frac{\alpha}{2})}$ (Stephens, 1974).

rates, across regions of Italy by re-estimating Equation (1) using the standard deviation of cause-specific mortality rates by region as the dependent variable (Janssen et al. 2016; Young et al. 2008).

V   Results

V.A   Mortality Decline

Table 2 reports results obtained by estimating Equation (1). Conditioning on year, region, and disease fixed effects as well as the regional age distribution, mortality rates among diseases sensitive to penicillin relative to those insensitive fell by approximately 0.3 per thousand (and is statistically distinguishable from zero, p < 0.01) with the introduction of penicillin. Relative to the mean mortality rate among deaths due to these causes prior to 1947 (0.469, see Table 1), this represents a reduction of 58%.[23] Column 2 adds region-specific linear time trends. In both cases, the estimate of β is robust, with the mortality rate decline associated with the introduction of penicillin remaining at about 0.3 per 1,000. Columns 3 and 4 repeat this estimation for log mortality, showing robust reductions in penicillin-sensitive mortality rates.

Figure 6 then examines the dynamic pattern of mortality decline associated with penicillin introduction in Italy, showing estimates and 95% confidence intervals for each year-specific ρ_j in Equation (2). Prior to the introduction of penicillin, there is little evidence of pre-existing declines in penicillin sensitive mortality rates (relative to insensitive ones). Year-specific estimates drop with the introduction of penicillin in 1947 and become negative and statistically different from zero by 1948 (and in all subsequent years) with the diffusion of penicillin. By the end of our study period in 1955, these year-specific estimates approach a decline of 2.8 per 1,000 deaths.

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[23]To estimate this effect we divide the post-1947 mean average reduction in the cause-specific mortality (regression coefficient in the first column of Table 2: -0.272), by the mean mortality rate for penicillin-sensitive causes in the baseline period, between 1924–1946.

V.B   Mortality Convergence

Figure 7 first shows year-by-year K-S p-values for tests of differences between each year's distribution of age at death against the distribution in 1955 (the last year in our sample). These p-values remain constant at nearly 0 for all years prior to the introduction of antibiotics, indicating strongly significant differences from 1955 – and then beginning in 1947, these p-values rapidly rise to 1 (indicating no difference from 1955). This sharply-timed compression in Italy's age distribution of deaths is highly consistent with the introduction of antibiotics leading to convergence in mortality rates.

Table 3 reports estimates obtained from Equation (1), stratified by level of penicillin-sensitive mortality rates prior to 1947 (above and below the median). The first and second columns show that after 1947, penicillin-sensitive mortality rates declined more in regions with higher (above median) initial rates (by 0.29 per 1,000) than in those with lower (below median) initial rates (0.26 per 1,000) – and significantly so. Compared to the mean of the pre-1947 penicillin-sensitive cause-specific mortality, these changes represent reductions of 61% and 55%, respectively.

Table 4 reports β-convergence estimates from Equation (3). Comparing penicillin-sensitive mortality rates before vs. after the introduction of penicillin, the estimate of β is almost four times greater after penicillin introduction (-0.075 vs. -0.021). Alternatively, for penicillin-insensitive mortality rates, the estimate is not statistically significant prior to 1947 – and is positive and statistically different from 0 afterwards, suggesting divergence in penicillin-insensitive mortality rates.

Finally, Table 5 (columns (1) and (2)) present estimates of sigma convergence by using the standard deviation of deaths across regions and years for each of the two disease categories as the dependent variable. We find that the standard deviation of penicillin-sensitive mortality declines after penicillin is introduced (-0.113, $p < 0.01$) – but not the standard deviation of penicillin-insensitive mortality (-0.004). The results remain consistent after truncating the sample in 1950 (row 2): the standard deviation of penicillin-sensitive mortality declines

significantly (-0.089, p < 0.01), but not for penicillin-insensitive mortality (-0.009).[24]

VI Identification and Threats to Validity

In this section, we discuss two potential treats to our interpretation of the effects of the introduction of antibiotics on infectious disease mortality. In Section VI.A, we consider the problem of competing risks – specifically, the survival benefit of antibiotics increased the exposure of the population to death from non-infectious causes. In Section VI.B, we discuss how the chaotic end to World War II may have affected infectious disease mortality in Italy during our sample period.

VI.A Competing Risks

In our context, the competing risks problem concerns a possible increase in non-communicable disease (NCD) mortality resulting from fewer people dying from infectious disease mortality as a result of the introduction of penicillin. This phenomenon can influence our estimates given that we compare penicillin-sensitive vs. penicillin-insensitive death rates over time (Tsiatis, 1975; Peterson, 1976; Honorè and Lleras-Muney 2006). In this section we study the influence that competing risks has on our estimation of the contribution of penicillin to the mortality decline in Italy.[25] We present a simple framework for defining the particular competing risk problem inherent in our main estimating equation, and describe an alternative approach to bound the estimates.

Period 0: In any period, deaths can be divided into mortality from two etiologies $E = \{I, NC\}$ where I indicates infectious diseases and NC reflects non-communicable diseases.

$$(4) \qquad\qquad\qquad\qquad D = I + NC$$

---

[24]We use a truncated sample to test the potential treat of competing risks in the interpretation of the effects of the introduction of penicillin on infectious disease mortality, including our interpretation of sigma convergence – see Section VI.A.

[25]Technically, if competing risks is a problem, it amounts to a violation of the Stable Unit Treatment Value Assumption (SUTVA), which is necessary for unbiased estimates in a difference-in-difference framework such as ours.

note that deaths from etiology E can be expressed as the mortality rate from E multiplied by the number of susceptible from that etiology at time t: $E = \mu^{e,t} * S^{E,t}$. We assume that mortality rate from non-communicable disease is exogenous to penicillin and, after period 0, there are N^0 persons surviving in this closed population without births or migration.

Period 1: At the beginning of period 1, penicillin, p, is introduced which immediately treats and cures those afflicted with infectious diseases, leading to a direct decline in mortality associated with diseases of infectious etiology:

$$(5) \qquad D^1 = S^{I,1}\mu^{I,1}(p) + S^{NC,1}\mu^{NC}$$

Period 2: By period 2, there are now indirect effects of penicillin, since those weaker individuals that otherwise would have died from infectious disease are now alive (e.g. the harvesting effect of infections has been reduced). These spared lives increase the size of the susceptible non-communicable disease population:

$$(6) \qquad S^{NC,2} = N^0 - S^{I,1}\mu^{I,1}(p) - S^{NC,1}\mu^{NC}.$$

Recall that $\frac{\partial \mu^{I,i}}{\partial p} < 0$ by the pharmacology of penicillin and $\frac{\partial S^{NC,2}}{\partial p} > 0$ by equation 6. Hence the total effect of penicillin over time reflects both the direct effect on infectious deaths and its indirect effect on non-communicable susceptibles.

Our difference-in-differences estimate compares the changes in infectious and non-communicable diseases related deaths, before vs. after the introduction of penicillin:[26]

$$(7) \qquad \left(S^{I,2}\mu^{I,2}(p) - S^{I,0}\mu^{I,0}\right) - \left(S^{NC,2}(p)\mu^{NC} - S^{NC,0}\mu^{NC}\right)$$

Given that the first term is negative (by the direct effects of penicillin) and the second, in

---

[26]Equation 7 is normalized by total population in our empirical framework. Note there is also a positive effect on susceptibles for infectious diseases at the beginning of period 2, but we ignore that detail since it is dwarfed by the first order effect of penicillin which is to reduce the mortality associated with many communicable causes.

the absence of an overall secular decline in mortality, is positive (by the indirect effects of penicillin), our estimates are biased away from the null.[27] Yet in our setting, there may be a very prominent secular decline in mortality for all causes – which is why a difference-in-differences framework is preferred. Thus, estimates from both the simple and double differences are biased, the former by a secular decline and mis-attribution of penicillin to secular patterns, and the latter by competing risks.

To gauge the relative importance of these two sources of bias, we zoom in on the period very soon after penicillin was introduced (i.e. Period 1), so that our difference-in-differences estimator is not influenced by competing risks (i.e. there is no indirect effects on non-communicable disease): $\left(S^{I,1}\mu^{I,1}(p) - S^{I,0}\mu^{I,0}\right) - \left(S^{NC,1}\mu^{NC} - S^{NC,0}\mu^{NC}\right)$. Shortly after penicillin is introduced, we are more likely to isolate the direct effect of penicillin on the infectious disease mortality as the harvesting and death for more chronic, non-communicable entities would not have not had time to occur. Specifically, we estimate the effect of penicillin on sensitive (i.e. infectious) and insensitive (i.e. non-communicable) causes in a pre vs. post framework and using the full vs. a truncated time period.

These results are gathered in Table 5. For the truncated sample, ending in the year 1950 – three years following the introduction of penicillin into Italy – the results demonstrate that both sensitive and insensitive mortality decline (row (2) columns (3) and (4)) though the effect is much larger for the former. The estimates point to an important secular decline in mortality, independent of penicillin, hence the negative post coefficient in column (4). The difference-in-differences estimate $((-0.486) - (-.0363))$ is about -0.12, smaller than the main estimates in Table 2 and a lower bound on penicillin's effects.

Using the full sample, with an end year of 1955, the effect of penicillin introduction on insensitive causes is more positive, reflecting the competing risk issue. Yet the magnitude of this change is slight and statistically indistinguishable from the estimates using the 1950 cutoff. Moreover, the fact that the difference-in-differences point estimates are increasing

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[27]In the presence of a secular decline, the second term will be less negative than in the counterfactual of absent an indirect effect of penicillin.

over time as per our event study is attributable to the first term in equation 7: the direct effect of penicillin on infectious disease mortality (see row (3)). As discussed above, this likely reflects the technology's diffusion. When turning to sigma convergence, there is no major concern for competing risks in any specification: convergence is limited to infectious causes.

In summary, the framework and results presented in this subsection show that the competing risks problem in our context is small, given that a longer time window does not greatly bias the second term in equation 7 in a positive direction. On the other hand, controlling for a secular decline in mortality – which is what differencing out of non-communicable causes affords – is important for obtaining less biased estimates.

VI.B   The End of World War II

Another potential concern with our results is the influence of the end of World War II on infectious disease rates. Because infectious disease mortality rates commonly surge during wartime (Erdem et al. 2011; Zapor and Moran 2005), their decline relative to non-infectious mortality rates could partly reflect the end of conflict. Figure 2 (Panel A) provides at least some prima facie evidence that this is not an important concern in our case – mortality rates sensitive to penicillin are declining until 1930, generally remain stable through 1945 (rather than rising), and then resume their decline. However, we probe this issue further in two ways.

First, we test for differential penicillin effects in areas with varying degrees of war-related destruction. Specifically, we re-estimate Equation (1) separately for regions with above- and below-median degrees of war intensity, measured using conflict-related mortality rates between 1940 and 1945.[28] Columns 3 and 4 of Table 3 report estimates separately for regions with higher and lower intensity of exposure to WWII. In general, the penicillin effect is larger in areas with lower war intensity (0.29 per 1,000) relative to those with higher war intensity

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[28]This data is available in "Morti e dispersi per cause belliche negli anni 1940–45" (ISTAT, 1957) and is also online at https:lipari.istat.it/digibib/causedimorte/IST3413mortiedispersipercausebellicheanni1940_45+OCRottimizz.pdf.

(0.26 per 1,000), and this difference is statistically significant.[29]

Second, we simply exclude years 1943–1945 (the years of greatest conflict in Italy) from our sample and again re-estimate Equation (1). Columns 5 and 6 of Table 3 show these results – the estimates are statistically equivalent to those that include these years.

VII   Conclusion

Although technological progress in health has produced dramatic gains in life expectancy around the globe over the past century, it can also have unintended consequences for the distribution of disease. Health technologies that are inexpensive and substitute for older, more expensive ones may lead to population health convergence, but they could also disproportionately benefit elites, widening health disparities. Notably, there has been little empirical evidence to date on the consequences of major new health technologies for the distribution of health in populations.

Studying the seminal case of penicillin and focusing on Italy using newly digitized vital statistics over several decades, we find that the introduction of penicillin not only reduced average infectious disease mortality rates dramatically (by 58%), but it also led to a substantial reduction in the variance of mortality rates across Italian regions. Specifically, the standard deviation in the age of death fell by nearly eight years after the introduction of penicillin – a decline of 27%. Our findings relate to the scholarship of researchers investigating post-World War II health convergence across countries, such as Acemoglu and Johnson (2007) and Deaton (2006), we find that the distribution of penicillin, at least in Italy, played an important role in such convergence and suggest an important role for point-of-care technologies in reducing health inequalities.

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[29]We test for the significance of the difference between the coefficients obtained in the separate models by pooling the samples used in both models, and specifying a triple interaction that includes an indicator for high and low destruction. The coefficient for this interactions term was statistically significant (p-values < 0.01).

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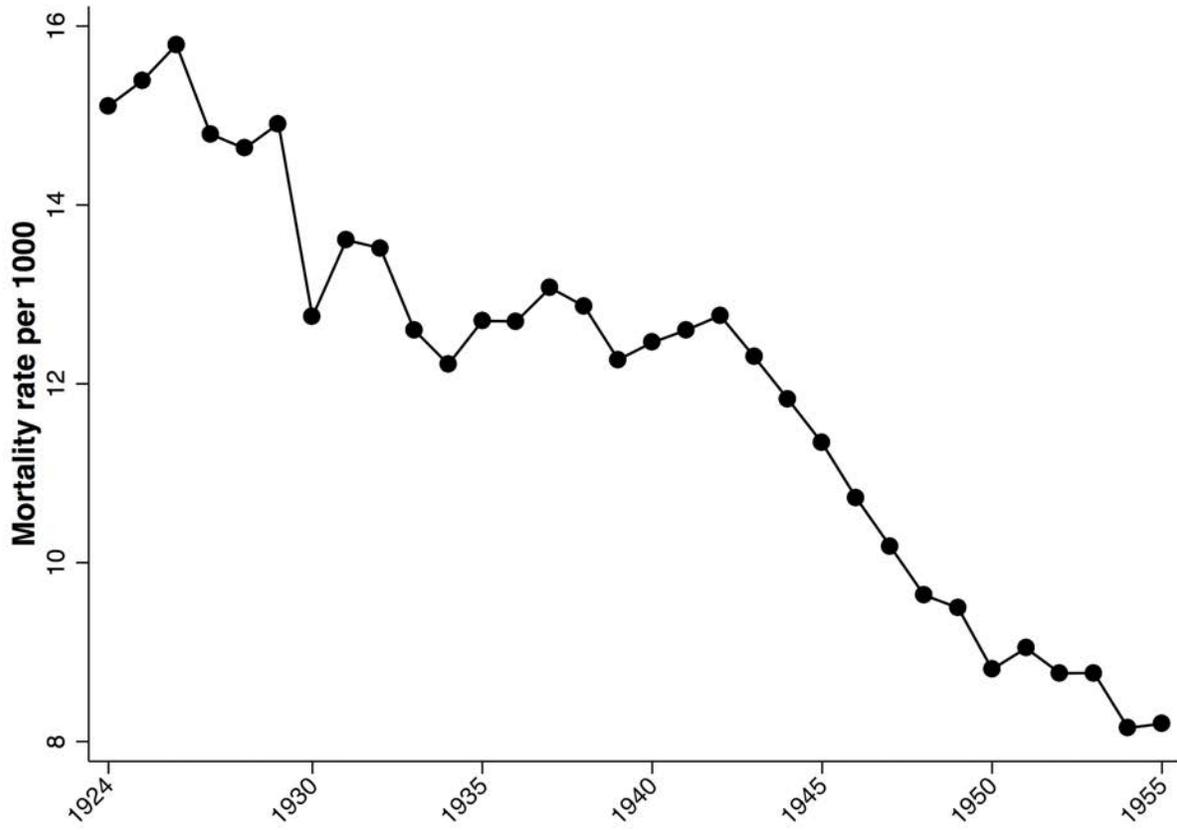
Figure 1: All-cause mortality rates across all regions in Italy, 1924-1955. The unit is number of deaths per 1,000 people. *Source*: ISTAT
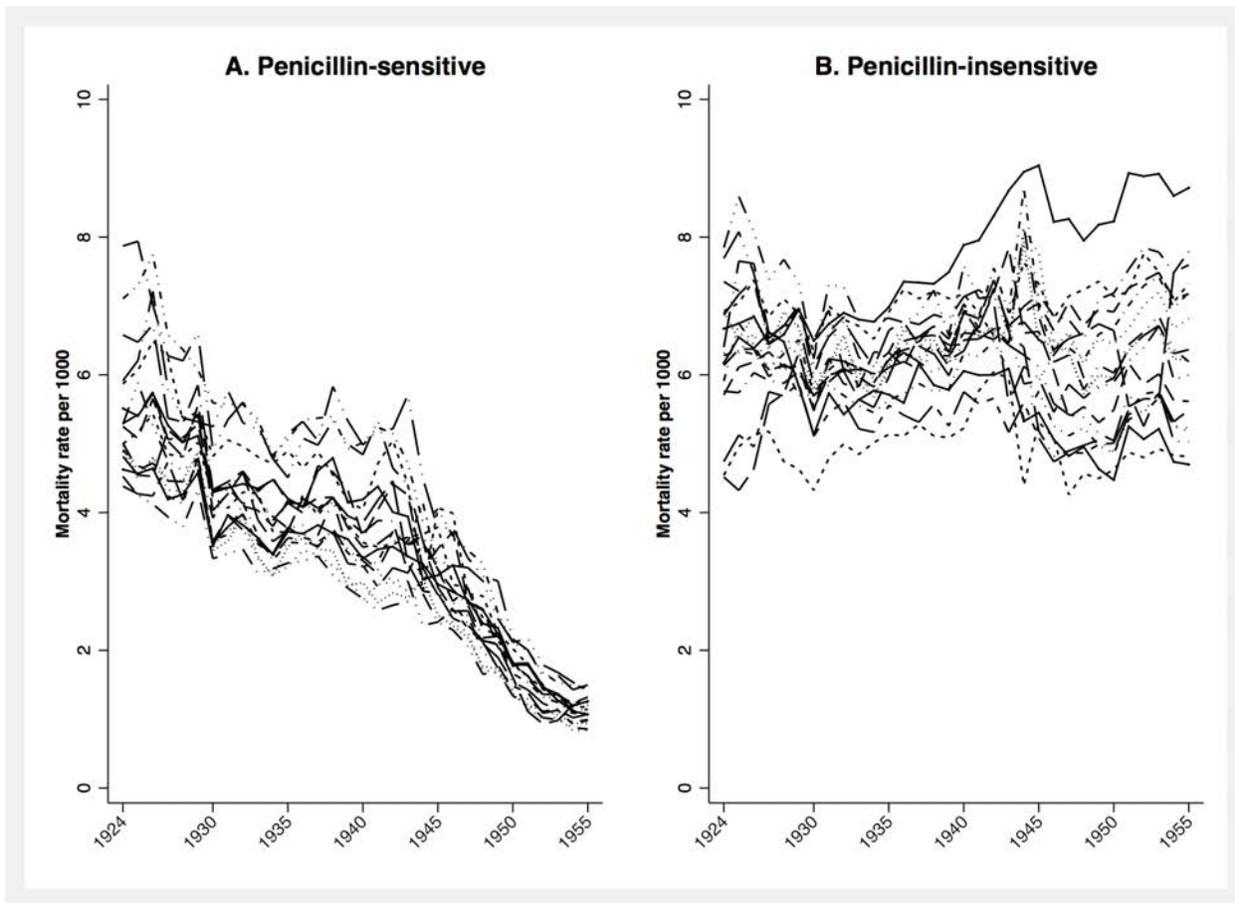
Figure 2: Penicillin-sensitive (Panel A) and penicillin-insensitive (Panel B) disease mortality rates by region in Italy, 1924-1955. The unit is number of deaths per 1,000 people. *Source*: ISTAT
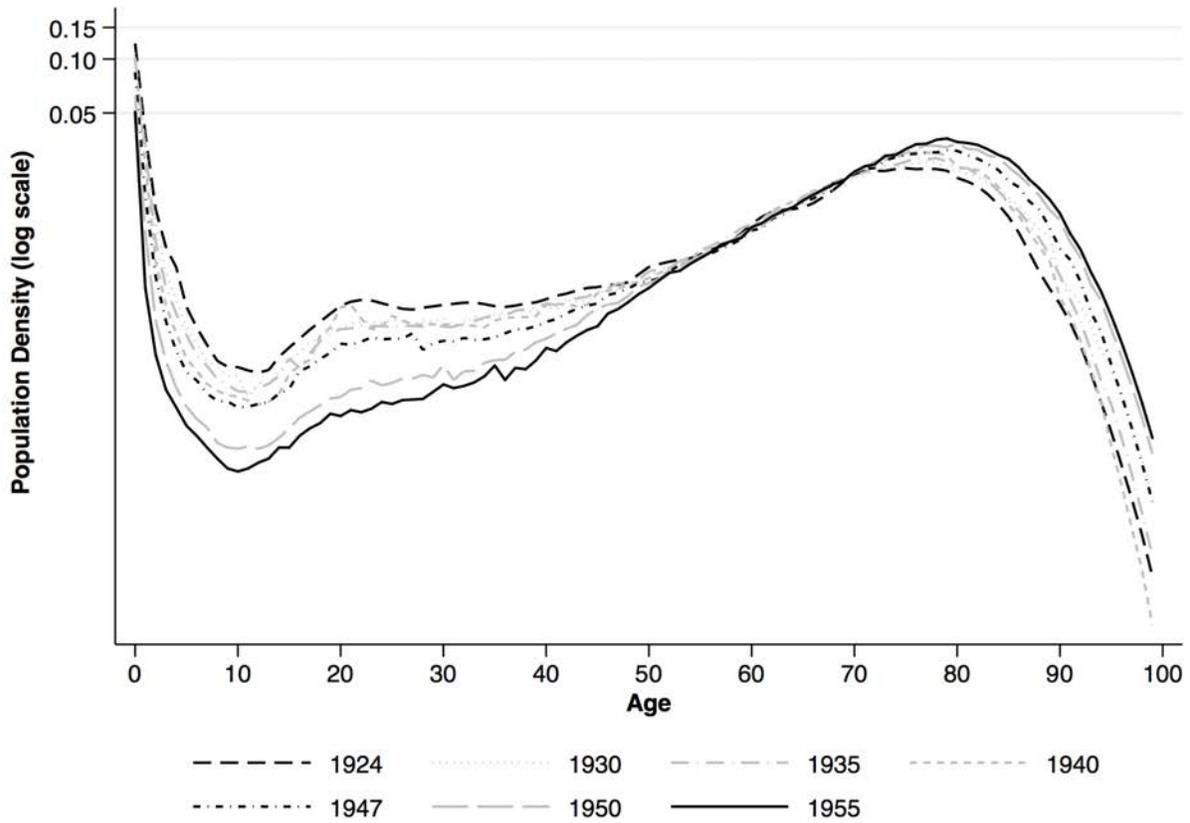
Figure 3: Period life-table distributions of age at death in Italy for selected years between 1924 and 1955. The unit is the logarithm of the probability density of deaths. *Source*: Human Mortality Database (HMD)
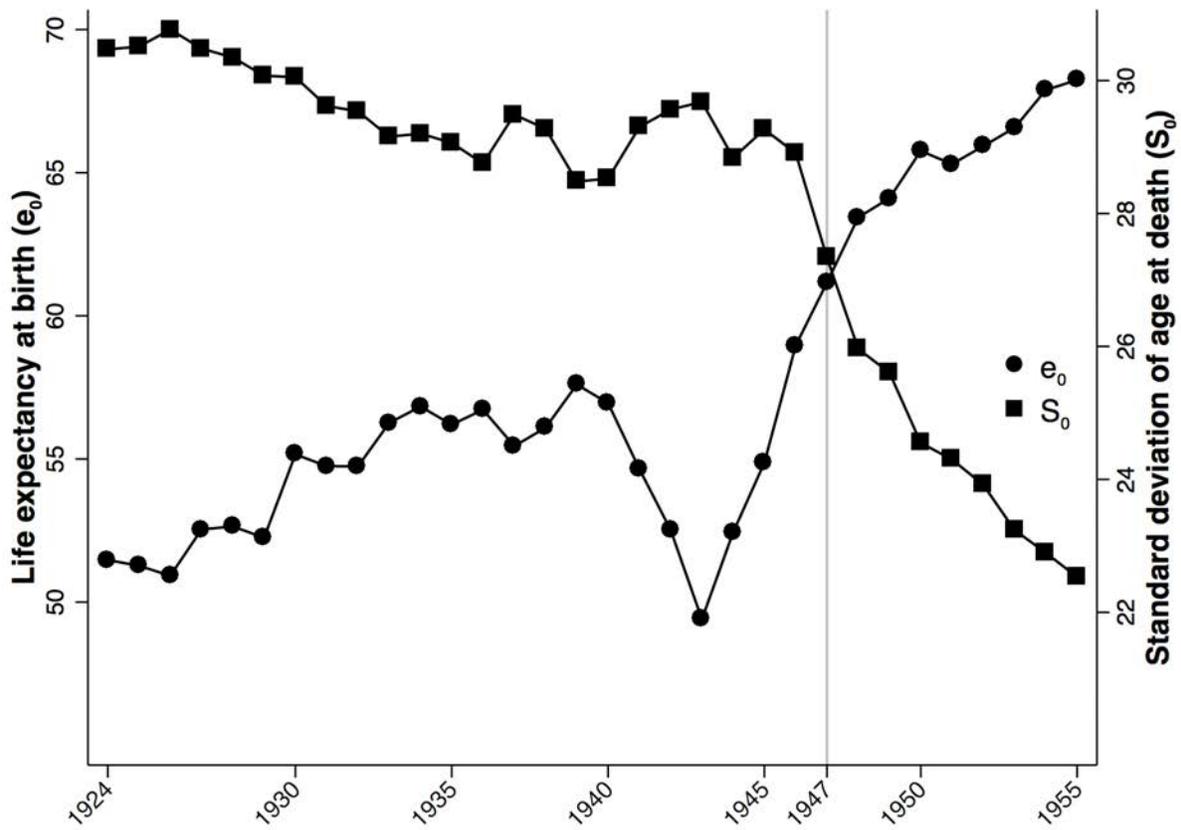
Figure 4: Life expectancy at birth and standard deviation of age at death in Italy, 1924–1955. The trajectories of the life expectancy at birth (left-hand side scale), and the standard deviation of age at death (right-hand side scale)are based on the distributions of age at death from Fig. 3.
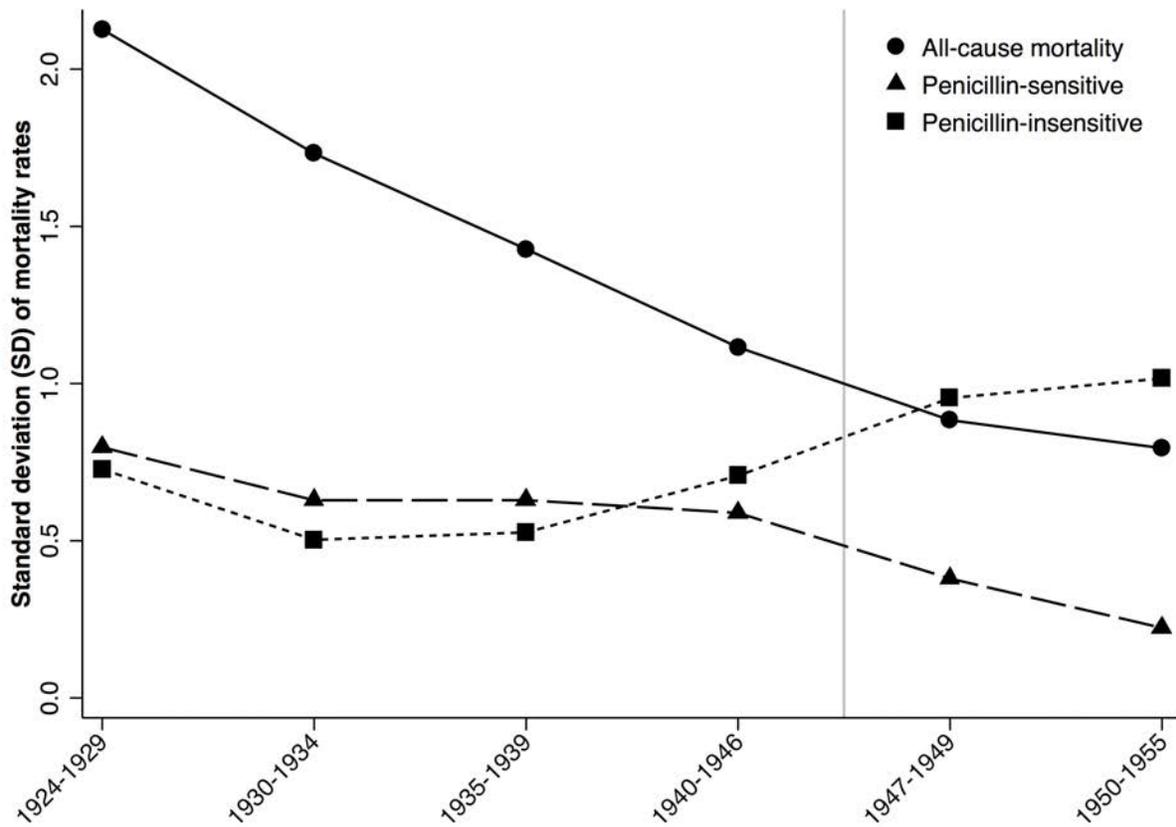
Figure 5: Standard deviation (SD) of all-cause, penicillin-sensitive, and penicillin-insensitive disease mortality in Italy, 1924–1955. The figure shows absolute levels of the SD by age grouped in approximately 5-year bins. For the decade of 1940, we consider two age groups using 1947 as a cut off to illustrate the effect of the introduction of penicillin in that year.
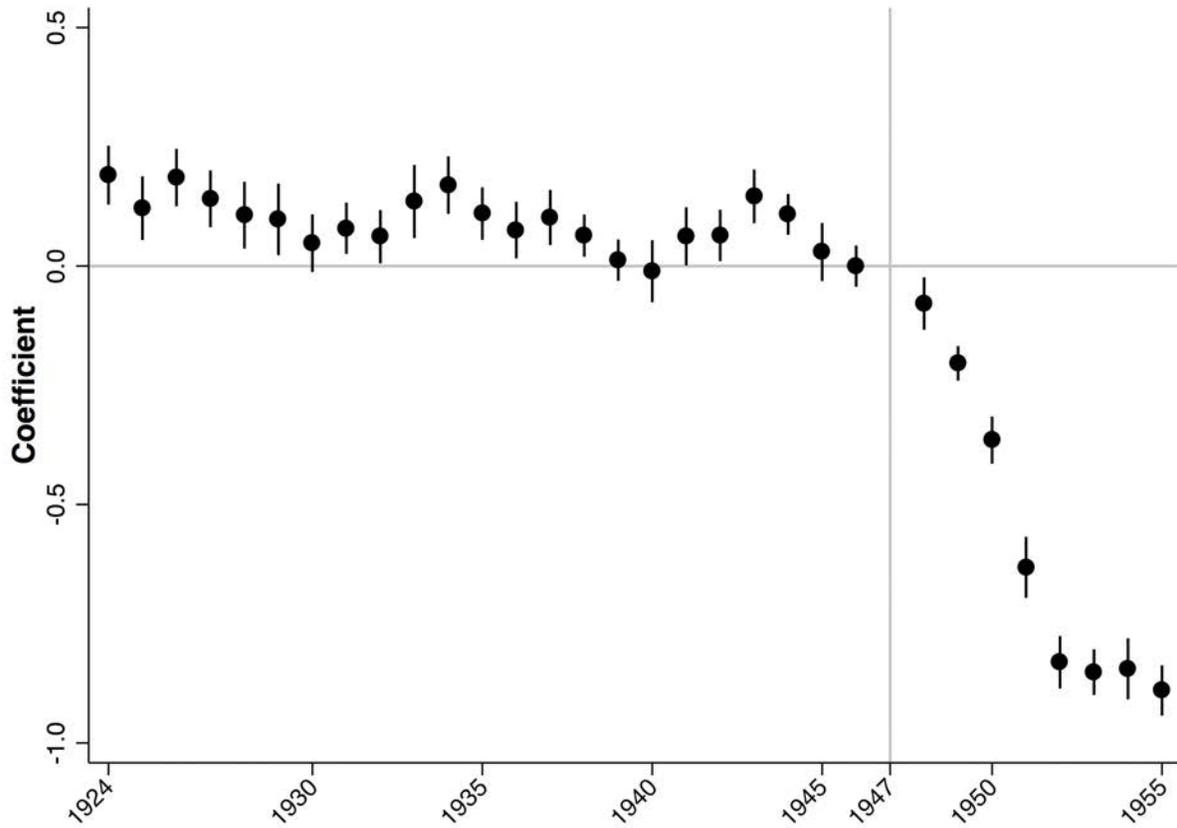
Figure 6: Penicillin-sensitive disease regression coefficients by year (log mortality), 1924–1955. The figure shows regression coefficients for penicillin-sensitive diseases by year, pre-1947 and post-1947. The outcome is log mortality per 1,000. Regression included year and region fixed effects, disease fixed effects, region-disease specific trends, and an interpolated population estimate for age bins 0–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, 71–75, 76+. Standard errors are clustered by region.
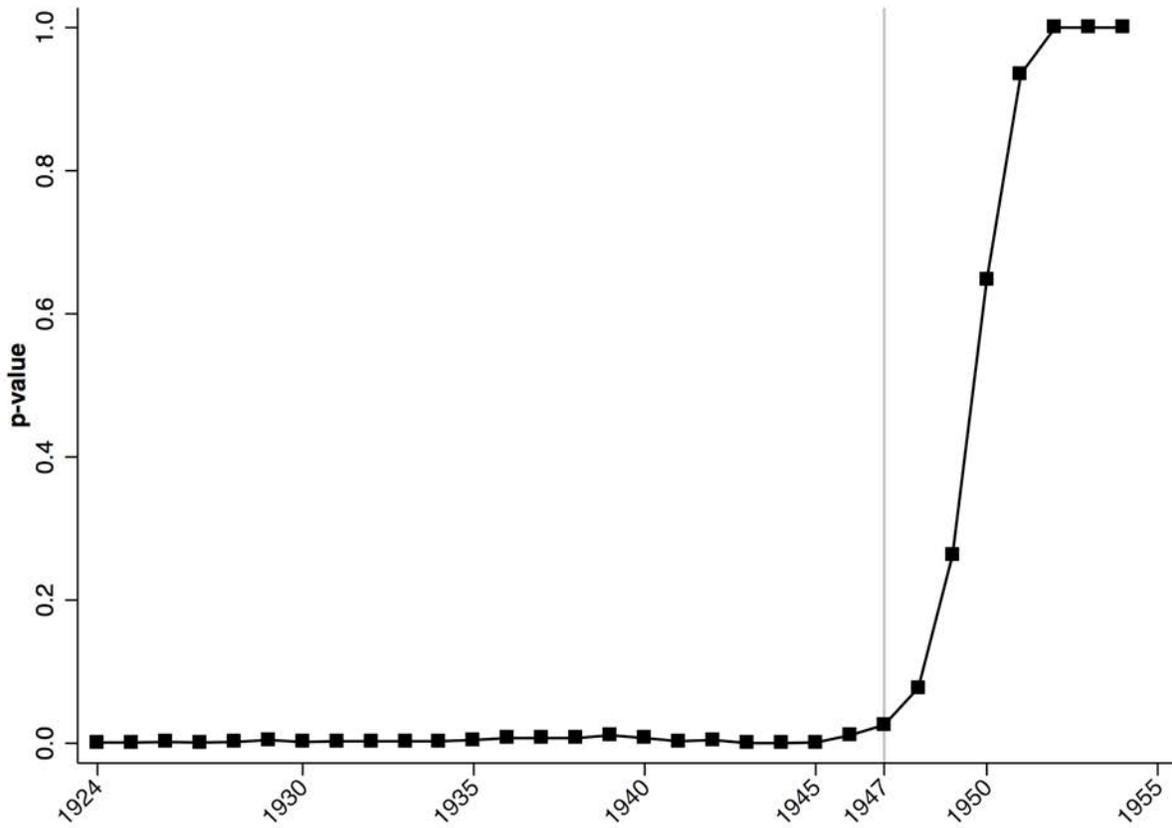
Figure 7: Kolmogorov-Smirnov (KS) test of the equality of age at death mortality distributions in Italy, 1924–1958. The figure illustrates the significance level (p-value) of the KS test for the equality of mortality distributions depicted in Fig. 3, using the distribution of 1955 as the baseline.

Table 1 Descriptive statistics comparing cause-specific mortality before and after 1947

Descriptive Statistics			
1924–1946			
VARIABLES	N	Mean	SD
Penicillin-Sensitive Cause-Specific Mortality (per 1,000)	3,726	0.469	0.652
Penicillin-InsensitiveCause-Specific Mortality (per 1,000)	11,093	0.237	0.510
1947–1955			
VARIABLES	N	Mean	SD
Penicillin-Sensitive Cause-Specific Mortality (per 1,000)	1,457	0.189	0.265
Penicillin-Insensitive Cause-Specific Mortality (per 1,000)	4,622	0.217	0.518

Note: The table reports descriptive statistics on the penicillin-sensitive and -insensitive specific mortality from 1924–1946 and 1947–1955. Cause-specific mortality is the number of deaths per 1,000 people.
Source: ISTAT.

Table 2 Baseline regressions of cause-specific mortality in Italy by regions, 1924–1955

Outcome	Cause-Specific Mortality per 1,000		Log Cause-Specific Mortality per 1,000	
	(1)	(2)	(3)	(4)
Sensitive*Post	-0.272***	-0.272***	-0.611***	-0.610***
	(0.008)	(0.008)	(0.023)	(0.023)
Block Bootstrap SE	(0.008)	(0.008)	(0.022)	(0.023)
Block Bootstrap p-value	{0.002}	{0.002}	{0.002}	{0.002}
Observations	20,898	20,898	20,892	20,892
R-squared	0.867	0.868	0.887	0.887
Year FE	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes
Disease FE	Yes	Yes	Yes	Yes
Region Trends	No	Yes	No	Yes
No. Clusters	18	18	18	18

Note: The table presents coefficient estimates for the regressions of cause-specific mortality per 1,000 on a dummy variable for disease specific penicillin-sensitivity equal to 1 starting from 1947. In columns (1) and (2) cause-specific mortality per 1,000 is in levels. In columns (3) and (4) cause-specific mortality is in logs. All columns include year, region, disease fixed effects (FE), and interpolated population estimates for age bins 0–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, 71–75, 76+. Columns (2) and (4) additionally include region-specific trends. Standard errors (SE) in parentheses are clustered by region. Block bootstrap p-values are indicated in curly brackets

Table 3 Regression results by median of pre-1947 characteristics in Italy, 1924-1955

			Sensitivity to WWII Mortality			
			Approach 1: Varying Degrees of War-Related Destruction		Approach 2: Same as Columns (1) and (2), but Excluding Years Between 1943–1945	
Sample	Above the Median of All-Cause Pre-1947 Mortality	Below the Median of All-Cause Pre-1947 Mortality	Regions with High Destruction	Regions with Low Destruction	Above the Median of All-Cause Pre-1947 Mortality	Below the Median of All-Cause Pre-1947 Mortality
	(1)	(2)	(3)	(4)	(5)	(6)
Sensitive*Post	-0.287***	-0.257***	-0.257***	-0.287***	-0.303***	-0.271***
	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)
Block Bootstrap SE	(0.011)	(0.010)	(0.010)	(0.012)	(0.012)	(0.011)
Block Bootstrap p-value	{0.002}	{0.004}	{0.004}	{0.002}	{0.004}	{0.002}
Observations	10,484	10,414	10,414	10,484	9,460	9,408
R-squared	0.875	0.901	0.899	0.873	0.873	0.899
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Disease FE	Yes	Yes	Yes	Yes	Yes	Yes
Region by Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region Trends	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table presents coefficient estimates for the regressions of cause-specific mortality per 1,000 on an indicator variable for disease specific penicillin-sensitivity after year 1947 in comparison to the pre-1947 regional mortality (columns 1-2), and in regions with high and low WWII destruction above the median (columns 3-4). High and low cutoffs are determined respectively by being above and below the median of the given sub sample mortality. Columns 5 and 6 present coefficient estimates for the regressions of annual change of cause-specific mortality per 1,000 on the region-cause specific mortality at a baseline year, based on the first sub-period (1924–1946) and for the second sub-period (1947–1955), respectively. The baseline year is 1924 for the first sub-period, while it is 1947 for the second sub-period. The values in parentheses represent robust standard errors (SE). We test the statistical significance of the difference between the coefficient estimates from columns (1) vs. (2), (3) vs. (4), and (5) vs. (6) by pooling the samples from the corresponding models and looking at the significance level of the estimate of a triple interaction term, that we construct using the indicator variables for disease specific penicillin-sensitivity, post-47 level of mortality, and the corresponding characteristic [e.g., for columns (1) and (2), the interaction term using the pooled sample is Sensitive*Post*(High Penicillin-Sensitive Mortality)]. Cause-specific mortality per 1,000 is in levels. All columns include year, region, disease fixed effects, region-specific trends, and an interpolated population estimate for age bins 0–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, 71–75, 76+. Standard errors in parentheses are clustered by region. Block bootstrap p-values are indicated in curly brackets.

Table 4 Regression results for β-convergence by high vs. low penicillin-sensitive mortality

Sample	Pre Penicillin Period (1924–1946)		Post Penicillin Period (1947–1955)	
	High Penicillin-Sensitive Mortality	Low Penicillin-Sensitive Mortality	High Penicillin-Sensitive Mortality	Low Penicillin-Sensitive Mortality
	(1)	(2)	(3)	(4)
Baseline mortality (1924 or 1947)	-0.021***	-0.002	-0.075***	0.009***
	(0.001)	(0.002)	(0.002)	(0.002)
Observations	162	424	161	508
R-squared	0.913	0.059	0.936	0.149
Region FE	Yes	Yes	Yes	Yes

Note:The table presents coefficient estimates for the regressions of annual change of cause-specific mortality per 1,000 on the region-cause specific mortality at a baseline year. Columns 1 and 2 show results for the first sub-period (1924–1946), and columns 3 and 4 for the second sub-period (1947–1955). The baseline year is 1924 for the first sub-period, while it is 1947 for the second sub-period. The values in parentheses represent robust standard errors.

Table 5 Effect of Penicillin on the Standard Deviation of Mortality Rates and Level of Mortality for Penicillin-Sensitive and -Insensitive Diseases

Outcome	Standard Deviation (Sigma-convergence)		Mortality Rate	
Category	Sensitive	Insensitive	Sensitive	Insensitive
	(1)	(2)	(3)	(4)
Post (Full Sample –*end 1955*)	-0.113***	-0.004	-0.600***	-0.340***
	(0.014)	(0.009)	(0.075)	(0.095)
Post (Truncated Sample –*end 1950*)	-0.090***	-0.009	-0.486***	-0.363***
	(0.014)	(0.009)	(0.075)	(0.097)
Difference in Post Coefficients (*1955-1950*)	-0.023	0.005	-0.114	0.023

Note: OLS regressions collapsed across deaths within region-years on an indicator for post introduction of Penicillin, region fixed effects, population in various age categories and linear time trends. The outcome in columns (1) and (2) is the standard deviation in mortality for sensitive and insensitive diseases, respectively. The outcome in columns (3) and (4) is the level of mortality from sensitive and insensitive diseases, respectively. Each cell in rows (1) and (2) reports the coefficient on the post indicator. The sample varies by row, extending over the entire analytical time period in row (1) and truncating in 1950 in row (2). Row (3) reports the difference between the full and truncated sample values. If competing risks are driving the results, the effects in row (2) should be considerably less negative in row (1), columns (2) and (4), due to individuals in the lowest part of the health distribution surviving infectious disease due to the introduction of Penicillin but dying at higher rates a few years later from non-communicable mortality.

Appendix A

A.1 - The data-set on Causes of Death in Italy (1924-1955)

In Italy data on mortality are collected routinely by the Italian National Statistical Office (ISTAT) since 1888 and are published in the Health Statistics Yearbooks (Annuari di Statistiche Sanitarie). As disease classifications have changed over time, we can identify 5 time intervals, based on 5 different classifications: 1888-1955, 1956-1957, 1958-1967, 1968-1969 and after 1969. For our study we focus on the 1888-1955 period, although for convenience we use the classification adopted in 1956-1957 as our reference classification (it presents the less disaggregated set of information: 17 main causes of death and 99 more specific pathologies) and, therefore, we have re-organized the 1888-1955 classifications to reflect the 1956-1957 classification.

Originally, data for the period 1888-1955 were available only on paper in a single document printed by ISTAT (ISTAT, 1958) and presented in form of time series by region and cause of death. For our purposes all tables have been scanned and saved in form of excel files. These row data have been further processed and double-checked in order to avoid errors from the scanning process. During the 1888-1955 period the classification follows the International Analytical Classification (IAC) code, which was approved in 1948 (ICD, 1948) and adopted in Italy from 1951. The reconstruction of the time series before year 1951 has been carried out by ISTAT. The classification adopted in 1956 and 1957 has changed from the IAC to the ISTAT Intermediate Classification (IIC) coding system. Table A.1 provides a detailed list of all diseases with the relative IIC code, while Table A.2 provides a link between the IIC and the IAC coding system.

The first column provides a brief description of the 17 main causes of death; the second column reports the ISTAT classification used to identify causes (ranging from I to XVII) and pathologies (ranging from 1 to 99); the third column describes the identification code that we implemented starting from the ISTAT classification. It consists of 7 digits: the first 3 digits denote 1 out of the 17 causes of death (101 to 117); the following 2 digits denote 1 out of the 99 pathologies (from 01 to 99). The final 2 digits range from 00 to 10: they equal zero for any of the 99 pathologies resulting from the 1956-1957 classification, and take on different values (from 01 to 10) for further disaggregation of pathologies possibly occurred either between years 1888-1955. In terms of regional disaggregation it is worth mentioning that until 1923 data refers to the Italian partition of territories prior to the WWI; from 1924 to 1942, data are referred to the borders established after WWI; from 1943 onward, to the borders after the WWII. Data prior to 1943 are referred, for each region, to the partition of territories adopted at that time. Thus, the comparability across territories is imperfect for those regions that have experienced border changes from 1927 (i.e., Veneto, Friuli-Venezia Giulia, Umbria, Lazio, Abruzzi, Molise and Campania). To account for these geographical border changes and in order to have an harmonized regional disaggregation, we have grouped together Abruzzi and Molise and Piedmont and Valle dAosta, that leads to have the dataset disaggregated in the following 18 regions: Piedmont and Valle dAosta, Lombardy, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Liguria, Emilia Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzi and Molise, Campania, Apulia, Basilicata, Calabria, Sicily and Sardinia.

A.2 - Construction of mortality rates

Mortality rates are obtained dividing number of deaths by resident population. Unfortunately, data on resident population by region is available only starting from 1922 and is obtained through a reconstruction made by Golini, Ciucci, Caselli and ISTAT (1983). As it is only from 1924 that Italy was organized in 18 administrative regions (with only minor changes with small borderline municipalities changing regions after that date) we decided to start our analysis starts in 1924. For all these reasons we limit our analysis from 1924 to 1955.

Table A.1. Structure of the 1956 -1957 classification (reference classification)

Description	1956-1957 ISTAT Classification		Code ("number")	
	Causes of death	Pathologies (IIC)	Causes of death	Pathologies
Infective/parasitic diseases	I	1-10	1010000	1010100-1011000
Tumors	II	11-26	1020000	1021100-1022600
Allergic/endocrine glands diseases	III	27-31	1030000	1032700-1033100
Blood/hematopoietic diseases	IV	32-33	1040000	1043200-1043300
Psychic/personality disorders	V	34-36	1050000	1053400-1053600
Nervous system diseases	VI	37-45	1060000	1063700-1064500
Circulatory system diseases	VII	46-56	1070000	1074600-1075600
Respiratory system diseases	VIII	57-60	1080000	1085700-1086000
Digestive system diseases	IX	61-70	1090000	1096100-1097000
Genitourinary system diseases	X	71-76	1100000	1107100-1107600
Complications of pregnancy	XI	77-80	1110000	1117700-1118000
Skin/tissue diseases	XII	81	1120000	1120000
Bones locomotive organs diseases	XIII	82-84	1130000	1138200-1138400
Congenital malformations	XIV	85-86	1140000	1148500-1148600
Early Childhood particular diseases	XV	87-91	1150000	1158700-1159100
Senility and pathologic states	XVI	92-93	1160000	1169200-1169300
Accidents/traumatisms/poisonings	XVII	94-99	1170000	1179400-1179900
Total deaths	**XVIII**		**1180000**	**1180000**

Table A.2 – Causes of death by ISTAT Identification Code (IIC) and International Classification Code (ICC)

IIC Code		Description	International Classification Code
Code (1)	Code (2)		
1010000	1010101	All forms of tuberculosis	001-019
	1010300	Syphilis and consequences	020-029
	1010400	Typhoid and paratyphoid fevers	040,041
	1010500	Diphtheria	055
	1010600	Pertussis	056
	1010700	Tetanus	061
	1010800	Acute anterior poliomyelitis	080,081
	1010900	Measles	085
	1011000	Other infectious and parasitic diseases	044,045-048,050,052,053,063, 057,062,082,083,110-117,125
1020000	1021101	All malignant tumors	140-200,202,203
	1022301	Hodgkin disease	201
	1022400	Leukemia/ a-leukemia	204
	1022600	All benign tumors	210-229
	1022608	Tumors of not specified origins	230-239
1030000	1032900	Diabetes	260
	1032804	Diseases of thyroid and parathyroid glands	250-254,271
	1032700	Allergic diseases	240,241
	1033001	Diseases of other endocrine glands and other metabolism diseases	281,283,284,288
1040000	1043203	Other anemias	290.2,291-293
	1043300	Other blood diseases and hematopoietic organs	295,296
	1043201	Pernicious anemias and other hyper-chronic diseases	290.0.1
1050000		Psychic/ personality disorders (alcoholism only)	322
1060000	1063900	Vascular lesions of central nervous system	330-334
	1064001	Meningitis	340
	1064100	Epilepsy	353
	1064201	Cerebral paralysis	350
	1064400	Eyes diseases	370-398
1070000		Circulatory system diseases	400-468
1080000	1085703	Influenza	480-483
	1085700	Pneumonia	490-493,763
	1085900	Bronchitis	500-502
	1086008	Pleurisy	518,519
1090000	1096104	Stomach and duodenal ulcers and other diseases of stomach/duodenum	540-545
	1096200	Appendicitis	550-553
	1096302	Abdominal hernia with obstruction	560,561,570
	1096600	Gastroenteritis, colitis and ulcerative colitis	571,572,764,772
	1097004	Peritonitis	576,577
	1096700	Liver cirrhosis	581
	1096900	Other diseases of liver, pancreas	580,582,583
	1096801	Bladder diseases and biliary tract diseases	584-586
1100000		Genitourinary system diseases	590-637
1110000		Complications of pregnancy	640-689
1120000		Skin/tissue diseases	690-716
1130000		Bones locomotive organs diseases	720-749
1140000		Congenital malformations	750-759
1150000		Early Childhood particular diseases	760-762,765-771,773-776
1160000		Senility and pathologic states	304,794
1170000	1179701	Accidental deaths	E(800-965,999)
	1179800	Suicides	E(970-979)
	1179900	Homicides	E(980-985)

Appendix B

Tab. B1 - LIST OF PENNICILIN SENSITIVE CAUSE OF DEATH

FLAG
1 antib.
2 no antib.
3 uncertain

TOTAL DEATH BY 17 MAIN CAUSES

YEARS AVAILABLE

FLAG	CODE	10	14	26	DESCRIPTION	FROM	UNTIL	
1	1010000	101,000	1010,000	10100,000	infective and parasitic diseases (total)	1887	1969	
1	1010001	101,000	1010,001	10100,010	infective and parasitic diseases (females)	1958	1969	
1	1010010	101,001	1010,010	10100,100	infective and parasitic diseases (males)	1958	1969	Tubercolosys
1	1010100	101,010	1010,100	10101,000	tubercolosis of respiratory system	1956	1969	Syphilis and its consequences
1	1010101	101,010	1010,101	10101,010	all forms of tubercolosis	1887	1955	Typhoid and paratyphoid fevers
1	1010102	101,010	1010,102	10101,020	pulmonary tubercolosis	1958	1967	Meningitis
1	1010103	101,010	1010,103	10101,030	pleural tubercolosis	1958	1967	Pneumonia
1	1010104	101,010	1010,104	10101,040	adenopatia tubercolosis, tracheo-bronch. with symptoms	1958	1967	Bronchitis
1	1010105	101,011	1010,105	10101,050	other tubercolosis of respiratory system	1958	1967	Appendicitis
1	1010200	101,020	1010,200	10102,000	other types of tubercolosis (total)	1956	1969	Peritonitis
1	1010201	101,020	1010,201	10102,010	tbc of menings and central nervous system	1958	1967	Nephritis and nephrosis.
1	1010202	101,020	1010,202	10102,020	intestinal tbc, peritoneal and mesenteric glands	1958	1967	
1	1010203	101,020	1010,203	10102,030	tbc of the bones	1958	1967	
1	1010204	101,020	1010,204	10102,040	tbc linfatic system	1958	1967	
1	1010205	101,021	1010,205	10102,050	tbc genitourinary system	1958	1967	
1	1010206	101,021	1010,206	10102,060	other types of tubercolosis (residual)	1958	1967	
1	1010300	101,030	1010,300	10103,000	syphilis and consequences	1887	1969	
1	1010301	101,030	1010,301	10103,010	syphilis of central nervous system	1958	1967	
1	1010302	101,030	1010,302	10103,020	other types of syphilis and its consequences	1958	1967	
1	1010400	101,040	1010,400	10104,000	typhoid and paratyphoid fevers	1887	1969	
1	1010401	101,040	1010,401	10104,010	typhoid fevers	1958	1967	
1	1010402	101,040	1010,402	10104,020	paratyphoid fevers	1958	1967	
1	1011001	101,100	1011,001	10110,010	gonococcic infections	1958	1967	
1	1011002	101,100	1011,002	10110,020	other venereal diseases	1958	1967	
1	1011003	101,100	1011,003	10110,030	brucellosis	1958	1967	
1	1011004	101,100	1011,004	10110,040	alimentary infections	1958	1967	
1	1011005	101,101	1011,005	10110,050	scarlat fever	1958	1967	
1	1011006	101,101	1011,006	10110,060	septicemia and piemia	1958	1967	
1	1064001	106,400	1064,001	10640,010	meningithis	1887	1967	
1	1064401	106,440	1064,401	10644,010	keratitis	1959	1967	
1	1064402	106,440	1064,402	10644,020	inflammations of lacrimal glands and tear duct	1958	1967	
1	1064403	106,440	1064,403	10644,030	other inflammatory eye diseases	1958	1967	
1	1064404	106,440	1064,404	10644,040	corneal ulcer	1958	1967	
1	1064501	106,450	1064,501	10645,010	mastoiditis and otitis media	1958	1967	
1	1074602	107,460	1074,602	10746,020	acute articular rheumatism with cardiac complications	1958	1967	
1	1074701	107,470	1074,701	10747,010	mitral valve diseases, rheumatic and non specified diseases	1958	1967	
1	1075201	107,520	1075,201	10752,010	endocarditis, myocarditis, and acute and subacute pericarditis	1958	1967	
1	1085700	108,570	1085,700	10857,000	pneumonia	1887	1969	
1	1085701	108,570	1085,701	10857,010	acute tonsillitis	1958	1967	
1	1085702	108,570	1085,702	10857,020	other acute infections of upper respiratory tract	1958	1967	
1	1085706	108,571	1085,706	10857,060	lobar pneumonia	1958	1967	
1	1085707	108,571	1085,707	10857,070	other pneumonias	1958	1967	
1	1085708	108,571	1085,708	10857,080	acute infections of respiratory tract, influenza and pneumonia	1958	1967	
1	1085800	108,580	1085,800	10858,000	bronchopneumonia	1956	1969	
1	1085900	108,590	1085,900	10859,000	bronchitis	1887	1969	
1	1085901	108,590	1085,901	10859,010	acute and subacute bronchitis and not-specified bronchitis	1958	1967	
1	1086001	108,600	1086,001	10860,010	other diseases and infections of upper respiratory tract	1958	1967	
1	1086003	108,600	1086,003	10860,030	tonsils abscess	1958	1967	
1	1086009	108,601	1086,009	10860,090	lung abscess	1958	1967	
1	1096200	109,620	1096,200	10962,000	appendicitis	1924	1969	
1	1096201	109,620	1096,201	10962,010	acute appendicitis	1958	1967	
1	1096202	109,620	1096,202	10962,020	other types of appendicitis	1958	1967	
1	1097004	109,700	1097,004	10970,040	peritonitis	1887	1967	
1	1107100	110,710	1107,100	11071,000	nephritis and nephrosis	1887	1969	
1	1107101	110,710	1107,101	11071,010	acute nephritis	1958	1967	
1	1107102	110,710	1107,102	11071,020	other nephritis or nephrosis	1958	1967	
1	1107103	110,710	1107,103	11071,030	hydronephrosis and pyelorenal infections	1958	1967	
1	1107104	110,710	1107,104	11071,040	pyelorenal infections	1958	1967	
1	1107302	110,730	1107,302	11073,020	cistitis	1958	1967	
1	1107502	110,750	1107,502	11075,020	orchitis and epididymitis	1958	1967	
1	1107602	110,760	1107,602	11076,020	salpingitis and oophoritis	1958	1967	
1	1107604	110,760	1107,604	11076,040	infective diseases of uterus, vagina, and vulva	1958	1967	
1	1117701	111,770	1117,701	11177,010	infections of genito urinary system during pregnancy	1958	1967	
1	1117702	111,770	1117,702	11177,020	pregnancy toxemia	1958	1967	
1	1117802	111,780	1117,802	11178,020	abortion with infection	1958	1967	
1	1128101	112,810	1128,101	11281,010	furunculus, anthrax and other abscesses	1958	1967	
1	1128102	112,810	1128,102	11281,020	other skin and cellulat tissue infections	1958	1967	
1	1138202	113,820	1138,202	11382,020	rheumatoid arthritis and similar diseases	1958	1967	
1	1138300	113,830	1138,300	11383,000	osteomyelitis and periostitis	1956	1969	
1	1158800	115,880	1158,800	11588,000	infections of newborns	1956	1957	
2	1010500				difterite	1887	1969	
2	1010600				pertosse	1887	1969	
2	1010700				tetanus	1887	1969	
2	1010800				acute anterior poliomyelitis and its postums	1899	1969	
2	1010801				poliomyelitis	1958	1967	
2	1010802				postums of acute anterior poliomyelitis	1958	1967	
2	1010900				morbillus	1887	1969	
2	1011007				parotite epidemica	1958	1967	
2	1020000				tumors (total)	1887	1969	
2	1020001				tumors (females)	1958	1969	
2	1020010				tumors (males)	1958	1969	
2	1021100				cancers of mouth and throat	1956	1969	
2	1021101				all malignant tumors	1887	1955	
2	1021102				cancers of lips	1958	1967	
2	1021103				cancers of tongue	1958	1967	
2	1021105				other cancers of mouth and throat	1958	1967	
2	1021200				cancers stomach	1956	1969	
2	1021201				cancers esophagus	1958	1967	
2	1021300				intestinal cancers	1956	1969	
2	1021301				intestinal cancers and duodenal cancers	1958	1967	
2	1021302				rectal cancers	1958	1967	
2	1021400				cancers biliary tract and liver	1956	1969	
2	1021500				other cancers digestive system	1956	1969	
2	1021600				laryngeal cancers, cancers of trachea, bronchial tubes, and lungs	1956	1969	
2	1021601				laryngeal cancers	1958	1967	
2	1021602				cancers of trachea, bronchial tubes, and lungs	1958	1967	
2	1021700				other cancers of respiratory system	1956	1969	
2	1021800				breast cancers	1956	1969	
2	1021802				cancers of female genital organs	1958	1967	
2	1021900				cervical uterus cancers	1956	1969	
2	1021901				cancers of other parts of uterus	1958	1967	
2	1022000				cancers of other female genital organs	1956	1969	
2	1022100				prostate cancers	1956	1969	
2	1022101				other cancers of male genital organs	1958	1967	
2	1022200				cancers of urinal organs	1956	1967	
2	1022300				cancers of other areas	1956	1969	
2	1022301				hodgking disease	1942	1967	
2	1022302				cancers of skin	1958	1967	
2	1022303				cancers of brain and of other parts of nervous system	1958	1967	
2	1022304				cancers of bones, cancers of connective and muscular tissue	1958	1967	
2	1022305				other non-specified cancers	1958	1967	
2	1022400				leukemia and aleukemia	1931	1969	
2	1022500				others lymphoblastomas	1956	1969	
2	1022600				all benign tumors	1931	1969	
2	1022601				other benign tumors of non specific origins	1958	1967	
2	1022602				benign tumors of breast	1958	1967	

Tab. B1 - LIST OF PENNICILIN SENSITIVE CAUSE OF DEATH - Cntd

FLAG   TOTAL DEATH BY 17 MAIN CAUSES

1 antib.
2 no antib.
3 uncertain   YEARS AVAILABLE

FLAG	CODE	10	14	26 DESCRIPTION	FROM	UNTIL	
2	1022603			benign tumors of uterus	1958	1967	
2	1022604			benign tumors of skin	1958	1967	
2	1022605			benign tumors of bones and cartilages	1958	1967	
2	1022606			lipomas	1958	1967	
2	1022607			other not specific benign tumors	1958	1967	
2	1022608			tumors of not specified origins	1933	1967	
2	1030000			allergic diseases, endocrine gland disorders, metabolic and nutrition diseases (total)	1887	1969	
2	1030001			allergic diseases, endocrine gland disorders, metabolic and nutrition diseases (females)	1958	1969	
2	1030010			allergic diseases, endocrine gland disorders, metabolic and nutrition diseases (males)	1958	1969	
2	1032700			allergic diseases	1924	1967	
2	1032701			asthma	1958	1967	
2	1032702			other allergic diseases	1958	1967	
2	1032800			diseases of thyroid gland	1956	1969	
2	1032801			goitre	1958	1967	
2	1032802			thyrotoxicosis	1958	1967	
2	1032803			other diseases of thyroid gland	1958	1967	
2	1032804			diseases of thyroid and paratyroid glands	1887	1955	
2	1032900			diabetes	1887	1969	
2	1033000			diseases of other endocrine glands	1956	1969	
2	1033001			diseases of other endocrine glands and other methabolism diseases	1887	1955	
2	1033100			vitamine deficiency and other metabolic diseases	1956	1969	
2	1040000			blood diseases and hematopoietic disorders (total)	1887	1969	
2	1040001			blood diseases and hematopoietic disorders (females)	1958	1969	
2	1040010			blood diseases and hematopoietic disorders (males)	1958	1969	
2	1043200			anaemias	1956	1969	
2	1043201			pernicious anaemia and other hyperchromic anaemias	1924	1967	
2	1043202			hypocromic amaemias	1958	1967	
2	1043203			other anaemias	1924	1967	
2	1050000			psychic disorders, psychoneurosis and personality disorders (total)	1887	1969	
2	1050001			psychic disorders, psychoneurosis and personality disorders (females)	1958	1969	
2	1050010			psychic disorders, psychoneurosis and personality disorders (males)	1958	1969	
2	1053400			psychosis	1956	1969	
2	1053401			schizophrenia (premature dementia)	1958	1967	
2	1053402			manic depressive psychosis	1958	1967	
2	1053403			involutional melancholia	1958	1967	
2	1053404			paranoia and paranoid psychosis	1958	1967	
2	1053405			senile psychosis	1958	1967	
2	1053406			alcoolic psychosis	1958	1967	
2	1053407			other psychosis	1958	1967	
2	1053500			psychoneurosis	1956	1969	
2	1053501			anxiety states without somatic symptoms	1958	1967	
2	1053502			hysterical reaction without anxiety state	1958	1967	
2	1053503			neurodepressive reaction	1958	1967	
2	1053504			psychoneurosis with somatic symptoms	1958	1967	
2	1053505			other psychic disorders	1958	1967	
2	1053600			psychic disorders of personality, intelligence, and behaviour	1956	1969	
2	1053601			alchoolism	1958	1967	
2	1053602			oligophrenia	1958	1967	
2	1053603			other psychic disorders of personality, intelligence, and behaviour	1958	1967	
2	1060000			nervous system diseases and sensory organs diseases (total)	1887	1969	
2	1060001			nervous system diseases and sensory organs diseases (females)	1958	1969	
2	1060010			nervous system diseases and sensory organs diseases (males)	1958	1969	
2	1063700			hemorragia cerebral	1956	1969	
2	1063800			cerebral thrombosis and embolism	1956	1969	
2	1063900			vascular lesions of central nervous system	1887	1969	
2	1064000			inflammatory diseases of central nervous system	1956	1969	
2	1064002			other inflammatory diseases of central nervous system	1958	1967	
2	1064100			epilepsia	1887	1969	
2	1064200			other non-inflammatory diseases of central nervous system (total)	1956	1969	
2	1064201			cerebral paralysis	1931	1967	
2	1064202			other non-inflammatory diseases of central nervous system (residual)	1958	1967	
2	1064300			diseases of peripheral nervous system	1956	1967	
2	1064301			sciatica	1958	1967	
2	1064302			other neuralgias and neuritis	1958	1967	
2	1064303			other diseases of peripheral nervous system	1958	1967	
2	1064405			strabismus	1963	1967	
2	1064406			cataract	1958	1967	
2	1064407			retina detachment	1958	1967	
2	1064408			glaucoma	1958	1967	
2	1064409			other non-inflammatory eye diseases	1958	1967	
2	1064500			ear and mastoid apophysis diseases	1956	1969	
2	1074600			acute articular rheumatism	1956	1969	
2	1074601			acute articular rheumatism without cardiac complications	1958	1967	
2	1074700			chronic rheumatic cardiopathies	1956	1969	
2	1074702			other chronic rheumatic cardiopathies	1958	1967	
2	1074800			heart atherosclerosis and coronary diseases	1956	1969	
2	1074900			chronic non rheumatic endocarditis	1956	1967	
2	1075000			degenerative myocardial atherosclerosis	1956	1967	
2	1075100			other myocardial degenerations	1956	1969	
2	1075200			other heart diseases	1956	1969	
2	1075202			functional heart diseases	1958	1967	
2	1075203			other heart diseases	1958	1967	
2	1075300			hypertension with heart disease	1956	1969	
2	1075301			benign hypertension with heart disease	1958	1967	
2	1075302			other hypertensions with heart disease	1958	1967	
2	1075400			hypertension without heart disease	1956	1969	
2	1075401			benign hypertension without heart disease	1958	1967	
2	1075402			other hypertensions without heart disease	1958	1967	
2	1075500			generalized atherosclerosis	1956	1969	
2	1075600			other diseases of arteries and vascular peripheral	1956	1969	
2	1075601			varicose veins lower limbs	1958	1967	
2	1075602			hemorrhoids	1958	1967	
2	1075603			other varicose veins with specified localizations	1958	1967	
2	1075604			phlebitis and thrombophlebitis	1958	1967	
2	1075605			other veins diseases and circulatory system diseases	1958	1967	
2	1085703			influenza	1887	1969	
2	1085704			influenza with bronchitis and bronchopneumonia	1958	1967	
2	1085705			other types of influenza	1958	1967	
2	1086002			tonsils hypertrophy and adenoids	1958	1967	
2	1086005			nasal septum deviation	1958	1967	
2	1086006			polyp nasal cavity	1958	1967	
2	1086010			pneumoconiosis	1958	1967	
2	1086011			bronchiectasia	1958	1967	
2	1096100			gastric, duodenal and digiunal ulcer	1956	1969	Note: This was not treated with antibiotics during this period
2	1096102			teeth diseases	1958	1967	
2	1096104			stomach and duodenal ulcers and other diseases of stomach and duodenum	1887	1955	
2	1096105			stomach ulcer	1958	1967	Note: This was not treated with antibiotics during this period
2	1096106			duodenal ulcer	1958	1967	Note: This was not treated with antibiotics during this period
2	1096107			gastro-digiunal ulcer	1958	1967	
2	1096108			gastritis, duodenitis and other diseases of stomach and duodenum	1958	1967	
2	1096109			gastritis, duodenitis	1958	1967	
2	1096110			other diseases of stomach and duodenum	1958	1967	
2	1096300			abdominal hernia	1956	1969	
2	1096301			abdominal hernia without mention of obstruction	1958	1967	
2	1096302			abdominal hernia with obstruction	1887	1967	
2	1096400			intestinal obstruction without mention of hernia	1956	1969	
2	1096500			gastroenteritis, colitis, and non-ulcerative colitis 29th day to 3rd year	1956	1957	
2	1096600			gastroenteritis from the 3rd year onwards and chronic colitis	1956	1967	
2	1096602			gastroenteritis, colitis and ulcerative colitis	1887	1955	
2	1096700			liver cirrhosis	1887	1969	
2	1096800			biliary lithiasis and cholecystitis	1956	1969	
2	1096801			bladder diseases and biliary tract diseases	1931	1955	
2	1097002			functional disorders of intestine	1958	1967	

Tab. B1 - LIST OF PENNICILIN SENSITIVE CAUSE OF DEATH - Cntd

FLAG   TOTAL DEATH BY 17 MAIN CAUSES
1 antib.
2 no antib.
3 uncertain   YEARS AVAILABLE

FLAG	CODE	10	14	26	DESCRIPTION	FROM	UNTIL
2	1097003				rhagades, anal and rectal abscess	1958	1967
2	1097006				cholecystitis without mention of calculus	1958	1967
2	1107200				calculus urinary system	1924	1969
2	1107400				prostatic hypertrophy and hyperplasia	1956	1969
2	1107501				hydrocele	1958	1967
2	1107605				genital prolapse	1958	1967
2	1107606				uterus deviations	1958	1967
2	1107608				menstrual disorders	1958	1967
2	1117703				placenta previa and hemorrhages in pregnancy	1958	1967
2	1117704				extra uterine pregnancy	1958	1967
2	1117801				abortion without infections, with or without toxemia	1958	1967
2	1118001				placenta previa and hemorrhage post-partum	1958	1967
2	1118002				dystocia due to anomaly of bone pelvis	1958	1967
2	1118003				dystocia due to anomaly of fetus	1958	1967
2	1128103				eczema	1958	1967
2	1138200				arthritis and rheumatism (except acute articular rheumatism)	1956	1969
2	1138201				acute arthritis	1958	1967
2	1138203				arthrosis and similar diseases	1958	1967
2	1138204				other, not specified arthritis	1958	1967
2	1138205				rheumatism (except acute articular rheumatism)	1958	1967
2	1138401				osteitis deformans and osteochondrosis and other bone diseases	1958	1967
2	1140000				congenital malformations (total)	1887	1969
2	1140001				congenital malformations (females)	1958	1969
2	1140010				congenital malformations (males)	1958	1969
2	1148500				congenital malformations of circulatory system	1956	1969
2	1148600				other congenital malformations	1956	1969
2	1148601				congenital malformations of genitourinary system	1958	1967
2	1148602				congenital malformations of bones and articulations	1958	1967
2	1148603				remaining congenital malformations	1958	1967
2	1158700				obstetrical disorder, asphyxia and newborn infections	1956	1969
2	1158900				nutrition disorders	1956	1969
2	1160000				symptoms, senility, and pathological states (total)	1887	1969
2	1160001				symptoms, senility, and pathological states (females)	1958	1969
2	1160010				symptoms, senility, and pathological states (males)	1958	1969
2	1169200				senility without mention of psychosis	1956	1969
2	1169300				symptoms and causes mis-defined and unknown	1956	1969
2	1179702				accidental poisoning	1958	1967
2	1179800				suicides	1887	1969
2	1179900				homicides	1887	1969
2	1179901				suicides and homicides	1959	1967
3	1011000				other infectious and parasitic diseases	1887	1969
3	1011008				other infectious diseases	1958	1967
3	1043300				other blood diseases and hematopoietic organs	1887	1969
3	1064400				eyes diseases	1924	1969
3	1064502				other ear and mastoid apophysis diseases	1958	1967
3	1070000				circulatory system diseases (total)	1887	1969
3	1070001				circulatory system diseases (females)	1958	1969
3	1070010				circulatory system diseases (males)	1958	1969
3	1080000				respiratory system diseases (total)	1887	1969
3	1080001				respiratory system diseases (females)	1958	1969
3	1080010				respiratory system diseases (males)	1958	1969
3	1085902				chronic bronchitis	1958	1967
3	1086000				other diseases of respiratory tract	1956	1969
3	1086004				chronic sinusitis	1958	1967
3	1086007				remaining diseases and chronic infections of upper respiratory tract	1958	1967
3	1086008				pleurisy	1887	1967
3	1086012				remaining diseases of respiratory tract	1958	1967
3	1090000				digestive system diseases (total)	1887	1969
3	1090001				digestive system diseases (females)	1958	1969
3	1090010				digestive system diseases (males)	1958	1969
3	1096101				diseases mouth cavity and esophagus	1958	1967
3	1096103				other diseases mouth cavity and esophagus	1958	1967
3	1096900				other diseases of liver, pancreas	1924	1969
3	1097000				other diseases of digestive system	1956	1969
3	1097001				other diseases of intestine and peritoneum	1958	1967
3	1097005				remaining diseases of intestine and peritoneum	1958	1967
3	1100000				genitourinary system diseases (total)	1887	1969
3	1100001				genitourinary system diseases (females)	1958	1969
3	1100010				genitourinary system diseases (males)	1958	1969
3	1107105				hydronephrosis	1958	1967
3	1107300				other diseases of urinary system	1956	1969
3	1107301				other renal diseases and urethritis	1958	1967
3	1107303				remaining diseases of urinary system	1958	1967
3	1107500				other diseases of male genital organs	1956	1969
3	1107503				remaining diseases of male genital organs	1958	1967
3	1107600				breast diseases and disease of female genital organs	1956	1969
3	1107601				breast diseases	1958	1967
3	1107603				other diseases of female pelvic peritoneum	1958	1967
3	1107607				other uterus diseases	1958	1967
3	1107609				other disorders female genital organs	1958	1967
3	1110000				complications of pregnancy, childbirth, and the puerperium (total)	1887	1969
3	1117700				pregnancy complications	1956	1969
3	1117705				other complications in pregnancy	1958	1967
3	1117800				abortion	1956	1969
3	1118000				complications of childbirth, and the puerperium	1956	1969
3	1118004				other complications of childbirth	1958	1967
3	1118005				puerperium complications	1958	1967
3	1118006				breast-feeding disorders	1958	1967
3	1120000				skin and tissue diseases (total)	1887	1969
3	1120001				skin and tissue diseases (females)	1958	1969
3	1120010				skin and tissue diseases (males)	1958	1969
3	1128104				erythematous affections	1958	1967
3	1128105				psoriasis and similar disorders	1958	1967
3	1128106				other skin and cellular tissue infections	1958	1967
3	1130000				bone diseases and locomotive organ diseases (total)	1887	1969
3	1130001				bone diseases and locomotive organ diseases (females)	1958	1969
3	1130010				bone diseases and locomotive organ diseases (males)	1958	1969
3	1138400				other diseases of bones locomotive organs	1956	1969
3	1138402				knee intra-articular disease	1958	1967
3	1138403				intervertebral disc diseases	1958	1967
3	1138404				other articular diseases	1958	1967
3	1138405				synovitis, bursitis and tenosynovitis	1958	1967
3	1138406				remaining diseases of osteo-muscolar system	1958	1967
3	1150000				early childhood particular diseases (total)	1887	1969
3	1150001				early childhood particular diseases (females)	1958	1969
3	1150010				early childhood particular diseases (males)	1958	1969
3	1159000				immaturity	1956	1969
3	1159100				other particular diseses of early childhood	1956	1969
3	1170000				accidents, traumatisms and poisonings (total)	1887	1969
3	1170001				accidents, traumatisms and poisonings (females)	1958	1969
3	1170010				accidents, traumatisms and poisonings (males)	1958	1969
3	1179400				accidents caused to pedestrian by motor vehicle	1956	1969
3	1179500				other accidents caused by motor vehicle	1956	1969
3	1179501				traffic accidents	1958	1967
3	1179600				accidents caused by other motor vehicles	1956	1969
3	1179602				accidents by transportation through waterways	1958	1967
3	1179603				aviation accidents	1958	1967
3	1179604				railway accidents	1958	1967
3	1179700				other accidents	1887	1969
3	1179703				accidental downfalls	1958	1967
3	1179704				accidents caused by fire-arms	1958	1967
3	1179705				accidental drowning	1958	1967
3	1179706				other accidents	1958	1967
3	1179707				trauma war	1958	1967
	1180000				total deaths	1887	1957