



## Article

# The effects of nutrition on maternal mortality: Evidence from 19th-20th century Italy

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## ABSTRACT

The role of nutrition on maternal mortality has been long debated in the historical and scientific literature. Some scholars refute any role of nutrition and diet in the decline of maternal mortality, privileging other causes such as the diffusion of professional midwifery and medical and scientific progress, while others are more open-minded about some possible nutritional effects.

The present paper investigates the relationship between maternal mortality and nutrition in Italy between 1887 and 1955 with the purpose to provide new elements and new data to the knowledge of such an association. Using time-series techniques on the official data provided by the National Institute of Statistics, the analysis demonstrates that the trend of maternal mortality was affected by both long- and short-term dynamics of the average daily caloric intake of the Italian population once controlled for the economic situation, here proxied by the annual time series of the GDP per capita. The same analysis clarifies that the impact of nutrition is just one element of a complex picture in which the major role is played by medical advances and scientific progress. The introduction of sulphonamides, in the second half of the thirties of the twentieth century, emerges, in fact, as the turning point in the fight against maternal death.

## 1. Introduction

Maternal mortality was a dramatic and common event in past societies, characterized by poverty, ignorance, and backwardness. Until the eighteenth century, the levels of maternal mortality were therefore generally high across the whole of Europe, and it was only during the nineteenth century that it started to decline in many Western countries. The decline was not continuous, however, because periods of steeper drop alternated with periods of resurging levels of maternal mortality, especially at the beginning of the twentieth century. Loudon has described a pattern of the decline of maternal mortality that is common to many countries (1988 and 1992). It has three stages. A first phase, between 1880 and 1900–10, in which the rate drops on account of the introduction of antiseptic techniques in hospitals and maternal institutes. An intermediate period, roughly between 1910 and 1935, characterized by a stagnation when not a slight increase in maternal mortality, followed by a third and final phase in which it is possible to observe the ultimate drop, caused by the introduction of sulphonamides in the cure of bacterial infections.

Medical advances and scientific progress played therefore a key role in the reduction of maternal mortality, especially in contrasting

puerperal infections, which were responsible for the majority of maternal deaths until the thirties of the twentieth century. Many scholars claim that the developments and improvements in the care of parturients, the spread of professional assistance during childbirth, and the establishment of a public health care system represented the most effective factors in the decline of maternal mortality (De Browere, 2007; Högberg, 2004; Loudon, 2002). Some studies have also highlighted the role of some socioeconomic factors, such as household structure and kinship networks (Hammel & Gullickson, 2004). Besides, maternal mortality has long been associated also with demographic and individual features. Various studies have found evidence of the role of mother's age, number of previous births, birth spacing, twin births as well as stillborn as risk factors of maternal death (Conde-Agudelo & Belizan, 2000; Högberg, 1985; Knodel, 1986; Manfredini et al., 2020; Scalone, 2014).

The role of nutrition has been conversely considered as marginal (Loudon, 2000), or, when some evidence on maternal survival was found, as an effect associated with rising living standards and improvements in the general economic situation. However, Högberg (2004) does not exclude a possible effect of nutrition in reducing maternal mortality and Scalone (2014) has proved the role of nutritional

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stress on maternal mortality in a sample of six German villages. Other recent studies have postulated the existence of a causal link between nutrition and maternal mortality (Christian, 2018; Janssens & van Dongen, 2017).

The present study aims at investigating the association between nutrition and maternal mortality in Italy between 1887 and 1955 using the official data published by the Italian Institute of Statistics at that time. Given the strict connection between nutrition and living standards, the study's purpose is to check and disentangle the respective impacts of economic development and caloric intake on maternal mortality.

This study is part of a project whose purpose is to remedy the lack of studies on maternal mortality in historical Italy. The first work was carried out on a selection of rural populations across Italy, analyzed at the individual level to describe not only the levels of maternal mortality but also its determinants between the nineteenth and the twentieth century (Manfredini et al., 2020). Here, a step forward is made in order to widen the research perspective, passing from the analysis of single case-studies to a national-level investigation, and analyzing an undervalued potential risk factor – nutrition – that was not considered in the previous research.

This paper will start with an overview of the literature on the effects of nutrition in shaping maternal mortality levels. Next, the data and statistical methodology are described. This is followed by a short description of the evolution of maternal mortality within the economic and nutritional context of Italy, and, finally, the presentation of results and a conclusive discussion section.

## 2. Nutrition and maternal mortality: a never-ending debate

The role of nutrition in shaping maternal health and maternal mortality has been debated for a long time and still remains unclear. As above mentioned, Loudon supports the thesis that nutrition and socioeconomic status mattered little in the decline of maternal mortality, stating that “in the 19th and first half of the 20th century, it was care at parturition and not malnutrition and other concomitants of poverty that determined the level of maternal mortality” (Loudon, 2000, p. 244). The role of professional assistance to parturients was emphasized also by De Browere (2007), who did not mention nutrition as a potential determinant of the decline of maternal mortality. In contrast, Scalone (2014) found a positive effect of short-term crises on maternal mortality. He claims that those crises which affected food supply and food availability played a role especially on the risk of experiencing the maternal depletion syndrome (Jelliffe & Maddocks, 1964), a disease not directly associated with pregnancy or childbirth, but rather with a gradual deterioration of mother's health during her reproductive life (Imhof, 1984; Manfredini et al., 2020; Perrenoud, 1981, pp. 89–104). This syndrome was typical of pretransitional populations and developing countries where repeated reproductive cycles, associated with low caloric intake and the need to work during and immediately after pregnancy, may lead mothers to physical and psychological exhaustion (Higgins & Alderman, 1997; Merchant et al., 1990). The consequences could be weight loss and nutrient drainage, which could, in turn, lead to anemia, infections, and fatigue, thereby increasing the risk of a mother's death. The more specific term of nutritional status, that is the “balance between the food consumed by each individual and the claims made upon it” (Harris, 2004, p. 380), is today considered the most distinctive element of the maternal depletion syndrome.

The effects of the maternal depletion syndrome are however not always easy to disentangle and observe, affected by problems of selection bias and difficulty to proxy food availability through grain prices in rural settings. The results concerning the city of Sart (Belgium) and rural Scania (Sweden), populations investigated within the Eurasian Project on Population and Family History, showed only a limited impact of maternal depletion, explained by the authors as the result “that mothers tend to die from the same social and environmental conditions that kill their children” (Alter et al., 2004, p. 354).

Other scholars conjecture that nutrition should have had a role in affecting and shaping maternal mortality. However, many of them acknowledge as well that there are scant evidence-based data on such a relationship (Christian, 2002; Högberg, 2004). Their supposition relies on the many studies that have recently highlighted the role of various macro- and micronutrients in the development of many pathologies associated with maternal health and mortality, infectious diseases in particular. There is a large consensus among epidemiologists, nutritionists, and medical researchers on the role of nutrition in the development of infectious diseases, although such a role may be different for different pathologies. For instance, the effects of nutrition on illnesses such as plague and smallpox are believed to be limited, whilst they could be important for infections such as cholera, respiratory infections, and tuberculosis (Harris, 2014). Tuberculosis, in particular, has close connections with maternal mortality as it is considered one of the major indirect causes of maternal death (Reid & Garrett, 2018; Sobhy et al., 2017).

An insufficient supply of calories may as well negatively affect not only the capacity of mothers to face adequately the increased energy demand of pregnancy and successive lactation but also some immunological functions, thereby increasing the risk of infections. As mentioned above, low caloric intake is often associated with maternal depletion syndrome.

As for the role of micro and macronutrients, there are some established facts which might usefully be stressed. Recent studies carried out especially in the developing countries have found evidence of the links between some nutritional deficits and increased maternal mortality. Anemia is today considered one of the most important risk factors of maternal death, placing mothers at higher risk of death during and after childbirth (Young et al., 2019). Severe anemia causes maternal death often from heart failure (Sanghvi et al., 2010), while moderate anemia is associated with antepartum and postpartum hemorrhage, infection, obstructed labor, and increased risk of circulatory shock and death (Christian et al., 2015; Daru et al., 2018; Rukuni et al., 2016). The causes of anemia are both non-nutritional and nutritional, with the former including malaria and hemoglobinopathies, and the latter comprising various forms of micro and macronutrient deficiencies. Iron and folic acid deficiencies represent the most common causes of anemia, inducing hematological changes that can evolve to an anemic state. In particular, the role of folate in severe anemia and embryogenesis has been the object of many studies on maternal and infant health for its role in neural tube closure defects (see, for instance, Bailey et al., 2015).

Anemia has been also found to be associated with Vitamin A deficiency (Semba & Bloem, 2002). This evidence, along with the positive effects of vitamin A on maternal infections (Elom et al., 2017; McCauley et al., 2015), has been taken as a sign of its indirect link with maternal mortality. However, findings on the association between lack of vitamin A and maternal mortality are still inconsistent and the biological mechanism still unclear. A study by West et al. (1999) showed that supplementation of vitamin A during pregnancy was associated with reduced maternal mortality risk, but later works did not support the same finding (Costello & Osrin, 2010; Kirkwood et al., 2010).

Another micronutrient whose deficiency could be responsible for increasing maternal death is zinc. Besides its importance for the immune system, it plays also a fundamental function in the synthesis mechanism of hormones and enzymes essential to childbirth. The lack of zinc has been found to be associated with long labor and therefore to a higher risk of maternal death (Caulfield et al., 1998; Hess & King, 2009).

## 3. Data and methodology

### 3.1. Data

Founded in 1861, the Italian Kingdom began to require and collect information on causes of death starting from 1881. However, from that year up to 1886, the data concerned only the Italian county seats,

amounting to about one-fourth of the total population. From 1887 onward, the recording was extended to the entire territory, thereby making it possible to describe the overall process of maternal mortality's decline. The register here used was published by the Italian National Institute of Statistics (ISTAT, 1958a) and divides mother's deaths into two sub-groups, one defined as deaths due to "Complications during pregnancy, delivery, and puerperium", and the other as deaths due to "Septicemia and puerperal infections". This latter category includes also maternal deaths from septic abortion. The series stops in 1955 because, after that date, the maternal mortality level was considered so low as to count maternal deaths in the residual category "Other causes of death".

Some problems of data quality could affect the national series of causes of death. A correct attribution of cause of death requires profound medical knowledge and standardized case definitions which were not typical of the late nineteenth- and early twentieth-century Italy. Moreover, the inclusion of indirect causes of maternal death, just like the maternal depletion syndrome, is not always clear, thereby leading to misreporting and misattribution of a certain amount of female deaths.<sup>1</sup> The time series of causes of death used in this paper, however, were made homogeneous by ISTAT according to the classification proposed by the ICD revision 6.

As for the coverage of the data on causes of death, the civil registers of deaths recorded during WWI (1915–18) do not include the deaths taking place in the zone of operations of war and the foreign territory, and, for the years 1917–18, also the civilians died in the Venetian provinces occupied by the opposing army. For the period 1935–39, the registers do not include the soldiers and civilians died for reasons of war in Africa and Spain. During WWII (1940–45), all the deaths that took place in the zone of operations of war and the foreign territory were excluded as well. In the present study, moreover, the deaths that occurred in the territories and regions not belonging with continuity to the Italian Kingdom (or to the Italian Republic) were not included in the analysis. They are Trentino-Alto Adige and Friuli-Venezia Giulia.

The time series of GDP per capita and daily caloric intake have been used as explanatory variables of the maternal mortality trend. The GDP per capita is a common measure for the living standards and economic welfare of a nation. The values of GDP are expressed in thousands of euros, calculated on chained values with reference 2010, according to ISTAT estimates. The caloric intake is a proxy for the nutritional level of the Italian population. It is expressed in average daily per capita caloric intake, excluding calories from alcohol because of the lack of nutritional value (ISTAT, 1958b).<sup>2</sup> This variable captures preferentially changes in available energy and some macronutrients such as proteins, fat, and carbohydrate. Although not necessarily associated with changes in the intake of micronutrients, reductions in caloric intake do often coexist with a reduction in micronutrients.

### 3.2. The methodology

To investigate the relationship between those variables, a time series approach is used. Standard OLS regression models can be applied only when the series are stationary, that is when mean and variance do not change over time. A non-stationary time series can be transformed into stationary by using a series of successive differences. The minimum number of differences needed to do it is called "order of integration", which is a useful information not only to explain some peculiarities of the time trends but also to determine the successive steps of the analysis.

<sup>1</sup> See Reid and Garrett (2018) for a discussion of the quality of the official statistics on maternal mortality.

<sup>2</sup> The mean number of total calories available per person has been determined considering the average availability of each food group, their theoretic percent composition in terms of proteins, fats, and carbohydrates, and the consequent number of calories developed by each food group in the process of metabolism. For a discussion on this topic, see Barberi (1939).

If  $d$  is the order of integration, a variable  $I(d)$  is a variable that has become stationary after  $d$  differences. Thus,  $I(0)$  denotes a stationary variable and  $I(1)$  denotes a variable become stationary after the first difference. Just in consideration of the fact that many time series are not stationary, describing long-run processes whose means and variances vary over time, cointegration analysis was used in this paper. This statistical procedure is a well-known methodology used to investigate non-stationary time series, estimating long-run parameters in systems with unit-root variables (Rao, 2007). Operatively, it consists of various stages. The first step concerns the check of stationarity and unit root. A unit root is just one of the main causes of non-stationarity. More precisely, a unit root denotes time series with a stochastic trend and a consequent unpredictable evolution, which poses problems in the estimation of regressive models and forecasts. The augmented Dickey-Fuller test (ADF) is one of the tests most widely used to check for non-stationarity in a time series (Dickey & Fuller, 1981), whose null hypothesis is that the time series contains a unit root against the alternative, in this paper, of stationarity around a linear time trend.<sup>3</sup> Given the low statistical power of the ADF test, it is often suggested to run a further test to see whether the conclusions agree. In this regard, the KPSS test is frequently used as it is complementary to the ADF test for its null hypothesis of trend-stationarity (Kwiatkowski et al., 1992).

The possible inconsistency of results between the two tests can be explained by the existence of structural breakpoints, sudden changes in the trend and/or in the level of a variable that may lead to erroneous conclusions of non-stationarity (Buseti & Taylor, 2003; Chaudhuri & Wu, 2003). Thus, the ZA test<sup>4</sup> (Zivot and Andrews, 1992) and the CMR test (Clemente, Montañés, and Reyes, 1998) were employed as well. These tests allow determining the stationarity of a time series also in presence of structural breakpoints, which are in turn determined endogenously from the data. The key difference is that while the former checks for the existence of only one breakpoint, the latter allows for the presence of two structural breaks in the time series. Both tests have the null hypothesis that the series has a unit root with a structural break(s) against the alternative hypothesis that they are stationary with a break (s). Moreover, the CMR method was applied in two forms, the additive outlier model (AO), which captures a sudden change in the mean of a series, and the innovational outlier model (IO), which allows for a gradual shift in the mean of the series.

All these tests are preliminary to the real cointegration analysis. One of the most-used techniques of cointegration is the Autoregressive Distributed Lag Models (ARDL), which is applied in this paper to model the relationship between the maternal mortality rate (MMR), on the one hand, and the per capita GDP and mean caloric intake (CAL), on the other. This kind of model analyzes the relationship between time series allowing for lagged effects of both dependent and explanatory variables (Engle & Granger, 1987). The long-run ARDL equation was therefore specified as follows

$$MMR_t = \beta_0 + \sum_{i=0}^n \beta_{1i} MMR_{t-1-i} + \sum_{i=0}^p \beta_{2i} CAL_{t-i} + \sum_{i=0}^q \beta_{3i} GDP_{t-i} + \varepsilon_t$$

where  $n$ ,  $p$ , and  $q$  are the lags of the variables,  $\beta_{1i}$  are the  $n$ -th coefficients of the lagged dependent variable,  $\beta_{2i}$  and  $\beta_{3i}$  are the  $p$ -th and  $q$ -th coefficients of the lagged independent variables, and  $\varepsilon_t$  is the disturbance term.

More precisely, this analysis makes use of the ARDL bound testing methodology proposed by Pesaran and Shin (1999) and Pesaran et al. (2001), which has the advantages of allowing the use of variables with

<sup>3</sup> The ADF test allows for more alternative hypotheses. Along with stationarity around a time trend, it is also possible to test either a simple stationary process or stationarity with a drift.

<sup>4</sup> In this paper, the ZA test was used to check for one structural break in the trend.

integration order  $d < 2$ , the selection of different lag-lengths for different variables, and of being fit for small sample sizes.<sup>5</sup> This technique provides, first of all, a bound test to assess the long-run equilibrium among the series involved in the analysis. Operatively, it uses both the  $F$ -test and the  $t$ -test assuming the null hypothesis of no cointegration among the time series against the alternative of cointegration. The next step is the estimation of the long-run effects of the independent variables included in the regression model. Finally, a reparameterization to the Error Correction Model (ECM) allows having also information on the short-run dynamics of the variables considered, as well as an estimate of the error correction term, which represents the speed of reverting to the long-run equilibrium after a short-run shock. The model is

$$\Delta MMR_t = \alpha_0 + \sum_{i=0}^n \alpha_{1i} \Delta MMR_{t-1-i} + \sum_{i=0}^p \alpha_{2i} \Delta CAL_{t-i} + \sum_{i=0}^q \alpha_{3i} \Delta GDP_{t-i} + \phi z_{t-1} + \epsilon_t$$

where  $\Delta$  is the difference operator,  $\alpha_{1i}$  are the  $n$ -th coefficients of the lagged dependent variable,  $\alpha_{2i}$  and  $\alpha_{3i}$  are the  $p$ -th and  $q$ -th coefficients of the lagged independent variables,  $z_{t-1}$  is the error correction term, and  $\epsilon_t$  is the disturbance term.

In other words, in just one single model it is possible to have results describing the short- and long-run relationship between the time series analyzed.

#### 4. Socioeconomic milieu and maternal mortality pattern in Italy 1887–1955

##### 4.1. A brief socioeconomic and nutritional outline of Italy between 1887 and 1955

The period here considered is marked by the slow process of transformation of the Italian economy into an industrialized one, but also by the participation of Italy in the two world conflicts of 1915–18 and 1940–45. At the beginning of the 20th century and according to the national census of 1901, the agricultural sector still employed 62% of the total working force, the illiteracy rate was still high, particularly among women (60.8%), and, among the demographic indicators, life expectancy at birth was around 43 years and the Total Fertility Rate (TFR) was about 5 children per woman. The social role of women was still primarily that of raising children and keeping the house (60% of women of 9+ years were recorded as housewives or servants), although the large majority of them, especially in the rural sector of the population, was also engaged in farm labors.

At the census of 1951, the profound change of the Italian society and economy was nearly realized. The population working in the agricultural sector dropped to 42% just like female illiteracy was dramatically reduced to 15.2%; life expectancy at birth was remarkably increased at 67.2 years, while TFR was decreased to about 2.35 children per woman.

This process is quite well represented in the trend of the GDP per capita (Fig. 1). Its evolution over time reflects exactly the industrialization process and its positive consequences over living standards. This upward trend is however deeply affected by the two World wars, especially WWII, which dramatically interrupted the GDP growth. Between 1939 and the end of the war (1945), the GDP dropped in fact by 46%, which contrasts with the much slighter effects of WWI, with only a 3.5% decrease in GDP between 1914 and 1919. After WWII, then, the recovery of GDP per capita is marked by a much faster pace than the pre-war period, signing the definitive passage from a rural country to an industrialized one.

The improvements in the economy and the labor market contributed

<sup>5</sup> In this case, the Schwarz's Bayesian information criterion (SBIC) and the Hannan and Quinn information criterion (HQIC) were employed as model selection criteria to determine the optimal number of additional lags.

also to expand social welfare and ameliorate the insufficient conditions of Italian public healthcare structures. According to an inquiry of the Italian government on the health and hygienic conditions of the Italian population, in 1885 there were 4.4 hospitals and 220 hospital beds per 100,000 people, which increased to 5.5 and 550, respectively, in 1932 (Manfredini & Breschi, in press). Despite these improvements, Italian mothers continued however to be unwilling to give birth in hospitals and preferred home births, which amounted to 83% of total deliveries still in 1953.

The daily calorie supply per capita is obviously interrelated with the economic context, showing, therefore, an upward trend, at least between 1897 and 1940. Before and after that period there is evidence of two important troughs, one again on the occasion of WWII (−34% in the period 1939–45) and the other in 1897, when a social and economic crisis, following the disastrous colonialist campaigns in Africa, broke out, eventually triggered by the rise in the cost of bread (Fig. 1).

The mean value of the daily caloric intake is about 2500 calories per capita. However, given that the average daily supply of calories for a pregnant woman not involved in hard works is 2200–2,900, that the very largest part of Italian women did very energy-consuming works, and that they had many children to raise, those values did not guarantee against problems of severe malnutrition, especially in the poorest strata of the population. The bad nutritional conditions of the Italian population at the turn of the 20th century are also confirmed by the diet composition of an average Italian woman (Fig. 2). Throughout the whole period considered, there is evidence of a poor diet exceeding in carbohydrates (always over 70% of total macronutrients), and with a corresponding low intake of fats, whose normal level should be between 20% and 35% (ISTAT, 1958b). The diet was therefore quite monotonous, with high consumption of cereals and poor-quality flour, whilst the meat was only rarely eaten, usually just on religious occasions or in exceptional circumstances (Barberi, 1961).

The poverty of the diet of many Italians is further confirmed by the large diffusion of pellagra, one of the diseases more associated with bad nutritional habits. It was spread all over Italy, but especially among the populations of Veneto, Emilia-Romagna and Lombardy. Unlike many other European countries, in Italy, the death toll of pellagra was of the order of thousands until the outbreak of WWI (Ginnaio, 2011). The official statistics on causes of death show that 3688 people died of pellagra in 1887 and were still 1030 in 1913.

##### 4.2. Maternal mortality pattern in Italy 1887–1955

Fig. 3 illustrates the evolution of the maternal mortality rate in Italy between 1887 and 1955. The measure is expressed in number of total maternal deaths per 1000 live births. The graph plots also the percentage of maternal deaths for septicemia in the same period. The curve describes the decline of this cause of death over time, recalling quite well the three-stage pattern of evolution described by Loudon (1988 and 1992) and previously described in the introduction. Between 1887 and 1914 the rate drops from about 6 to 2.2 per thousand, likely on account of the introduction of both antisepsis techniques in hospitals, which represented the first results of the struggle against infectious diseases, tuberculosis in particular,<sup>6</sup> and some laws aimed at protecting working women in factories (Angeli & Salvini, 2001).<sup>7</sup> Before the introduction of antisepsis techniques, the mortality of mothers in maternity hospitals was very high almost everywhere in Europe, caused mostly by serious epidemics of puerperal fever that pushed the maternal mortality rate up to 40 deaths per 1000 live births (Loudon, 1992). Giving birth was therefore definitely more risky in hospital than at home also in Italy

<sup>6</sup> The deaths for all the forms of tuberculosis dropped from 62,614 in 1887 to 51,959 in 1914 (−17%).

<sup>7</sup> The first law providing the reduction of the working hours for women was promulgated in 1902.

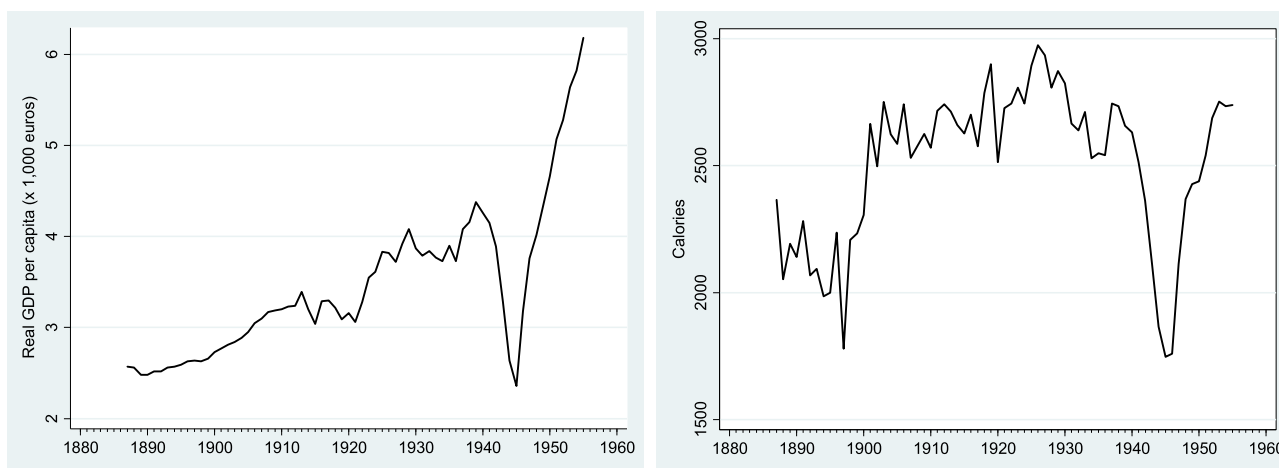


Fig. 1. Real GDP per capita (x 1000 euros, a) and daily caloric intake (b). Italy, 1887–1955

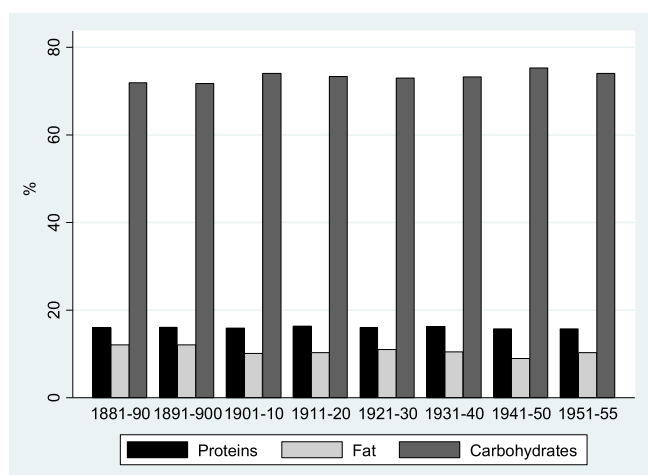


Fig. 2. Diet composition in macronutrients. Italy, 1887–1955

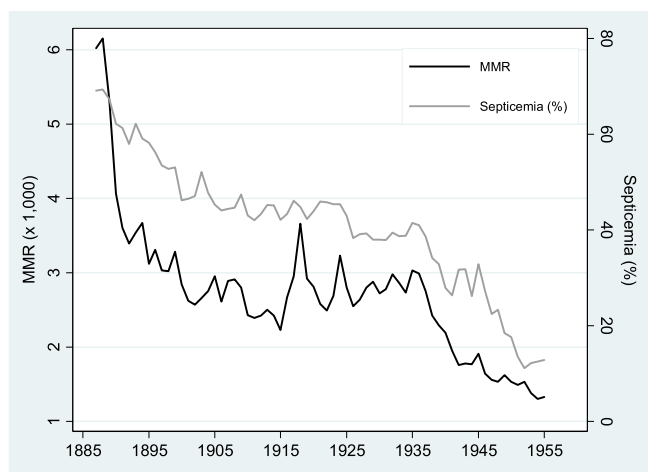


Fig. 3. Maternal mortality rate (x 1000 live births) and percentage of deaths for septicemia.

(Angeli & Salvini, 2001). The role of antiseptics techniques can be appreciated also from the decline of the percentage of maternal deaths from septicemia and puerperal infections, whose value declines from 69.1% in 1887 to 44.1% in 1906.

After that initial drop, however, the decline levelled off. The positive results of the employment of antiseptics in the maternity hospitals were constrained by the limited number of women who gave birth in health institutions.<sup>8</sup> The limited spread of hospitals in the rural areas of Italy and the ignorance of Italian families, whose distrust of science and medical doctors discouraged pregnant women from having births in institutions and from resorting to professional midwives,<sup>9</sup> kept, therefore, maternal mortality from decreasing further. After antiseptics techniques had been introduced in hospitals, home delivery entailed often an unhealthier setting and the assistance of an unskilled midwife, exposing mothers to higher risks of infections, unnecessary interventions, and other harmful effects.

Actually, during WWI and in the interwar period, the maternal mortality rate shows a slight increase, culminating in 1935 with a value of 3.0 per thousand. In that period, it is possible to remark also the peaks of mother’s deaths in 1918, when the effects of WWI came in addition to the dramatic consequences of the Spanish flu (3.7 per thousand). From that year onward, then, the rate decreases strongly and steadily up to 1955, when it falls to about 1.3 per thousand, only marginally touched by WWII.

The collapse of maternal mortality in this last period was the consequence of the introduction of sulphonamides in the cure of infections, which started to be produced on a large scale around 1935.<sup>10</sup> Consequently, from that year onward, the deaths for septicemia and other puerperal infectious, which accounted for over 50% of total maternal deaths until 1899, and around 40% up to 1925, reduced considerably, falling to 12.8% of total maternal deaths in 1955.

### 5. The relationship of maternal mortality with nutritional and economic factors: A cointegration analysis

In this section, the relationship between nutritional factors and maternal mortality in the period 1887–1955 is investigated using cointegration analysis once controlled for the GDP per capita. As already mentioned, despite the versatility of ARDL models in dealing with variables with different integration orders, they must be in any case I(1) at

<sup>8</sup> Still in 1953, about 80% of total births were delivered at home.

<sup>9</sup> This occurred despite many midwifery schools had been opened in Italy since the seventeenth century. However, the number of professional midwives was still insufficient for the Italian context, and, as already mentioned, they were not welcomed in many areas of Italy, especially in the countryside.

<sup>10</sup> Sulphonamides came on sale very early in Italy thanks to the promptness of some pharmaceutical industries and to the close political link between Germany (where they were discovered) and Italy (Capocci, 2013).

most. Thus, the first step to take is to check whether the considered variables have integration orders less than 2 in the period considered (Table 1). The Augmented Dicky Fuller test (ADF), whose null hypothesis is here non-stationarity against the alternative of stationarity around a linear time trend, was used. The results show that the maternal mortality rate is stationary at levels, whilst calories and GDP per capita are not. However, they become stationary after first difference, so that all the three time series meet the pre-condition of being integrated of order 0 or 1, which makes it possible to apply ARDL. However, some of the KPSS tests provide opposite results to the ADF test. This is true especially for the maternal mortality rate, whose conclusions address the refusal of trend stationarity, both at levels and at first difference. As for the GDP per capita, the inconsistency with ADF is limited to the analysis at levels.

Such inconsistent results could be due to the existence of structural breakpoints in the trend of the time series. ZA test and the two versions of the CMR test were therefore used to check for the presence of breakpoints in the time series (Table 2). As for MMR, the significant result of the ZA test at levels proves the stationarity of the MMR time series with only one break in the trend, specifically in 1936. The CMR tests do not bring to reject the null hypothesis of a unit-root time series in presence of two breakpoints. The break in 1936 coincides perfectly with the period in which sulphonamides were introduced in Italy, largely contributing to reducing the levels of maternal mortality in Italy. This means that the maternal mortality trend was profoundly marked by a discontinuity due to medical progress and the large availability of medicines to parturients against the infections of puerperium and childbirth.

The same pattern has been found for GDP time series, which was found to be stationary with one structural break at levels in 1948, just when the GDP started to recover after the end of WWII.

After first difference, the time series of mean calories per day gets stationary as well, with both one and two breakpoints on account of the statistical significance of both the ZA and CMR tests. These breaks coincide with WWII, in which the average caloric intake reduced dramatically, then followed by a robust recovery.

The structural breaks will be included in the ARDL model as exogenous dummy variables. Thus, the first dummy will control for the effects of the introduction of sulphonamides in 1936, whilst the second dummy variable will control for the effects of WWII, contrasting the pre-WWII period (1887–1939) with either WWII (1940–45) and the post-WWII period (1946–1955).

Once the pre-condition of the time series integrated at I(0) or I(1) has been met, and the dummy variables concerning the structural breaks in the time series have been defined, the ARDL bounds test has been run to examine the cointegration among the series. The model includes the maternal mortality rate as the dependent variable, the mean caloric intake (here expressed in hundreds of calories), and the annual GDP per capita as independent variables, and two exogenous variables aimed at controlling for the effects associated with structural breakpoints, as described above.

Table 3 shows the results of the ARDL model and bounds tests.

The bounds test shows that both the F and the t statistics are statistically significant at  $p < 0.001$ , implying the acceptance of the alternative hypothesis of cointegration among MMR, calories, and GDP per capita, thereby implying a long-run relationship among them. The long-

**Table 1**  
Tests for time series stationarity. Italy, 1887–1955.

	ADF		KPSS	
	At levels	First difference	At levels	First difference
MMR	-4.062**	0.157*	0.126*	0.157**
Calories	-2.315	-10.363***	0.182**	0.068
GDP p.c.	-0.371	-4.793***	0.062	0.082

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

**Table 2**  
Tests for structural breaks. Italy, 1887–1955.

	At levels		First difference	
	t-statistics	Year(s)	t-statistics	Year(s)
MMR				
ZA (trend)	-6.743***	1936		
CMR (IO)	-3.756	1914, 1936	-3.223	1891, 1917
CMR (AO)	-4.785	1897, 1939	-1.514	1916, 1922
Calories				
ZA (trend)	-3.310	1904	-10.900**	1944
CMR (IO)	-3.908	1896, 1939	-5.895**	1940, 1945
CMR (AO)	-2.218	1895, 1935	-12.686**	1940, 1944
GDP p.c.				
ZA (trend)	-4.315*	1948		
CMR (IO)	-2.504	1920, 1948	-3.731	1941, 1944
CMR (AO)	-1.869	1919, 1951	-4.044	1941, 1943

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

**Table 3**  
ARDL regression model and Bounds Test. 1887–1955.

ARDL Model	Coeff.	p-value	Bound test	p-value	
				I(0)	I(1)
ADJ					
MMR (L1)	-0.454	<0.001	F = 9.179	<0.001	0.001
LR			t = -5.120	<0.001	0.001
Calories (L1)	-0.076	0.032			
GDP per capita (L1)	0.204	0.231			
SR					
Calories (D1)	-0.034	0.044			
GDP per capita (D1)	0.093	0.225			
1887–1939 (ref.cat.)					
1940-45	-0.279	0.134			
1946-55	-0.499	0.017			
Introd. of Sulphonamides	-0.330	0.022			
Constant	1.875	<0.001			
Log-likelihood	11.049				
Adj. R <sup>2</sup>	0.276				

ADJ = speed of adjustment (error correction term); Long-run dynamics; SR = Short-run dynamics.

run results show that only the coefficient of average caloric intake is statistically significant, proving a negative impact on MMR: The lower the mean caloric intake per day, the higher the maternal mortality rate.

As for the short-run component of the model, the error correction term (ADJ) resulted statistically significant, showing that about 45% of the disequilibrium in the maternal mortality time series is restored within a year after a short-run shock. The pattern described by the single coefficients is then similar to that already highlighted for the long-run component. The relationship between average caloric intake and MMR is, in fact, statistically significant and negative, while the GDP per capita does not show any significant effect on the MMR. Finally, the exogenous variables. The enormous importance of sulphonamides in the reduction of maternal mortality is here confirmed by the statistically significant drop in the MMR with respect to the period prior to their introduction (-0.330). Their impact in the struggle against maternal deaths is reinforced by the evidence that after 1936 maternal mortality kept declining despite WWII and the dramatic consequences that it had on the economy and the living standards of the Italian population of the time (see Fig. 2). This consideration is supported by the evidence that maternal mortality appears to be largely unaffected by historical wartime events, as proved by the coefficient of the period 1940–45, which does not show any statistically significant differential in respect to the antebellum period. Conversely, this is what happens in the post-war period, when the rate of maternal mortality eventually displays a significant drop, always in

relation to the period 1887–1939.

Given the positive results of cointegration, a battery of post-estimation tests have been run to check for the respect of the statistical assumptions (Table 4). The alternative Durbin-Watson test (null of no first-order serial correlation), the Breusch-Godfrey LM test (null of no higher-order serial correlation), the Breusch-Pagan/Cook-Weisberg test (null of no heteroskedasticity), and the Ramsey test (null of no omitted variables) were performed.

All the null hypotheses were accepted, proving the adherence of the model to many of the necessary statistical assumptions, thereby confirming the validity of the results.

## 6. Discussion and conclusions

The debate about the role of nutrition on maternal mortality has been often characterized by uncertainty and doubts when not open denial. Only recently, medical and epidemiological studies have clarified some potential links that could influence the position of many. From an historical perspective, the relationship gets even more complex to analyze on account of both the quality of historical data and the ever-changing classification methods of maternal death applied across time and space, with particular emphasis on the problematics posed by the indirect causes of maternal death.

However, some studies started to shed some light on the association between a poor diet and an increased risk of maternal mortality. Scalone (2014), for instance, proved the association between maternal mortality, on the one hand, and poor diet coupled with hard works, on the other hand, during short-term economic crises which limited food supply and caloric intake among the rural population he studied.

A long-term association between nutrition and maternal mortality has been conversely never demonstrated, although some scholars have sustained the idea of such a relationship (Högberg, 2004) and others have claimed the existence of a long-term link between nutrition and overall mortality (See Harris, 2004). Mckeown's theory is one of the most well-known theoretical frameworks of that kind (McKeown, 1976). He explained the decline of mortality as a consequence of economic growth, rising living standards, and, most of all, improved nutrition. On the other hand, he minimized the role of scientific and medical progress as well as public health interventions in reducing mortality, especially up to the first decades of the twentieth century. His thesis has been criticized and questioned, there included a lack of experimental evidence (Colgrove, 2002; Szreter, 2002). Fogel (2004) gave new life to some of Mckeown's ideas, using price and height data to demonstrate indirectly the prominent role of nutrition in the demographic process, but his "nutritional reductionism" was criticized as well (see for instance Johansson, 2005).

The present paper provides quantitative support to the impact of nutrition on maternal mortality from the late-nineteenth to mid-twentieth-century Italy, but framing it within the context of medical advances and public health interventions. The analysis has highlighted that scientific and medical progress did play a relevant role in the drop of maternal mortality, first with the introduction of antiseptic techniques in the last years of the nineteenth century, then with the diffusion of sulphonamides in the second half of the thirties of the twentieth century. This analysis has pointed out that especially the latter event was the most significant and decisive fact in the decline of maternal mortality in the period investigated. Consequence of medical progress and public health intervention, the use of antibiotics marks a real discontinuity in the trend of maternal mortality in Italy. Their widespread use in the cure of maternal-related diseases allowed, in fact, a so drastic reduction of maternal deaths due to septicemia and infections that even WWII was unable to interrupt such a decline.

In this context of scientific progress and higher public expenditure in health facilities, the impact of nutrition on the levels of maternal mortality cannot go unrecognized. The statistical analysis has provided evidence of the significant negative association between daily caloric

**Table 4**

Post-estimation tests for the ARDL model. Italy, 1887–1955.

	Statistics	p-value
Durbin test for first-order serial autocorrelation	Chi2 = 0.162	0.688
Breusch-Godfrey test for higher-order serial autocorrelation	Chi2 = 0.184	0.668
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity	Chi2 = 0.68	0.410
Ramsey test for omitted variables	F = 0.22	0.883

intake and the maternal mortality rate. This association has concerned both the long and short-term dynamics of the average caloric intake, where the latter is a further confirmation of what Scalone (2014) had already highlighted in his work on short-term crises and maternal mortality.

Although there is evidence that the level of nutrition in the period of the Italian history here considered was not completely adequate for pregnant women, the cause of such an adverse impact on the survival of parturients was likely due to their poor nutritional status rather than the daily caloric intake per se. Defined as the balance between caloric intake and energy expenditure, the deteriorated nutritional status of Italian adult women was the result not only of a poor diet, frequently poorer than their male household counterparts, but also of the hard works in which they were engaged before, during, and after pregnancy, and of the high fertility and the consequent energy costs associated with the raising of children. This exhausted nutritional status made mothers weaker and put them at higher risk of developing infectious diseases during and after pregnancy.

These results were obtained once controlled for the GDP per capita. Clearly, social and economic progress spurred better nutritional levels in the Italian population, but once depurated from such effects, their role in the decline of maternal mortality appears limited. This lack of statistical significance, however, could be also due to the nature of the proxy here used, which could not be able to capture the real changes in living standards, at least for some specific social groups or geographic areas. This is the reason why further studies on this topic are greatly needed.

## Author statement

The paper has been entirely conceived and realized by the author, who is the only responsible for its content.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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