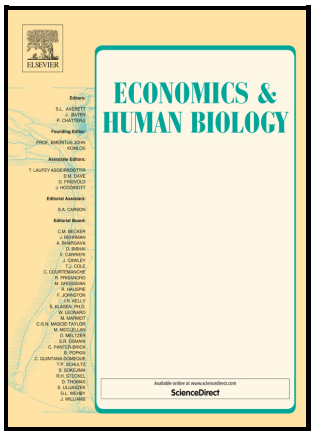

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Maternal mortality, tuberculosis and social deprivation in Madrid during the second and third decades of the 20th century

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Abstract

In this paper we jointly study maternal mortality and tuberculosis during the second and third decades of the 20th century in Madrid. Nicknamed the “city of death”, the Spanish capital was marked by a high mortality where tuberculosis accounted for approximately 26/28% of all deaths of women of reproductive age. Using a large longitudinal individual-level database including causes of death, we discuss the definitions of maternal mortality, then highlight its high level in the Spanish capital. However, the risk of dying was significantly lower for migrant women than for native. In the context studied, an evident example of the “healthy migrant” paradox with selection at origin is outlined. At the same time, there are clear links between tuberculosis as a cause of death during the 60 days following a delivery and the socio-spatial inequalities characteristic of a city that saw wealthy areas side by side with disadvantaged areas, characterized by low standards of living conditions and insufficient hygiene. The results of the statistical models analyzed are controlled for geographic, social and biological variables in addition to individual demographic characteristics. The robustness of the results is ensured by the size of the sample used, which allowed us to study an event - a death following delivery - that, even at the time of this study, was rare.

Keywords: Maternal mortality, Tuberculosis, Social deprivation, Spain, Longitudinal data

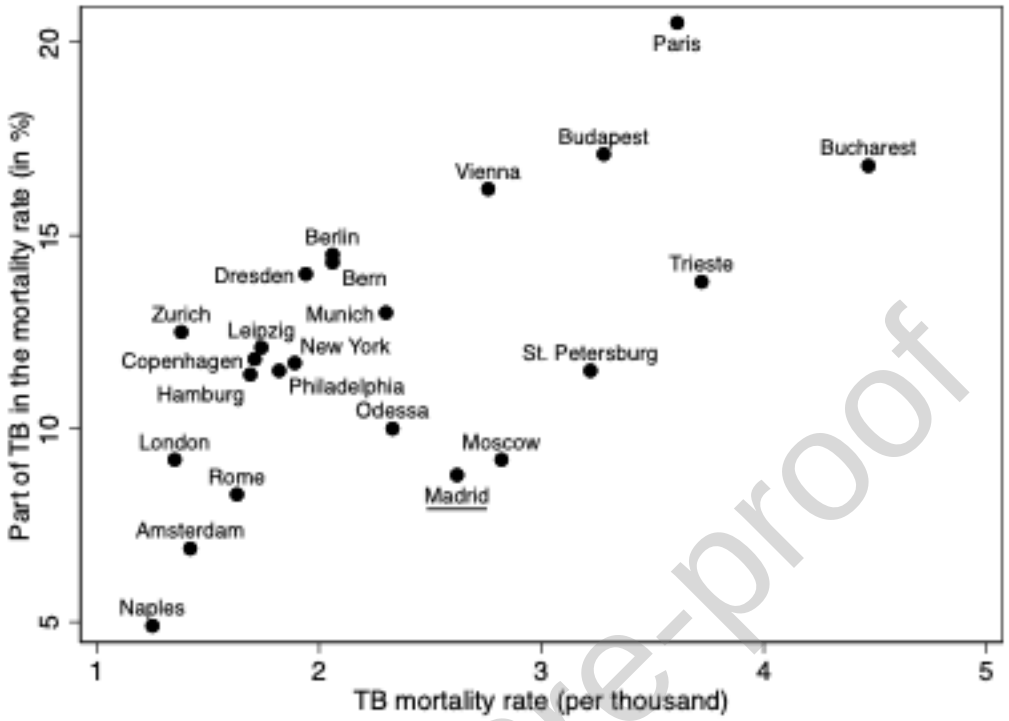
1. Introduction

In this article, we investigate the association between two childbirth-related health issues that are most often considered separately: maternal mortality and tuberculosis. Both health concerns have been important components of the mortality regime of Western populations in the past. During the 19th century, maternal mortality rates were high (Scalone, 2014; Manfredini et al., 2020) and remained unchanged until the mid-1930s, by which time infant and child mortality rates had already fallen significantly (Loudon, 1992). Pozzi et al. (2020) claim that mortality due to pregnancy and childbirth

accounted for over a third of preventable deaths. In Spain, during the first decades of the 20th century, maternal mortality accounted for up to 7% of mortality among women of childbearing age (Cortes-Majo et al., 1990b; Pérez-Moreda et al., 2015).

Tuberculosis, a bacterial infection, developed in a context of industrialisation and urbanisation (Mackenbach 2020, 155-162). In 1905-06, more than a quarter of deaths between the ages of 15 and 34 were attributed to this disease in Spain, and we know that this figure was underestimated (Pérez-Moreda et al., 2015, 102). Figure 1 shows that, compared with European and American cities, the prevalence of tuberculosis was high in Madrid at the beginning of the 20th century. Only Paris and the major cities of the Russian and Austro-Hungarian empires fared worse. If its contribution to the all-cause mortality rate seems low, this is only because this rate was very high (29‰), mainly due to infant and child mortality. If we consider only women aged between 15 and 44, tuberculosis generated 28% of reported deaths in the Spanish capital, between 1913 and 1926. Throughout Europe, from the 1920s onwards in the case of Spain, the decline in tuberculosis mortality played a crucial role in the transformation of the epidemiological landscape, in the transition from infectious to chronic diseases (Vallin, 2002; Harris, 2004; Pérez-Moreda et al., 2015; Reid and Garrett, 2018a).

Figure 1. Rate of mortality due to tuberculosis and contribution of tuberculosis to the all-cause mortality rate in a selection of European and American cities, ~1908-09



Source: Ayuntamiento de Madrid [1910], 76; Cliff et al. (1998), 241-258.

In addition, maternal mortality and tuberculosis have both been affected by gender, as well as socio-economic and spatial inequalities. Since the pioneering work of Tabutin (1978), the excess female mortality due to tuberculosis observed in late 19th-century Europe has classically been attributed to a deterioration in women's status. Building on this interpretation and McKeown's (1976) influential work on the role of nutrition in mortality decline, McNay and colleagues (2005) suggested that, due to their inferior social position, women were unable to negotiate equal access to food, which may have affected not only their susceptibility to tuberculosis, but also maternal mortality. Hinde (2015), along with Reid and Garrett (2018a), have questioned this conclusion and highlighted the role of male and female migrants in gender and rural-urban differences. With regard to the latter, the increasing supply of care from urban health facilities should not be overlooked (Pérez-Moreda et al., 2015, 100-106; Oris and Ramiro Fariñas, 2016). This brief overview of current discussions is enough to demonstrate that a holistic approach to integrated inequalities is needed.

This is particularly evident when examining maternal mortality patterns associated with tuberculosis, as socio-economic deprivation is closely linked to this specific mortality risk (Högberg and Broström, 1985; Högberg, 2004). However, the determinants of deaths associated with tuberculosis in pregnancy have long been neglected (Khan et al., 2001), in stark contrast to the evidence that this disease has been and still is one of the leading non-obstetric causes of maternal mortality (Mnyani and McIntyre, 2011). The most important factors have finally been studied in depth over the last twenty years (Goya et al., 2006; Mnyani and McIntyre, 2011; Zumla et al., 2014; Sobhy et al., 2017). Indeed, although our research is historical, it is pertinent to bear in mind that these questions also have contemporary relevance. Maternal mortality has declined considerably in recent decades, but remains a serious problem in countries of the South (Starke, 1997; Villanueva-Egan, 2012). In addition, research highlights that tuberculosis remains an important infection in women worldwide (Mnyani and McIntyre, 2011). Analysis of maternal deaths associated with tuberculosis during pregnancy is particularly relevant, as this disease is increasingly contributing to maternal morbidity and mortality in sub-Saharan African countries or parts of South Asia, among others (Khan et al., 2001; Grange et al. 2010; Sugarman et al., 2014). This persistent health challenge, linking the past to the present, highlights the need to explore the historical impact of tuberculosis on maternal health.

To this end, we study the Spanish capital during the first decades of the 20th century, a period during which Madrid continued to earn the nickname "ciudad de la muerte", city of death (see Revenga, 1901, and on the origins of this expression, Ruiz-Berdún, 2014, 171-172). To our knowledge, there is no comprehensive analysis of this phenomenon in Spain during the first third of the twentieth century and, more generally, there are very few, if any, works on maternal mortality and associated causes of death that use individual-level data. The aim of the present study is therefore to estimate the impact of the determinants of maternal mortality, but also to study in greater depth maternal deaths associated with tuberculosis, and to identify factors that may have amplified inequality in this dimension of health, using data from the Madrid Civil Registry from 1913 to 1926.

In the following pages, the first section presents a review of the literature focusing on factors influencing the risk of maternal death and, more specifically, the risk of maternal death associated with tuberculosis. The following sections include a brief description of the data sources used in the study, as well as the analysis techniques applied. Finally, the results of several statistical models are discussed and the main conclusions are presented.

2. Theoretical background

We study maternal mortality just before its decline, from the 1930s, which was attributed first to medical progresses. A better training of obstetricians and midwives, an improved access to maternity care and the institutionalization of childbirth have played a key role (Bernabeau-Mestre and Gáscon-Pérez, 1999). The introduction of sulfonamides - due to their efficacy against streptococci and puerperal fever - as well as penicillin and blood transfusions, and later the availability of antibiotics have also been particularly important (Abracinskas and López-Gómez, 2004; Chamberlain, 2006; Scalone, 2014). Other researchers attribute the main role to factors such as improved nutrition, better health for women of childbearing age and control of fertility through stopping behaviors, which have led to a reduction in risky motherhood for older mothers (Manfredini et al., 2020; Cortés-Majó et al., 1990a). The fall in maternal mortality has also been widely attributed to socio-economic progress, particularly improvements in hygiene, housing conditions and nutrition (Loudon, 2000).

These debates are not central for us, but they illustrate the factors affecting the risks of maternal mortality and their diversity.

2.1 *Determinants of maternal mortality*

As we have seen above, the factors associated with maternal mortality in the early decades of the 20th century were very diverse. In what follows, we discuss the role of biodemographic factors, the impact of social network and socio-economic position on maternal health outcomes, and also consider the influence of medicalization (institutionalization).

2.1.1. Physiological and biological factors

Studies on the determinants of maternal mortality have mainly considered the importance of the quality of medical care received by mothers during pregnancy, childbirth and the postpartum period (Scalone, 2014). However, medical care has not been the only relevant factor in historical populations; the distribution of birthing women's characteristics has also played a role in maternal mortality risk (Ory and Van Poppel, 2013).

In this respect, it is important to consider that maternal age had a strong impact on maternal mortality (Reid, 2020): this was not a linear effect, since both younger and older women had a higher risk of dying in the days following childbirth (Scalone 2014). This effect has been measured both in historical and contemporary studies (Ory and Van Poppel, 2013). However, some research postulates that this association between age and maternal mortality has a J-shape (Högberg and Wall, 1986; Scalone, 2014); the effect is found only in older mothers who have a higher risk of dying in childbirth or the puerperium (Högberg and Broström, 1985; Luque, 2010; Ory and Van Poppel, 2013; Manfredini et al., 2020).

Similarly, while Mitro et al. (2023) state that multiple gestations may entail additional risks and increase the likelihood of postpartum hemorrhage or pre-eclampsia, but do not necessarily increase the risk of maternal death, other studies conclude that giving birth to twins or more babies may significantly increase the risk of maternal mortality (Ory and Van Poppel, 2013; Scalone, 2014; Manfredini et al., 2020; Varea et al., 2023; Köck, 2024). According to Manfredini et al. (2020), mothers of multiple births were three times more likely to die than uniparous mothers.

Some research also suggests that differences in height and weight marked by the sex of the newborn are important in the probability of death: if it is a male, the risk of mortality is higher, due to his greater size (Scalone, 2014). Varea et al. (2023) report that deliveries of male babies present more obstetric complications due to the larger size of the newborn.

All this reveals the multidimensional nature of the factors that condition the probability of dying from maternity-related causes. However, it is necessary to take into account

other structural factors which affect the population differently, and which are also associated with a higher risk of maternal death.

2.1.2. Social and economic factors. Support network

In addition to biological risk factors, a woman's environment can influence her risk of maternal mortality (Ory and Van Poppel, 2013). Household structure, position in the family and marital status have been recognized as relevant factors in maternal mortality in various studies (Razum and Jahn, 2000; Alter et al., 2004; Hammel and Gullickson, 2004; Cordero and González, 2011; Singh, 2021). The importance of psychosocial factors - particularly support networks - on health status (Álvarez, 2009) and their crucial influence on maternal well-being during pregnancy and the puerperium are now fully recognized (Mabetha et al., 2022).

More specifically, some research concludes that celibacy is associated with higher maternal mortality risks, as unmarried women may lack social support during pregnancy and childbirth (Singh, 2021). Furthermore, in the early 20th century, the marital status of unmarried women reflected certain socioeconomic conditions (Singh, 2021) and unmarried women were more likely to give birth in medical institutions, where the risk of contracting puerperal infections was higher (Ory and Van Poppel, 2013; Revuelta-Eugercios, 2013).

2.1.3. Socio-economic determinants

Poverty, low social status of women, ignorance and lack of skilled assistance during and after childbirth are specific factors to be taken into account through proxy indicators of the socio-economic environment when analyzing the determinants of maternal mortality (Manfredini et al., 2020). Indeed, the importance of socio-economic status is widely recognized as a crucial dimension in mortality analysis (Pozzi and Ramiro-Fariñas, 2015) and, more specifically, some research reveals that the gradient of maternal mortality corresponds to economic and social conditions (Hammel and Gullickson, 2004). High maternal mortality was (and still is) associated with socio-economic deprivation (Högberg and Broström, 1985; Hamadeh and Glassroth, 1992; Högberg, 2004).

Maldonado and Pérez (2008) have suggested that area of residence provides relevant information on women's socio-economic characteristics. In an urban context such as Madrid's, we can therefore expect the incidence of maternal mortality to be higher in neighborhoods and districts that are more disadvantaged in terms of housing and sanitation.

2.1.4. Medicalization and institutionalization

However, authors such as Pozzi et al. (2020) disagree; they argue that in historical context, maternal mortality was relatively insensitive to social and economic factors, except insofar as these factors determined the type and quality of medical care received by women. In this sense, Reid (2012) emphasizes that the type of care was conditioned by individual, social and spatial factors.

In Spain, home births remained the norm until the 1970s (Ruiz-Berdún, 2016; Vilar-Rodríguez et al., 2024). Even in the capital, the institutionalization of childbirth was a very slow process (Casado et al., 2021; Varea et al., 2023). During the period studied, the percentage of institutional births fluctuated between 7.5% and 9%, and over 80% of these took place at the Maternidad (Casado et al., 2021). Although the number of women giving birth in medical institutions gradually increased during the first third of the century, the shortage of maternity care facilities was evident. Until 1924, there was only one maternity hospital, located in Inclusa (Casado et al., 2021)[1] , one of the city's most deprived and insalubrious districts (Mazzoni et al., 2023; Ruiz-Berdún, 2024).

In the early years when the maternity hospital was inaugurated, it was a resource linked to abandonment; however, from 1888 onwards, the assistance provided was extended to poor women who did not have the resources for a midwife and to those with complicated deliveries or pregnancies (Casado et al., 2021). Thus, a large proportion of the women who gave birth at this center came from working-class backgrounds (Casado et al., 2021). The women who attended this center were also mostly recent immigrants and therefore lacked the support networks of traditional midwives (Casado et al., 2021;

[1] It was at this time that the Casa de Salud Santa Cristina was inaugurated, marking an important turning point in the process of institutionalizing childbirth in this city (Casado et al., 2021; Ruiz-Berdún, 2016). However, during most of the years analyzed in this study, there was only the Casa de Maternidad de Madrid.

Varea et al., 2023). In this sense, the risk of complications during childbirth among women who gave birth in maternity hospitals also stems from the precarious working, hygiene and health conditions of immigrant women (Varea et al., 2023).

In addition, hospital use was also significantly associated with younger age and single status (Revuelta-Eugercios, 2013; Casado et al., 2021). Higher attendance by young primiparous women was also associated with longer deliveries and, consequently, greater complications (Varea et al., 2023). These trends have also been identified elsewhere, such as in Vienna, where an increase in hospitalization at the time of delivery has also been reported among poor women and women with illegitimate conceptions (Villanueva-Egan, 2012).

Finally, going to a medical center has been shown to increase the risk of contracting puerperal infections, due to poor hygiene conditions (Hauser, 1902; Pozzi et al., 2020; Casado et al., 2021; Ruiz-Berdún, 2024)[2] . This factor, along with the biological factors mentioned above, may have increased the risk of maternal mortality, insofar as they can contribute to complications during childbirth (Manfredini et al., 2020). It is therefore possible that the effect of delivery in a health-care facility was felt mainly in the first few days after delivery. However, reference will be made below to factors linked to indirect causes of mortality, which refer to pre-existing conditions aggravated by pregnancy (Manfredini et al., 2020) and which may lead to death at later stages.

2.2. Specific factors in maternal mortality associated with tuberculosis

The effects of socio-economic status on the probability of dying in childbirth are particularly evident when studying the specific causes associated with maternal mortality. Indeed, the importance of infectious diseases in maternal deaths reinforces the hypothesis that high levels of maternal mortality are linked to socio-economic deprivation (Högberg and Broström, 1985).

As mentioned above, the geographical area in which individuals live provides an approach to socio-economic indicators, as urban space is the result of different political, economic, social and cultural processes that make up society; the configuration of these

[2] Although these infections were common in the past, there is evidence that the opening of large maternity hospitals has favored their spread, increasing maternal mortality levels (Ruiz-Berdún, 2024).

spaces conditions opportunities and limitations (Vicente-Albarrán, 2015). This was particularly true in Madrid during the first decades of the twentieth century, where intra-urban inequalities in all-cause mortality risks reflected sensitivity to a highly segregated urban environment (Oris and Ramiro-Fariñas, 2016; Mazzoni et al., 2023). This is particularly important when it comes to deaths from infectious causes, such as tuberculosis (Miralles-Buil, 2014).

While it is not possible to conclude that pregnancy alone is associated with an increased risk of tuberculosis (Good et al., 1981; Espinal et al., 1996; Mnyani and McIntyre, 2011), there is evidence that an overall increase in tuberculosis incidence leads to higher rates of tuberculosis infection in pregnant women (Mnyani and McIntyre, 2011). In developing countries, around a third of tuberculosis deaths occur in women of childbearing age (Grange et al. 2010). Furthermore, active tuberculosis during pregnancy has been shown to be associated with adverse maternal and fetal outcomes (Sobhy et al., 2017): the presence of this disease during pregnancy, delivery and the puerperium leads to adverse outcomes (Sugarman et al., 2014). Thus, in contemporary data, tuberculosis is among the leading indirect causes of maternal mortality (Khan et al., 2001). Högberg and Broström (1985) also point to a link between families affected by tuberculosis and high maternal mortality.

With regard to the link between maternal mortality and this social disease linked to poverty and poor living conditions (Lozano et al., 2009; Nguipdop-Djomo et al., 2020), studies such as that by Mnyani and McIntyre (2011) reveal that women of childbearing age are disproportionately affected by tuberculosis in resource-limited settings (Sugarman et al., 2014). Historical studies also suggest that malnutrition could not only be a cause of tuberculosis, but also a consequence (Reid and Garrett, 2018a, 4) that can affect mothers' chances of survival (Alter et al., 2004).

With this in mind, it is worth recalling that in the early decades of the 20th century, a high prevalence of malnutrition, with a vicious circle of misery and disease, drove up overall morbimortality figures in Spain's provincial capitals (Bernabeu-Mestre et al., 2021). Until 1930, misery, insalubrity and overpopulation remained unchecked in certain regions of Spain (Anaut, 1999), and the uneven installation of many public services

(Vicente-Albarrán, 2015) prevented the spread of tuberculosis from being effectively curbed (Anaut, 1999).

3. The study area, the city of Madrid

At the beginning of the 20th century, Madrid underwent a demographic expansion that led to a deterioration in the city's hygiene and housing conditions, conditioning mortality levels (Oris et al., 2023). Although numerous investments in public hygiene and construction were made between 1880 and 1930, they mainly benefited the wealthy districts of the city center, while living conditions in outlying areas remained poor or worsened (Vicente-Albarrán, 2015; Oris et al., 2023). As mentioned above, this has important implications for maternal mortality, and more specifically for maternal mortality associated with tuberculosis.

We have just mentioned the unequal distribution of public services; this was particularly the case in Madrid during the first decades of the 20th century: the neighborhoods of Inclusa, Hospital and Latina were the most disadvantaged, while Buenavista enjoyed the greatest advantages (Oris et al., 2023). The absence of a coordinated health policy to tackle housing and insalubrity problems generated strong territorial differences, and meant that living in one neighborhood or another conditioned people's social status (Vicente-Albarrán, 2015): the middle and upper classes settled in the north and northwest, and the working classes in the southeast and east (Maldonado and Pérez, 2008).

Segregation is also marked by the area's economic specialization: occupations are closely linked to zones, clearly differentiating affluent from poor and disadvantaged neighborhoods, separated by physical and symbolic boundaries (Vicente-Albarrán, 2015). The division between the southern and eastern zones and other parts of the city is very clear, reflecting differences in real estate quality and housing rental prices (Vicente-Albarrán, 2015). This has conditioned the taxes collected and, consequently, the sewage systems and street paving, among other things (Casado-Ruiz, 2021). What's more, in the most run-down areas, cheap, small-scale housing was built for families of day laborers and workers, who were also unable to generate sufficient taxes to properly maintain the neighborhoods (Diaz-Simon, 2016).

Social stratification and spatial segregation have significantly influenced the different mortality patterns in Madrid's urban environment. The center and Ensanche Este enjoyed the best sanitation conditions, which reinforced the sharp differences in mortality rates between Madrid's neighborhoods in the first decades of the twentieth century. The lowest overall, infant and child mortality rates were observed in Buenavista, Hospicio, Palacio and Chamberí, while the highest values were found in Hospital, Inclusa, Latina and Universidad (Porras, 2002; Oris et al., 2023; Mazzoni et al., 2022), which were the neighborhoods with the worst housing conditions and highest overcrowding rates, as well as a greater number of buildings not connected to the sewage system (Huertas, 2002; Palao, 2010; Casado et al., 2021). This is all the more important for us as most births took place at home.

4. Data and methodology

Illness and death being the result of a variety of biological, social and cultural determinants (Pozzi and Ramiro-Fariñas, 2015), we need an analysis capable of taking into account the influence of different variables. For these reasons, different statistical methods are applied to analyze the effect of different factors. In this sense, it is also important to consider that the specific characteristics of the populations at risk only allow this reality to be analyzed on the basis of indicators that do not reflect specific risk factors, but rather approximations represented by contextual variables (Pozzi and Ramiro-Fariñas, 2015).

4.1 *The challenge of identifying maternal mortality*

To identify an event of maternal death after childbirth, we use Madrid's civil registers of births (~254,000 events) and deaths for the period 1913-1926, restricting the search to women aged 11-55, extending the usual group 15-49. Using this selection, we have isolated ~37,000 death records.

The first source includes: mother's first and last name and age, date and place (home or hospital) of child's birth, mother's province of birth, delivery district, street and number. The second source gives the date of death, surname and first name, age, province of birth, as well as the district, street and number. In addition, the cause of death is provided for all death events.

The two sources were linked using Stata 17 and the Dtalink module (Kranker 2018), a probabilistic approach to record linking already used and explained in previous articles (Oris et. al 2023; Mazzoni et al. 2022). After some exclusions and other arrangements in the data[3] , the final product consists of a huge database of 253,346 deliveries, which gives us the chance to observe a rare event such as maternal mortality: 1,064 cases of death of the mother within 60 days of the child's birth can be observed, which is quite a high number of cases when compared with existing studies on maternal mortality based on individual-level data.

The individual life histories thus obtained are followed from the time of delivery until the mother's death (if applicable) before the 60th day after delivery, or until the end of the study (December 31, 1926). In addition, the data are organized into episodes and prepared for different types of semi-parametric - Cox (1972) and Fine-Gray (1999) models - and parametric - Royston-Parmar model (2002) - regressions using the event history analysis technique. In what follows, all regression results are expressed in terms of hazard ratios (HR) and sub-distribution hazard ratios (SHR).

Under-reporting could affect our estimates insofar as, at that time, stillbirths were not registered at the individual level - a limitation of analysis shared by other countries. Furthermore, in Spain, until 1975, the births of children who died within the first 24 hours of life were not declared in civil registers, since these babies were considered as “abortive creatures” (INE, 2024; Mazzoni et al., 2022; Oris et al. 2023). There are a few articles on different ways of capturing maternal deaths (Reid and Garrett, 2018b; Kippen, 2005; Pantin, 1996), and one of them is to analyze causes of death, what indeed give us a chance to measure the impact of the non-registration of the children who died during the first 24 hours. To this end, we used the ICD-10h codes and classification recently proposed by a team of historical demographers (Reid and al., 2024a; Reid et al., 2024b). 1,198 deaths of Madrid women were classified as due to childbirth (direct causes, known from the causes of death), and only 349 were linked to a birth certificate. The remainder (849) corresponded to mothers whose children died within the first 24 hours of life.

[3] Some registrations contained incomplete information, such as the absence of region of origin or the mother's age. Similarly, twin births, although registered twice, were treated as a single birth.

Assuming that these 849 deaths occurred within 60 days of delivery, maternal mortality estimates for 1913-26 Madrid increase dramatically from 4.2 to 7.5 ‰.

In the following analyses, we work on the 1,064 maternal deaths linked to a birth certificate, with a distance of 1 to 60 days between the two events. Neglecting cases linked to the death of the child within the first 24 hours could lead to an underestimation of the true incidence of maternal deaths linked to tuberculosis. However, first without birth event the analysis would have been severely limited[4]. Second, among the 849 cases we neglect, those where the underlying cause of maternal death could have been tuberculosis were very rare. The “diseases of the respiratory system complicating pregnancy, childbirth and the puerperium" accounted for only 6 out of 849, and puerperal pneumonia (which could conceal tuberculosis) only 3. Of course, these figures depend on the reliability of the causes of death reported in the death certificates, but the diagnoses were made by doctors (Pujadas Mora, 2024, 85) and the vast majority were accurate[5] , with a secondary cause mentioned when necessary. What's more, as we will see in more detail below, compared with other causes, the importance of tuberculosis gradually increased, from the fifth cause of mothers’ death in the first week following the delivery to the leading cause in the second month of puerperium. Taken together, the available evidence suggests that the total number of missed deaths is very limited, and underlines the relevance of studying the association between maternal mortality and tuberculosis despite the limitations of our data.

4.2 Variables

Maternal death is defined as death from any cause related to complications resulting from pregnancy, childbirth or the puerperium, or from previous illnesses aggravated by pregnancy, and not from accidental or incidental causes (Cortes-Majo et al., 1990b, Conde-Agudelo and Belizán, 2000; Salazar-Agulló et al., 2008; Rodríguez-Ferrer et al.,

[4] Indeed, we need to know the time elapsed since childbirth. However, as a robustness check, we made a model assuming that all the unlinked maternal deaths (known from the cause of death but not linked to a birth certificate) implied that the baby died during the first 24 hours. Obviously, these models have fewer covariates than those presented in the paper because some of these cannot be inferred from the mother's death certificate, such as the sex of the child for example. However, for what we can see, adding these cases does not substantially change our results, either in the general model or in the competing risks model.

[5] In Madrid, during the period studied, the cause of death was not mentioned in only 0.03% of cases, and after coding, only 0.5% of causes of death remain classified as "ill-defined".

2009; Sitaula et al., 2021). To obtain a statistical indicator, the World Health Organization opts for a pragmatic approach, defining maternal deaths as those occurring while the woman is pregnant or during the 42 days following termination of pregnancy, irrespective of their duration, and caused by any cause related to or aggravated by pregnancy (Rodríguez-Ferrer et al., 2009).

In Madrid 1913-26, as we saw in the previous section, we can only observe the evolution of postnatal deaths. This is more of an approximation than a strict count (Scalone, 2014), as an undetermined number of events are not counted as maternal deaths because the pregnancy was not registered. However, research such as that by Wang et al. (2023) emphasizes that these deaths account for the majority of pregnancy-related deaths.

Although there is some consensus on the cut-off date for classifying deaths as maternal, it has been found that around one-fifth of maternal deaths occur after six weeks postpartum (Wang et al., 2023). In addition, studies such as that by Khan et al. (2001) show that taking late maternal deaths into account provides a better measure of the impact of indirect tuberculosis-related deaths. For this reason, and having found that many late deaths were due to obstetrical causes, deaths occurring up to 60 days after delivery have been included in our sample. Many studies in historical demography have taken a similar approach since the pioneering studies of the 1980s (Bardet et al., 1981; Gutierrez and Houdaille, 1983; Schofield, 1986).

Similarly, covariates were taken into account on the basis of the results of previous research mentioned above. Their choice was based on the literature review but conditioned by the availability of the data used for this study. The models include the mother's age as a categorical variable - since it is assumed to have a non-linear effect -, the child's gender and whether one or two or more children were born at the time. We also take into account the location of the event - whether the birth took place at home or in the maternity hospital - and introduce a variable indicating whether the woman was born in Madrid or is an immigrant born in Castilla y León, Castilla-La Mancha or elsewhere (Oris et al., 2023). Another variable reflects the district of the city where she gave birth. It is grouped into four categories: the first includes Buenavista, the second Centro, Congreso, Hospicio and Palacio, the third Chamberí and Universidad, and the

fourth Hospital, Inclusa and Latina. This variable is, as already mentioned, indicative of the hygienic conditions and social segregation existing in the city (Mazzoni et. al. 2022).

To assess whether there are any non-linear effects over time, a three-category time variable is included. The first for the years 1913-1917, corresponding to the period preceding the influenza pandemic of 1918. The second for the years 1918-1921, during which we should observe an increase in the risk of death due to the mortality crisis. Finally, the category relating to the years 1922-1926, which corresponds to the later period. This temporal covariate is the only time-varying covariate we use, and is constructed using the episode splitting technique (Cleves et al. 2008).

Causes of death were classified according to ICD-10h and HistCat coding rules, which are based on the World Health Organization's ICD-10 classification (World Health Organization, 2004) and adapted to the study of past populations (Reid et al., 2024a; Reid et al., 2024b).

5. Results

5.1. Maternal mortality

We calculated annual maternal mortality rates per thousand births, with and without correction for deaths due to childbirth but not related to a child's birth certificate. The main result is the absence of annual fluctuations, with the exception of a peak in 1918-1919 during the outbreaks of the influenza pandemic (see Reid, 2012, for a similar observation in Derbyshire).

Table 1 shows the causes of death during the period 1913-1926, for days 1 to 60 following childbirth. More than a third were pregnancy-related infections; the second most frequent cause was diseases of the circulatory system, followed by respiratory diseases and tuberculosis.

Table 1. Causes of death. 1-60 days, all districts

HistCat	Freq.	%
1. Childbirth	336	31.6
2. Circulatory	158	14.9
3. Respiratory	157	14.8
4. Tuberculosis	145	13.6
5. Digestive	80	7.5

6. Genitourinary	41	3.9
7. Infectious	41	3.9
8. Diarrhea	29	2.7
9. Nervous system	18	1.7
10. Ill defined	16	1.5
11. External	12	1.1
12. Other	11	1.0
13. Perinatal	11	1.0
14. Neoplasms	9	0.9
Total	1,064	100.0

To assess the effect of explanatory variables, various regression models were estimated. The general all-cause model shows that there was no decrease in maternal mortality over the period studied. Table 2 also shows that young maternal age, advanced age and multiple births have an impact on the incidence of maternal mortality. Women under 20 years of age were significantly more likely to die within 60 days of delivery (HR 1.473) than women of intermediate age. Similarly, women aged 35 to 39 (HR 1.345) and those over 40 (HR 1.694) had a higher risk of maternal death. Finally, women who had given birth to twins (HR 2.417) were more likely to die during childbirth than uniparous women.

Table 2. Cox regression, general model for all causes of death, 60 days. 1913-1926

Covariates	**Haz. Ratio**	**P>z**
Period (ref. 1913-1917)	1.000	
1918-1921	1.036	0.644
1922-1926	0.928	0.308
Mother age (ref. 25-29)	1.00**0**	
15-19	**1.473**	0.011
20-24	*1.174*	0.066
30-34	1.002	0.983
35-39	**1.345**	0.002
40+	**1.694**	0.000
Type of birth (ref. one birth)	1.000	
Twin	**2.417**	0.000
Sex (ref. male)	1.00	
Female	1.100	0.120
Districts (ref. Buenavista)	1.000	
Centro, Congreso, Hospicio y Palacio	0.991	0.940
Chamberí y Universidad	1.014	0.913
Hospital, Inclusa y Latina	1.143	0.257
Birth place (ref. home)	1.000	
Maternity delivery	**3.026**	0.000
Marital status (ref. father present)	1.000	
No father	**0.721**	0.013
Province of birth (ref. Madrid)	1.000	
Castilla-La Mancha	**0.756**	0.003
Castilla y León	**0.712**	0.000
Other regions	**0.757**	0.001
No. of subjects=	249,482	
No. of failures=	1,064	

Note: bold denote statistical significance (P < 0.05), italics (P<0.10)

On the other hand, the results of this model also reveal significant differences marked by place of delivery or immigrant status. Women who gave birth in a maternity hospital were three times more likely to die than those who gave birth at home. Immigrant women (those not born in Madrid) had a lower probability of dying during the puerperium - HR 0.756 for Castilla-La Mancha, HR 0.712 for Castilla y León, and HR 0.757

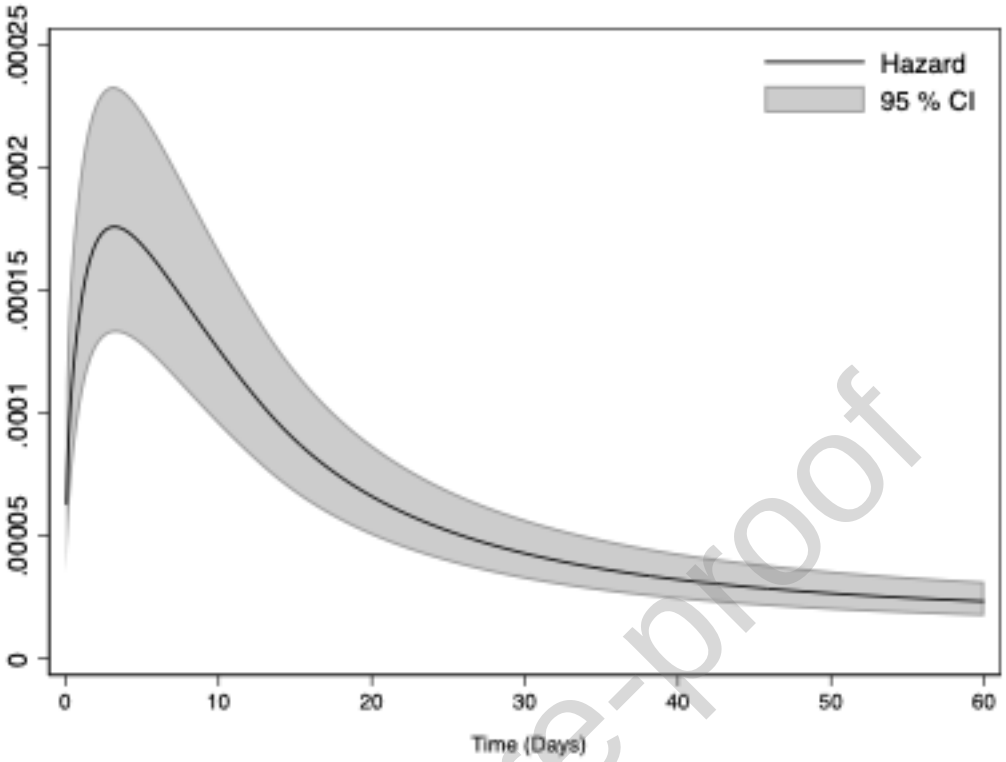
for the other regions. Finally, although the effect is intuitive, there were no significant differences associated with district of residence within Madrid.[6]

5.2 Trends in maternal mortality factors from day 1 to day 60

The previous model makes it possible to analyze the impact of factors during days 1 to 60 following childbirth. However, it is important to observe how the risk of death behaves during these two months. Figure 2 – Baseline hazard function (Royston-Parmar model) with covariates taken into account - shows the risk of mortality during this period: the black line represents the hazard function, i.e. the probability of death occurring in each point of time. The very beginning is affected by the lack of information on the first 24 hours; on the other hand, it is clear that this probability decreases with time from the second day after delivery. The first week was the most dangerous period for mothers.

[6] Nevertheless, analysis of causes of death by delivery district over the 60-day period suggests differences in mortality patterns. See table A2 in appendix. Although pregnancy-related infection was the main cause of death in all districts, there were differences in the incidence of other causes. Specifically, it was found that while in Buenavista, Centro, Congreso, Hospital, Palacio, Chambery and Universidad, tuberculosis was the fourth most common cause of maternal death, in the most disadvantaged districts in the south of the city -Hospital, Inclusa and Latina- 15.1% of maternal deaths recorded were associated with tuberculosis, which was the second most common cause of death. It should also be noted that in the wealthiest district, Buenavista, the second most frequent cause of maternal death -20.0%- was due to diseases of the circulatory system.

Figure 2. Baseline hazard function during the 60 days after childbirth, 1913-1926



To analyze the effect of the above-mentioned explanatory factors in relation to the time of delivery, three models were estimated, corresponding to the period from day one to the first week, from 7 to 30 days and during the second month.

Table 3 shows that older mothers were particularly at risk during the first week after delivery: HR of 2.333 for women over 40, HR of 1.442 for those aged 35 to 39. These differences narrowed between 7 and 30 days after delivery - HR 1.586 for women over 40, HR. 1.374 for women aged 35 to 39 - and were no longer significant during the second month, as shown by the third model. Similarly, the effect of multiple births was strongest in the first week (HR 3.291) and up to the first 30 days (HR 2.815), then disappeared in the last month.

With regard to place of delivery, the risk of maternal mortality in women who gave birth at the maternity hospital was extremely high (HR 6.039) compared to those who gave birth at home during the first week. This effect then diminished during the remaining days of the first month (HR 2.307), while remaining significantly elevated, and disappeared during the second month. Maternity delivery is mainly the lot of single

women, and the first variable has such a strong impact that it captures the effect of marital status, even creating an appearance of under-mortality for single mothers during the first week after delivery. An appearance because it is just a statistical artefact.

Differences according to region of origin were not significant during the first week. However, being from a region other than Madrid and Castile (i.e., being a long-distance migrant) protected against maternal mortality between days 7 and 60. In the second month after delivery, all immigrant women had a lower probability of maternal death - HR 0.515 Castilla-La Mancha, HR 0.480 Castilla y León, HR 0.629 other regions.

Table 3. Cox regressions, models for all causes of death, results for 1-7, 8-30 and 31-60 days. 1913-1926

Covariates	1 -7 days		8 - 30 days		Month 2	
	Haz. Ratio	**P>|z|**	**Haz. Ratio**	**P>|z|**	**Haz. Ratio**	**P>|z|**
Period (ref. 1913-1917)	1.000		1.000		1.000	
1918-1921	0.847	0.259	1.090	0.447	1.182	0.279
1922-1926	0.996	0.972	0.896	0.313	0.902	0.498
Mother age (ref 25-29)	1.000		1.000		1.000	
15-19	1.410	0.218	*1.460*	0.096	1.604	0.110
20-24	1.139	0.422	**1.314**	0.033	0.979	0.904
30-34	0.948	0.750	1.071	0.605	0.947	0.757
35-39	**1.442**	0.035	**1.374**	0.028	1.191	0.366
40+	**2.333**	0.000	**1.586**	0.020	1.153	0.623
Type of birth (ref. one birth)	1.000		1.000		1.000	
Twin	**3.291**	0.000	**2.815**	0.001	0.480	0.464
Sex (ref. male)	1.000		1.000		1.000	
Female	1.126	0.287	1.028	0.758	1.217	0.118
Districts (ref. Buenavista)	1.000		1.000		1.000	
Centro, Congreso, Hospicio y Palacio	1.038	0.878	0.968	0.856	0.969	0.897
Chamberí y Universidad	1.140	0.592	0.908	0.602	1.077	0.757
Hospital, Inclusa y Latina	1.364	0.177	1.070	0.692	1.055	0.817
Birth place (ref. home)	1.000		1.000		1.000	
Maternity delivery	**6.039**	0.000	**2.307**	0.000	1.330	0.406

Marital status (ref. father)	1.000		1.000		1.000	
No father	**0.475**	0.001	0.961	0.831	0.779	0.392
Province (ref. Madrid)	1.000		1.000		1.000	
Castilla-La Mancha	0.858	0.358	0.845	0.207	**0.515**	0.001
Castilla y León	*0.757*	0.087	0.833	0.142	**0.480**	0.000
Other regions	0.989	0.935	**0.695**	0.004	**0.629**	0.005
No. of subjects =	249,482		248,786		247,103	
No. of failures=	322		486		256	

Note: bold denote statistical significance (P < 0.05), italics (P<0.10)

5.3 Tuberculosis and maternal mortality

To achieve the final objective of this article, this section analyzes one of the main causes of indirect maternal mortality - particularly in the late post-partum period[7] - with a competing risk model on tuberculosis compared to other causes of death, during the period from 1 to 60 days following a delivery (see table 4). As this disease is closely linked to socio-spatial inequality and socio-economic deprivation, the following lines focus on Madrid's socio-spatial segregation and the importance of migratory status.

[7] Table A3 - included in the appendix - analyses causes of death according to the time elapsed since birth. While during the first week tuberculosis is the fifth most frequent cause of maternal death - accounting for 5.3% of all deaths - it becomes the fourth most frequent cause up to the 30th day - 11.9% - and begins to be the leading cause of death during the second month after delivery. Thus, its incidence during the last month is considerably high: 27.3% of all deaths during this period are tuberculosis-related. This is consistent with the findings of previous research, which indicates that during the first days after delivery, most deaths are related to infections during pregnancy - direct causes - while after the second month, deaths related to indirect causes, such as tuberculosis, are more frequent (Scalone, 2014).

Firstly, women who gave birth in the Hospital, Inclusa and Latina districts - disadvantaged areas in the south of the city - had a much higher probability of dying from tuberculosis infection in the days following delivery (SHR 2.042) than those who gave birth in the affluent Buenavista district. Secondly, significant differences were observed according to region of origin: women from Castilla-La Mancha (SHR 0.244) and Castilla y León (SHR 0.409) had a much lower risk of maternal death than those from Madrid, probably due to the high prevalence of tuberculosis in the city, and lower in their region of origin, for a disease that has a long latency period (this point is discussed in more detail in the conclusions). In addition, it is worth mentioning that the risk of maternal mortality associated with tuberculosis was higher in women aged between 15 and 19 (SHR 2.841).

Interactions between years and districts were calculated - testing different groupings - and no significant differences in temporal evolution were seen in any of the estimated models. However, it is likely that the impact of the 1918-1921 crisis was greater in the southern part of the city, since during this period the risk in terms of overall maternal mortality increased in the corresponding districts, widening the gap between the different zones. However, the results for tuberculosis-specific maternal mortality do not reflect significant variations over the period.

Table 4. Fine-Gray subdistribution Hazard models (tuberculosis), 1-60 days. 1913-1926

Covariates	SHR	P>z
Period (ref. 1913-1917)	1.000	
1918-1921	0.890	0.586
1922-1926	0.918	0.661
Mother age (ref. 25-29)	1.000	
15-19	**2.841**	0.000
20-24	0.953	0.835
30-34	0.813	0.390
35-39	1.087	0.751
40+	0.434	0.163
Sex (ref. male)	1.000	
Female	1.040	0.815
Districts (ref. Buenavista)	1.000	
Centro, Congreso, Hospicio y Palacio	1.217	0.608
Chamberí y Universidad	1.310	0.484
Hospital, Inclusa y Latina	**2.042**	0.047
Birth place (ref. home)	1.000	
Maternity delivery	1.083	0.803
Marital status (ref. father)	1.000	
No father	1.045	0.870
Province (ref. Madrid)	1.000	
Castilla-La Mancha	**0.244**	0.000
Castilla y León	**0.409**	0.001
Other regions	*0.699*	0.087
No. of subjects	249,482	
No. failed	145	
No. competing	919	

Note: bold denote statistical significance (P < 0.05), italics (P<0.10)

6. Summary of results and discussion

This study provides several relevant findings on the determinants of maternal mortality, based on a fair number of cases observed in Madrid from 1913 to 1926. Firstly, the global epidemiological context played a role, as shown by the peak of maternal mortality during the influenza pandemic years.

Secondly, early and advanced maternal age increased the probability of dying in childbirth. Multiple births also were clearly a risk factor. If these results concur with previous research findings, especially those who identified a U age effect, it is more original to show that the impact of these biological factors faded with time: They affected

the risk of maternal mortality directly during the first week after delivery, much less during the rest of the first month, and became insignificant during the second month.

A similar temporal pattern characterised institutional births: the risk to the mother's survival was much higher than for home births, but the danger was concentrated in the first week, then remained high over the following three weeks, disappearing in the second month.

Inversely, a significant migrants' advantage emerged only after the first week following the child birth, and was particularly strong during the second month. This relationship between origin and survival becomes clearer when we study specifically the most important indirect cause of maternal mortality, tuberculosis. Women coming from the Castilian plateau surrounding Madrid had much better chance to avoid dying from that frequent disease. Furthermore, while maternal mortality in the two months after giving birth was indifferent to the Spanish capital socio-spatial segregation, the specific risk for mothers to die from tuberculosis was clearly higher in the disadvantaged areas of the city.

In summary, biological and institutional factors were the most important contributors to maternal mortality, and their impact was rapid, suggesting that deaths were due to obstetric and other direct causes. Social determinants affected maternal survival mainly during the second month after childbirth, suggesting that their influence was exerted on indirect causes. Their clear impact on tuberculosis mortality supports this interpretation. In what follows, we discuss these results, relating them to the literature.

Among the biological factors, younger women present a physiological immaturity that may affect the risk of dying in childbirth (Manfredini et al., 2020). We also found that the risk of maternal mortality associated with tuberculosis was higher in women aged between 15 and 19. Although caution must be exercised as the numbers are small, this result is consistent with the findings of previous studies indicating a substantial effect of tuberculosis on young women (Mnyani and McIntyre, 2011). A high incidence of this infection in the young population was observed during the first decades of the 20th century in Spain (Valet, 1995). And it was in this age group that the sex ratio of tuberculosis mortality rates was highest, suggesting gender discrimination in access to

food and healthcare (Tabutin, 1978; Burke and Sawchuk, 2003; Beltrán Tapia and Szoltysek).

For its part, late age at delivery is associated with maternal exhaustion syndrome, as well as the likelihood of hemorrhage and toxemia (Ory and Van Poppel, 2013; Manfredini et al., 2020). Pérez-Moreda et al. (2015) also argue that these negative outcomes for older women are due to physiological issues that condition their ability to recover in the postnatal period. Similarly, biological complications can arise during multiple pregnancies and deliveries (Ory and Van Poppel, 2013; Scalone, 2014; Manfredini et al., 2020).

It has also been found that giving birth in a maternity hospital increased the risk of maternal death. In 1913-1926 Madrid, it was specifically during the few days following childbirth. As the only maternity hospital in the city until 1924, the Maternidad acted as a referral center for the most complex cases, particularly for women from impoverished backgrounds who lacked access to private care or skilled midwives. These transfers often occurred when complications had already developed and women arrived in critical condition, sometimes with delayed access to medical intervention (Botella Montoya, 1932). Also, our maternal mortality model showed a clear interaction between maternity deliveries and out of wedlock births. Single mothers accounted for 81% of the hospital deliveries against only 5% of the home childbirths. Usually young, primiparous, stigmatized and socioeconomically vulnerable, these unmarried women cumulated the risks factors and contributed to the high maternal mortality in hospital.

Although it is not possible to disentangle these effects from the preceding ones, the inadequate hygienic conditions of health facilities also played a role: medical assistance during childbirth in the first decades of the twentieth century was highly deficient (Cortes-Majo et al., 1990a, Casado et al., 2021). In 1902, Hauser pointed out that the deficiencies of the Madrid maternity hospital were obvious, with a perceived lack of hygiene and the inadequacy or poor condition of the instruments used to care for patients. In other settings, research such as that by Scalone (2014) also suggested that doctors and midwives frequently transmitted infections to patients. Home births were therefore preferable to avoid puerperal infections, which were very common in hospitals at the time (Villanueva-Egan, 2012; Pozzi et al., 2020; Ruiz-Berdún, 2024).

If the profound social inequalities present in Madrid in the early twentieth century were not absent from the hospital, they stand out more clearly when we focus on tuberculosis, which was (and still is) one of the main causes of indirect maternal mortality (Khan et al., 2001). In our results, women who gave birth in disadvantaged neighborhoods in the south had a higher risk of dying from tuberculosis within 60 days of delivery. This result was to be expected, as the incidence of tuberculosis was higher in neighborhoods with poorly maintained housing and high rates of overcrowding (Anaut, 1999; Palao, 2010), but also because it has been shown, even recently, that this disease reacts to economic crises and poor economic conditions (Palloni et. al, 1996). It is therefore possible to confirm that low-resource areas have a higher incidence of maternal mortality associated with tuberculosis (Sugarman et al., 2014).

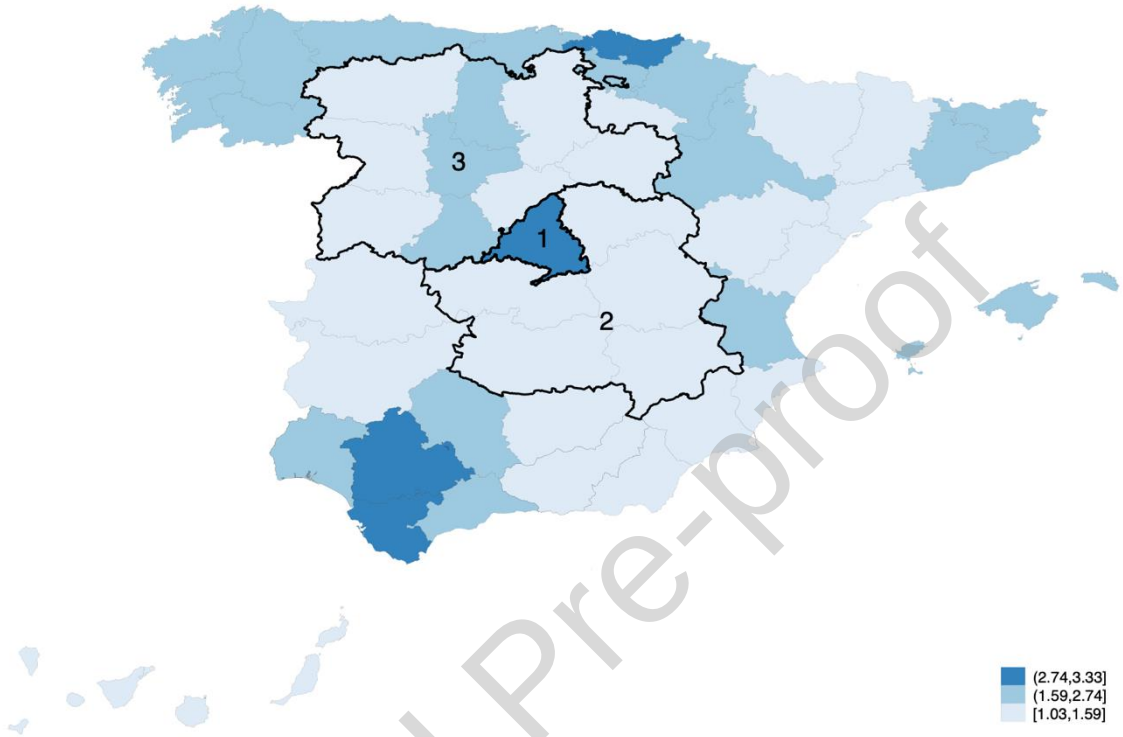
This incidence must also be considered to understand another result: immigrant women have been shown to be at lower risk of maternal mortality, at least from the second week after childbirth, and this is even truer when considering an indirect cause such as tuberculosis. This is an illustration of the "healthy migrant paradox", i.e. the under-mortality of poor migrants in their place of destination, mainly due to their selection in their region of origin (Kesztenbaum and Rosental 2011; Puschmann et al. 2016; Oris et al., 2023; Sesma Carlos et al., 2024).

Evidence of migrant selection in Madrid in the early 20th century is sparse. In a study covering the period 1880-1930, Beltrán Tapia and De Miguel Salanova (2017) showed that migrants in Madrid were more literate than those who remained in their home provinces. Knowledge of the preventive messages disseminated by social medicine at the time could have been an advantage. However, women, who were these affected by maternal mortality, were at least 15% less literate than men, and immigrant women were less literate than women born in Madrid, although the former had an advantage. This aspect of migrant selection cannot therefore be considered a valid explanation. In a study based on military data, and therefore only on young men, Juip and Quiroga (2019) observed that migrants were taller than those who had stayed behind, and that this difference was greatest in the 1920s and early 1930s, approximately during the period we are studying. There is no reason to believe that the selection process identified by Juip and Quiroga (2019) did not apply to both sexes, suggesting that the robustness of

migrants helped them cope with the risks of maternal mortality, particularly when combined with tuberculosis. However, to consolidate this interpretation, we draw on a recent study of tuberculosis in Madrid between 1905 and 1908 (two out of ten districts), which provides the clearest evidence. This study shows that migrants had lower mortality rates from this disease, which was particularly evident among newcomers and decreased with length of residence in the city. This trend was the same for women and men (Oris et al., 2025). This is consistent with our findings in this article, both in terms of maternal mortality and deaths from tuberculosis within 60 days of giving birth.

Another contribution, although speculative, to the understanding of the healthy migrant paradox is to consider the conditions in their place of origin, the impact of which was perceived in women's state of health before childbirth and, consequently, manifested in the later phases of puerperium. With this in mind, the study by Chabas (1914), which gathered information on the incidence of tuberculosis in Spain during the years 1901-1910, revealed that Madrid province was one of the Spanish territories most affected by this disease, with a rate of between 2.73 and 3.33 (see figure 3). Some provinces in Castilla y León were at intermediate risk (1.59 to 2.74), while Castilla-La Mancha belonged to the group of regions with the lowest incidence (1.03 to 1.59). The vast majority of migrants to Madrid came from these two Castilian regions.

Figure 3. Cause specific (tuberculosis) mortality rate in Spain (1901-1910)



Notes: Authors' elaboration based on data from Chabas (1914). 1) Madrid province, 2) Castilla-La Mancha, 3) Castilla y León.

All empirical research is a step-by-step process, with answers to initial questions leading to new ones. Future research will focus on the relationship between maternal and infant mortality and causes of death.

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Author Statement

Alba Teresa González-Esteban: Writing original draft, Data curation, Investigation. Stanislao Mazzoni: Writing original draft and Formal analysis Writing – review & editing, Validation, Supervision and Software. Michel Oris: Writing – review & editing, Validation, Supervision. Diego Ramiro-Fariña: Project administration, Funding acquisition, Validation

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APPENDIX

Table A1. Descriptive statistics at birth for the data used in the multivariate analyses

Variables	%	**Variables**	%
Periods		Districts	
1913-1917	33.4	1	9.8
1918-1921	27.8	2	26.6
1922-1926	38.8	3	23.3
Mother's age		4	40.3
15-19	3.3	Place of birth	
20-24	20.9	Home	94.0
25-29	32.6	Maternity	6.0
30-34	23.9	Couple	
35-39	14.1	In couple	90.5
40+	5.2	Single	9.6
Delivery		Region of origin	
Single birth	99.2	Madrid province	42.0
Tween birth	0.8	Castilla-La mancha	15.6
Sex		Castilla y leon	19.2
Male	51.4	Other regions	23.1
Female	48.6	Total	100.0

Table A2. Distribution of causes of maternal death in district groups. 1-60 days postpartum

Buenavista	Freq.	%	Centro, Congreso, Hospital & Palacio	Freq.	%	Chambery & Universidad	Freq.	%	Hospital, Inclusa & Latina	Freq.	%
1) Childbirth	30	33.3	1) Childbirth	81	33.6	1) Childbirth	70	32.1	1) Childbirth	155	30.1
2) Circulatory	18	20.0	2) Respiratory	41	17.0	2) Circulatory	40	18.3	2) Tuberculosis	78	15.1
3) Digestive	12	13.3	3) Circulatory	40	16.6	3) Respiratory	35	16.1	3) Respiratory	73	14.2
4) Tuberculosis	9	10.0	4) Tuberculosis	30	12.4	4) Tuberculosis	28	12.8	4) Circulatory	60	11.7
5) Respiratory	8	8.9	5) Digestive	12	5.0	5) Digestive	15	6.9	5) Digestive	41	8.0
6) External	3	3.3	6) Genitourinary	12	5.0	6) Genitourinary	10	4.6	6) Infectious	25	4.9
7) Neoplasms	3	3.3	7) Infectious	8	3.3	7) Diarrhoea	7	3.2	7) Diarrhoea	19	3.7
8) Genitourinary	2	2.2	8) Nervous system	5	2.1	8) Infectious	6	2.8	8) Genitourinary	17	3.3
9) Infectious	2	2.2	9) Ill defined	3	1.2	9) External	3	1.4	9) Ill defined	11	2.1
10) Diarrhoea	1	1.1	10) Other	3	1.2	10) Nervous system	2	0.9	10) Nervous system	11	2.1
11) Ill defined	1	1.1	11) Perinatal	3	1.2	11) Ill defined	1	0.5	11) Perinatal	8	1.6
12) Other	1	1.1	12) Diarrhoea	2	0.8	12) Neoplasms	1	0.5	12) Other	7	1.4
			13) External	1	0.4			0.0	13) External	5	1.0
									14 Neoplasms	5	1.0
Total	90	100.0	Total	241	100.0	Total	218	100.0	Total	515	100.0

Table A3. Distribution of causes of maternal death from day 1 to 7, 8-30 days and 31-60 days after delivery

1-7 days	Freq.	%	8-30 days	Freq.	%	Month 2	Freq.	%
1) Childbirth	121	37.6	1) Childbirth	179	36.8	**1) Tuberculosis**	70	27.3
2) Respiratory	49	15.2	2) Circulatory	80	16.5	2) Respiratory	44	17.2
3) Circulatory	39	12.1	3) Respiratory	64	13.2	3) Circulatory	39	15.2
4) Digestive	32	9.9	**4) Tuberculosis**	58	11.9	4) Childbirth	36	14.1
5) Tuberculosis	17	5.3	5) Digestive	33	6.8	5) Diarrhoea	16	6.3
6) Genitourinary	14	4.4	6) Infectious	21	4.3	6) Digestive	15	5.9
7) Infectious	12	3.7	7) Genitourinary	17	3.5	7) Genitourinary	10	3.9
8) Ill defined	10	3.1	8) Diarrhoea	9	1.9	8) Nervous system	9	3.5
9) Other	8	2.5	9) External	7	1.4	9) Infectious	8	3.1
10) Perinatal	7	2.2	10) Nervous system	6	1.2	10) Ill defined	4	1.6
11) Diarrhoea	4	1.2	11) Perinatal	4	0.8	11) Neoplasms	4	1.6
12) External	4	1.2	12) Neoplasms	3	0.6	12) External	1	0.4
13) Nervous system	3	0.9	13) Other	3	0.6			
14) Neoplasms	2	0.6	14) Ill defined	2	0.4			
Total	322	100.0	Total	486	100.0	Total	256	100.0

Highlights

- We study the association between maternal mortality and tuberculosis
- We use longitudinal individual data with detailed causes of death
- Our database size authorizes the study of a rare phenomenon as maternal mortality
- And its relationships with tuberculosis, which is still an issue in poor countries
- We provide an illustration of the "healthy migrant paradox”