TERRITORIAL DISPERSION AND CONVERGENCE IN INFANT MORTALITY AND ITS COMPONENTS: ITALY 1950- 2019

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Abstract. The steep decline in infant mortality is undoubtedly one of the most significant changes Italy and Europe have experienced during the last centuries. This paper focuses on the temporal and spatial evolution of survival in the first year of life, using Italian provincial data from 1950 to 2019. After World War II to the present, the decline of infant mortality risks was a process that took place with different intensities and speeds among regions and provinces. Nonetheless, the convergence process was slow even continuously in action. This work has three main objectives. First, the timing and distribution over time and by province of the drop of mortality in the first year of life are pictured. Second, we analyse the convergence process at the territorial level together with the persistence and potential concentration of inequality in survival by means of classical measures of dispersion. Third, we control the evolution of neonatal and post-neonatal mortality with a sub-national approach. To achieve these objectives, we make use of a provincial-level database that has so far been little used, and which covers 70 years, from 1950 to 2019.

After providing theoretical explanations about the emergence and the persistence of geographical inequalities in neonatal, post-neonatal and infant mortality, we will show how the geographical inequality follows the North-South gradient, and whether the process of convergence comes to an end for both the component of infant survival.

1. Introduction

In the initial decade of the 21*st* century, Italy achieved one of the world's lowest infant mortality rates. Nonetheless, studies reveal persistent and noticeable spatial variations in infant survival that have endured for a significant part of the 20*th* century (Aleotti et al., 1985; Del Panta, 1990; Pozzi 2000), mostly of whom still unexplained. Italy has a historical background of demographic inequalities, particularly in the socio-economic gap between the Northern and Southern regions, affecting various aspects such as per capita income (Daniele & Malanima, 2007; De Rose & Strozza, 2015), unemployment rates, healthcare quality, and neonatal care and infant survival (Bonati & Campi, 2005; Mazzucco et al., 2011).

Analyzed with high territorial granularity, the history of infant mortality in the country reveals unexpected patterns. In the late 19*th* century, the southern regions (Campania, Abruzzi, and Molise) exhibited lower infant mortality than the northern and central ones (Veneto, Lombardy, Emilia-Romagna, Marche, and Umbria, or rather, in some provinces of these regions) (Bellettini 1987; Del Panta 1990). The literature shows that it is primarily

mortality within the first month of life that underlies the higher risk of death during this period. The causes are likely endogenous, related to maternal health conditions and respiratory system disorders (Pozzi 2000). However, by the 1920s and 1930s, improvements attributed to increased wages and enhanced public and private hygiene in industrialized towns led to a reversal of this trend, portando le regioni meridionali a primeggiare sulle altre (Berlinguer & Terranova, 1972).

Understanding the origins and reasons behind these territorial variations is crucial (Del Panta 1990). Above all, the two components of mortality in the first year of life, neonatal and post-neonatal, may be influenced differently by territorial characteristics and vary spatially (Pozzi 2000; Scalone & Samoggia 2018; Scalone et al. 2017). Then, our focus should necessarily be on disparities between neonatal mortality (0-1 month) and post-neonatal mortality (1 month to 1 year), considering their distinct geographical influencing factors. For endogenous causes, mostly linked to neonatal mortality, the reference is to physical and biological variables of the newborns and the mother (Dalla Zuanna & Rosina 2011). Dealing with post-neonatal deaths, we will mostly refer to exogenous aspects that spatial inequalities, cultural factors, and socio-sanitarian attitudes might influence (Pozzi & Rosina 2000).

Methodologically, we start from the neonatal mortality rate (NMR), postneonatal mortality rate (PMR) and Infant mortality rate (IMR) calculated for all the Italian provinces from 1950 to 2019. The focus is on exploring spatiotemporal trends of sub-national inequalities at the provincial level to identify the existence of a plausible convergence in infant mortality until the second decade of the 21*st* century and how it has been determined by the possible different processes in neonatal and post-neonatal components. We adopted a novel approach for the Italian data to measuring national mortality convergence, making use of a simple but informative measure like the Dispersion Mortality Measure (DMM) calculated for the period from 1950 to 2021 (Moser *et al*. 2005). The DMM quantifies the degree of dispersion that exists at a given point of time in the mortality experiences of a particular country. It is calculated as the average of the absolute difference in mortality, weighted by population size, between every pair of geographical entities. From a descriptive point of view, trends in the DMM indicate global convergence and divergence of the phenomenon under study (Goli et al 2019). We have used also other simple measures of dispersion as the Coefficient of variation.

2. Italian geographical differences in mortality: the state of the art

At the National Unification of 1861, a division among the economically wealthiest and poorest regions, respectively located in the country's northern and southern parts, was already evident. However, on closer inspection, infant mortality presented a more fragmented geographical profile. On the one hand, the Alps and the Apennines Mountain zones registered lower infant mortality than others due to the better environmental conditions and pure water sources. On the other extreme, the populations living in the

marshlands and the malaria provinces experienced the highest infant mortality levels linked to the substantial incidence of gastroenteric and parasitic diseases. Moreover, these high mortality zones were seldom independently located in the country's northern or southern part of the country. (Dalla Zuanna & Rosina, 2011

The disparities in infant survival persisted also during Postwar Italy. Several studies pointed out still evident geographical inequalities both at regional and provincial levels, with the lowest Infant Mortality Ratios (IMRs) registered in northern areas and the highest ones in the more deprived southern provinces (Fantini *et al*., 2005; Lauria & De Stavola, 2003). However, in the decades following the National Unification and during most of the twentieth century, land reclamations, hygienic and sanitary interventions, improvements of the housing conditions progressively reduced the importance of exogenous determinants of infant mortality, removing the most dangerous environmental risk factors.

As research interest in the topic increases, the differences in infant mortality between provinces has also been associated with the general and long-term socioeconomic gaps between Northern and Southern Italy (De Rose & Strozza, 2015), such as wealth inequalities (Materia *et al*., 2005), higher unemployment and lower income levels (Dallolio *et al*., 2013; Lauria & De Stavola, 2003). Moreover, since scarce caregiving to mothers and their babies is one of the leading infant mortality determinants (Scioscia *et al*., 2007; Parazzini *et al*., 1992), the higher IMRs in southern provinces have also been related to delays in the development of neonatal care services (Bonati & Campi, 2005; Mazzucco *et al*., 2011).

Once the environmental and contextual factors had been reduced, one should have expected that spatial inequality in infant mortality diminished consequently with a straight convergence on territorial and spatial dimension (Gächter & Theurl, 2011; Omran, 1998). Persistent disparities in infant mortality in modern welfare states appear then as a puzzling paradox (Mackenbach, 2012). Following Vallin and Meslé (2004), during the epidemiological transition improvements in medical practices produce a first divergence between individuals who can have an immediate access to them and those who exploit this advantage only later. In our case study, geographical disparities in infant mortality could persist because some provinces lagged in introducing advanced techniques and practices in obstetric departments and neonatal intensive units.

3. Data and measures

3.1 Data

Italy represents a positive case for investigating the spatial infant mortality inequalities and convergence. Yearly data, available from the Italian National Institute of Statistics databases (ISTAT), refer to 92 provinces over 67 years (1950-2019). The number and extension of provinces changed along the time interval. Our study maintains the same administrative borders as the initial year throughout the study period. Data consists of

births and infant death counts at age 0 (before one year, before one months and between one month and eleven months) in the *s-th* province for the *t-th* year and are the basis for the computation of mortality indexes. Where data are lacking, they are calculated as averages of the previous and the following year for 1972, 1982, 1984, 1986.

3.2 Measures

As previously stated, we aim to capture whether there is a progressive convergence in provincial infant mortality and when this occurs (Congdon 2001; Congdon et al. 2004).

The mortality indexes we refer to are the Neonatal Mortality Rate (NMR), Post-Neonatal Mortality Rate (PMR), and Infant Mortality Rate (IMR)[1].

Starting from the matrixes of the three rates for 92 provinces from 1950 to 2019, we consider the Coefficient of variation and the dispersion measure of mortality (Goli et al. 2019). The DMM quantifies the degree of dispersion that exists at a given point of time in the mortality experiences of a particular area. It is calculated as the average absolute inter-province mortality difference, weighted by population size, between each pair of provinces. This approach draws on more generic mathematical work on measures of dispersion (Moser *et al*. 2005, Kendall & Stuart 1977).

Changes in the DMM over time indicate whether mortality is becoming similar across the provinces; decreases indicate convergence, while increases indicate divergence.

The formula of DMM is as follows:

$$\mathrm{DMM} = \frac{1}{2(\mathrm{W_Z})^2} \sum_{\mathrm{i}} \sum_{\mathrm{J}} (|\mathrm{M_i} - \mathrm{M_j}| * \mathrm{W_I} * \mathrm{W_J})$$

where i and j are provinces; $1 \leq i$ and $j \leq 92$. *Z* indicates the total aggregate in terms of the entire country or macro-areas when considered. M is the mortality rate, and W is the weight for whom we use the number of live births in each province. Let's either consider that $\sum iWi = \sum jWj = Wz$ where Z is equal to 1.

4. First results

Figure 1[2] represents the provincial distribution of NMR, PMR and IMR in 1950 and 2019. In 1950, the geography of survival in the first year of life is entirely determined by post-neonatal mortality, which explains more than 60% of the rate in the first year of life.

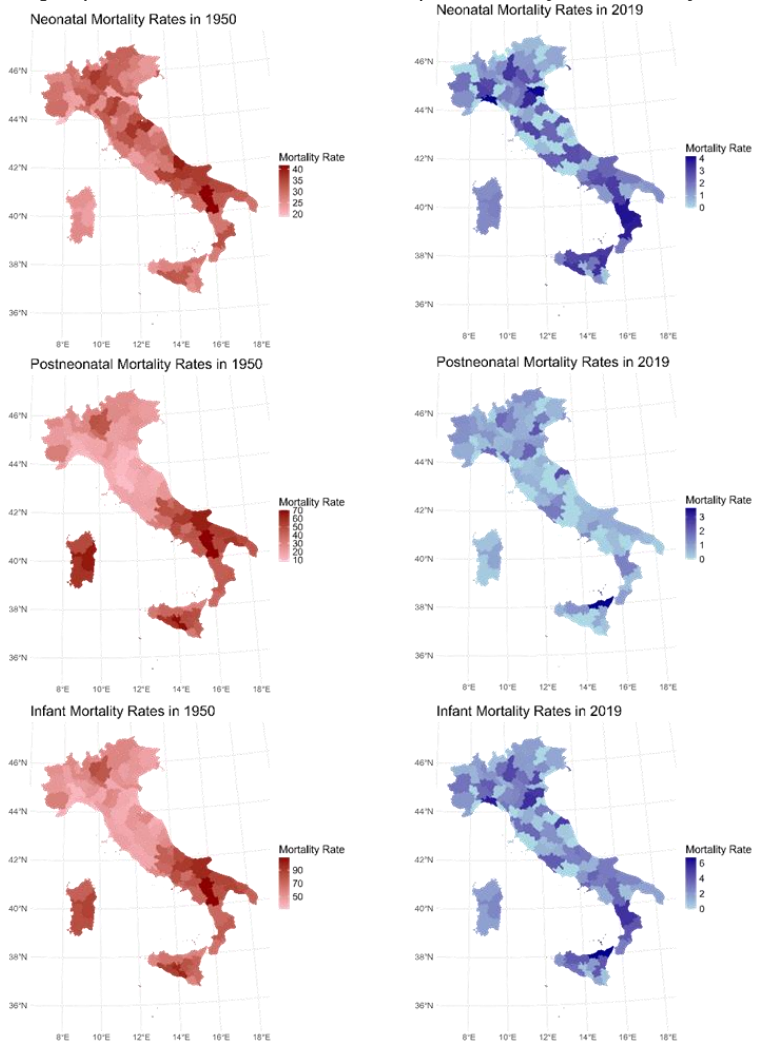
[1] NMR is the ratio between the deaths in the first month of life and the number of live births in the same year. These deaths are considered primarily caused by endogenous components such as traumatic childbirth, congenital malformations, and prematurity. PMR is the ratio of deaths between 1 and 11 months of life and the annual cohort of live births, mainly influenced by exogenous factors related to hygienic and environmental conditions causing infectious and parasitic diseases. IMR combines NMR and PMR and reflects mortality within the first year of life.

[2] In Figures 1 and 2, it is important to note that the scales of the y-axis used to represent the indices are not homogeneous, as their ranges of variation differ significantly. The chosen representations allow for a clearer visualization of the temporal evolution and the variations between provinces.

The highest values are found in the South and Islands, and Italy is clearly divided into two differentiated areas. With a national average of 30‰, values range from 41.7 in the province of Potenza (Basilicata) to 9.41 in Siena (Tuscany). This inequality is no longer visible in 2019 when with a national average of 0.67‰, the provincial distribution is puzzling, with areas of higher intensity no longer concentrated only in the South.

The NMR, on the other hand, shows a more persistent regionalization where southern provinces remain a homogeneous area with higher intensity as the rate diminished from an average around 30‰ in 1950 to 1.46‰ in 2019.

Figure 1 – *Maps of Neonatal, Post Neonatal and Infant Mortality Rates in Italy, 1950 and 2019.*



To observe the existence of a convergence process we plot NMRs, PMRs and IMRs for all provinces in Figure 2[3]. The 92 provinces are indicated by the grey watermarked lines while the solid-colored lines identify the macro-regional (North, Centre, South and Islands) and national trends. All the three panels show the progressive reduction in infant mortality with relevant differences in the speed, time, and geography of decline.

As the time of decline, a joint reading of the three panels shows three phases of evolution. The first one is the 1950-1975 interval. During this period, PMR declined more rapidly than NMR especially in the southern part of the country.

Neonatal mortality shows a slower decreasing trend and a more limited dispersion of provincial levels than PMR. The national NMR index average values reached 30‰ in 1950 and slowed to 16‰ in 1975. Up to the mid-1960s, rates ranged from a minimum of 20 to a maximum of 40‰ and only in 1974 did the South and Island go below the 20‰ level attributable to the North twenty years before. On the contrary, PMR began its intense decline in the 1950s, starting from average values of 37‰ and reaching 5‰ in 1975. In 1951, the index ranged from 87,1‰ at Potenza (Basilicata region) to 8,37 ‰ at Ravenna (in Emilia-Romagna region).

The dispersion of the provinces is at its maximum in the first years of observation, underlining extreme inequalities at a territorial level.

We can place the second period between 1975 and the beginning of the new century. This interval is characterized by the onset of the speediest decrease in NMR and the continuation of the decline in PMR. Neonatal mortality settled below 10‰ for all national areas in 1984, and again, the South with Islands came later in this transition.

PMR is already very low, no more than 2‰, while the more interesting aspect is

the reduction of dispersion, which testifies to a high level of improvement in terms of social well-being. However, the North-South divide persisted: in 1972, the PMR was already below 5‰ for the North and Center while, in the South and Islands, it reached 10,81, going below 5‰ in 1978 when the other areas were just around 2‰.

The last phase can be placed in the 2000s, when PMR has already levelled off around 1,2‰ and NMR continues to reduce. It shows values below 3‰ in 2006. Finally, it should be underlined that for NMR, the presence of dispersion around the average value is more visible than for PMR, a sign of a mortality difficult to defeat.

The general Infant Mortality rate basically is the sum of the PMR and NMR. The neonatal mortality accounted for 45% of the mortality in the first year of life at the beginning of the 1950s, its weight reached 76% in 1975 and maintained the level until more recent years.

[3] See footnote 2.

Figure 2 – *Neonatal, Post Neonatal and Infant Mortality Rates in Italy by Macro-Regions and Provinces, 1950-2019 on primary graphs and 2000-2019 on secondary graphs.*

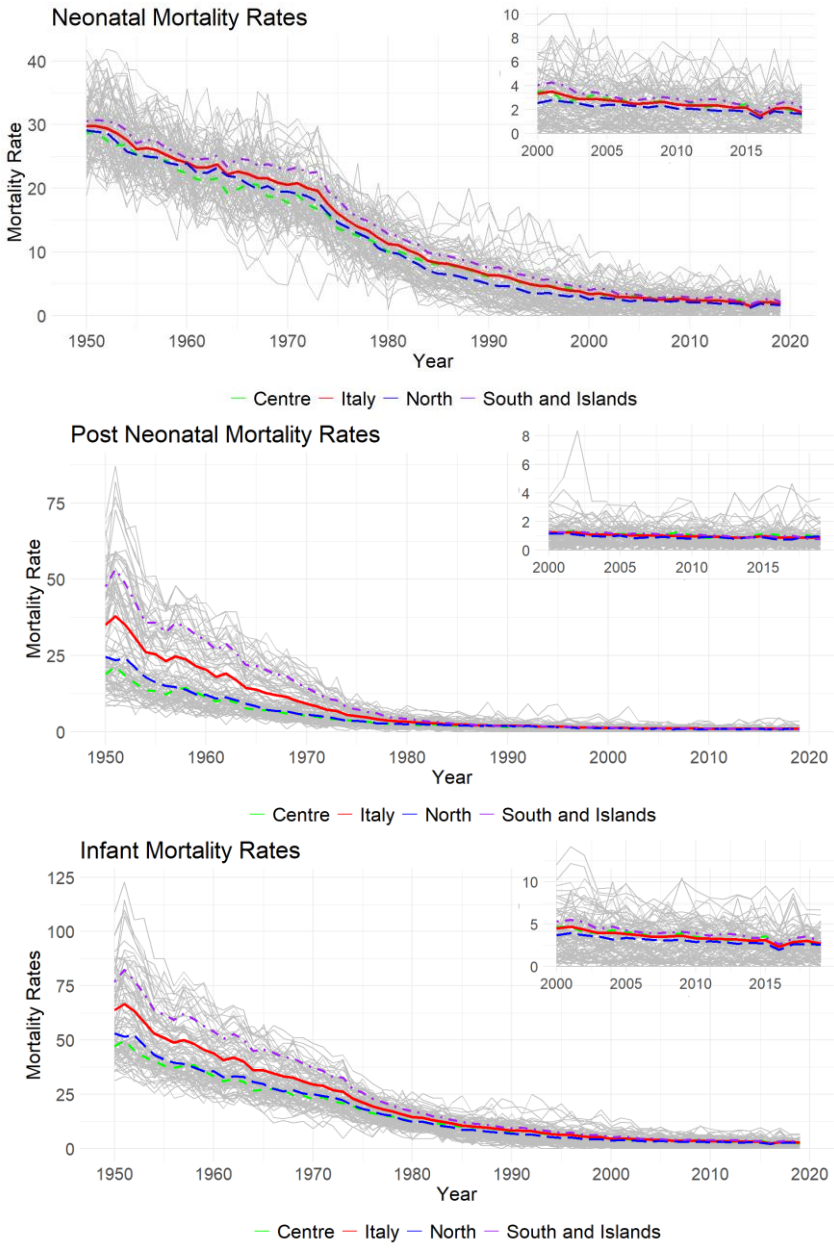


Figure 3 – *Coefficients of variation for Neonatal, Post Neonatal and Infant Mortality Rates in Italy, 1950 and 2019.*

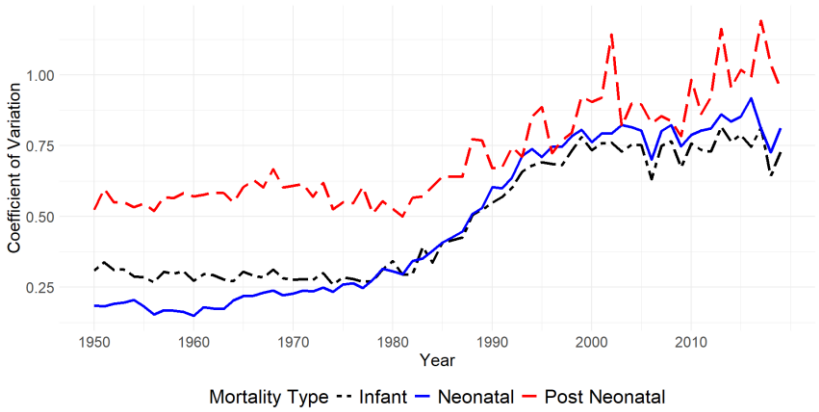
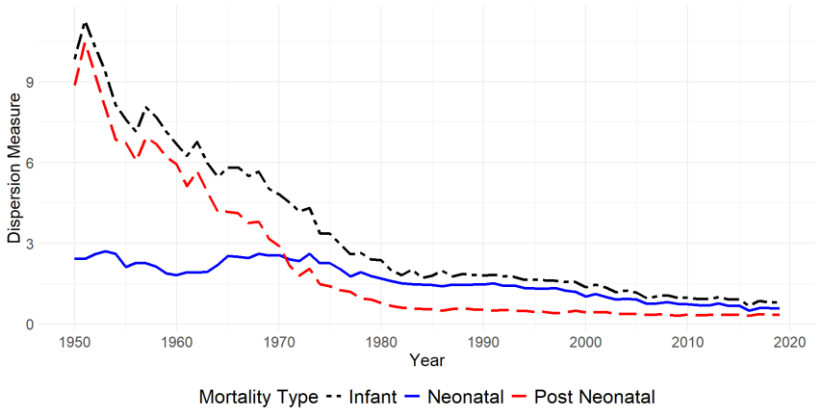


Figure 4 – *Dispersion Measures of Mortality for Neonatal, Post Neonatal and Infant Mortality Rates in Italy, 1950 and 2019.*



The Coefficient of Variation (CV)[4] shows that a higher dispersion around the mean of the post-neonatal mortality (fig. 3) should be expected. This characteristic persists throughout the period under study and, as PMR decreases, the dispersion increases, probably highlighting outliers to be identified.

[4] The coefficient of variation (CV) is the ratio of the standard deviation to the mean. The higher the CV, the greater the level of dispersion around the mean.

PMR appears to have a more significant variability until at least the early 1990s. However, there is a general increase in the coefficients of variation also in NMR.

This trend could be due to the general convergence of a growing number of provinces over time, leaving behind those territories in which aspects of health or environmental deficiencies are more difficult to eradicate.

It is also worth noting that with the decrease in the numbers of deaths and the population at risk (births), we found a more significant variability due to small numbers. That could be observe in the PNM peaks in 2002, 2010, 2013 and 2017.

The convergence process has different times per geographical area (table 1). For post-neonatal mortality the areas of the South and Islands show a greater slowness while the North and Centre accelerate already in the first evolutionary phase, up to 1975. After this date the rapprochement seems to be rapid in all the macro-areas. As for mortality in the first month of life, the central area seems to be the most dynamic in terms of convergence between 1950 and 1975. Starting from the 1980s the process speeds up everywhere, especially favouring the North.

5. Conclusions

This paper examines the evolution of exogenous and endogenous mortality in the transition from high to low infant mortality in Italy at the provincial level. The objective is to describe territorial inequality in increasing child survival and highlight the existence of a robust convergence process in the provinces.

Trends in neonatal, post-neonatal, and infant mortality were affected by a large oscillation in the ‘50s and ‘60s and remained divergent until the ‘80s.

DMM evolution shows that the convergence was rapid between 1950 and the mid 1970s, after it seemed to level and then started again to decrease from the late 1990s, even though more slowly. This trend is closely linked to the different post-neonatal and neonatal mortality trends. The first intense decrease is entirely due to post-neonatal mortality and went hand in hand with improving socio-economic and health conditions. For the neonatal component, the trend contrasts with a first initial convergence followed by a new divergence movement from the mid-1960s until the mid-1970s. A more evident provincial convergence for neonatal mortality began in the late 1990s and has continued until now.

The analysis clearly shows that provinces with the highest infant mortality rates are predominantly located in southern Italy. Given that neighboring provinces often share similar environmental, demographic, and socio-economic characteristics, these differences could be related to unequal standards of neonatal healthcare, which is generally managed locally on an infra-regional scale.

Additionally, changes in reproductive behavior have led to an increase in the age at childbirth, thereby raising the number of high-risk births and premature infants born to older mothers. Stability in these values, where present, is largely due to the different

standards of healthcare established by regional regulations. Extending the excellent medical standards of the Northern provinces to the Southern ones is a difficult mission to accomplish, even in a universal public welfare system like Italy's.

Table 1 – *Dispersion Measures of Mortality (DMM) for Neonatal, Post Neonatal and Infant Mortality Rates in Italy by Macro-Regions and Provinces, 1950-2019 (5-years intervals).*

Anni	DMM - Neonatal Mortality			DMM -Postneonatal mortality			DMM- Infant Mortality		
	North	Centre	South and I.	North	Centre	South and I.	North	Centre	South and I.
1950-54	2.26	2.40	2.54	4.50	3.23	5.24	5.56	4.21	6.62
1955-59	1.93	1.89	2.09	2.41	2.37	3.67	3.62	2.85	4.84
1960-64	1.85	1.52	1.80	1.58	1.61	3.24	2.79	2.41	4.27
1965-69	2.19	1.58	2.45	1.07	0.86	2.66	2.82	1.95	4.26
1970-74	2.06	1.47	2.43	0.88	0.69	1.53	2.70	1.80	3.68
1975-79	1.80	1.28	1.76	0.70	0.64	0.92	2.27	1.68	2.32
1980-84	1.44	1.10	1.30	0.55	0.57	0.50	1.80	1.44	1.52
1985-89	1.25	1.30	1.16	0.60	0.66	0.41	1.77	1.83	1.32
1990-94	1.18	1.60	1.14	0.55	0.57	0.41	1.59	2.03	1.38
1995-99	1.01	1.55	1.09	0.40	0.56	0.41	1.33	2.02	1.33
2000-04	0.78	1.23	0.90	0.38	0.47	0.40	1.08	1.64	1.19
2005-09	0.68	0.94	0.75	0.27	0.41	0.34	0.85	1.29	0.97
2010-14	0.59	0.84	0.65	0.32	0.36	0.34	0.83	1.09	0.85
2015-19	0.48	0.70	0.55	0.30	0.35	0.35	0.68	0.96	0.77
N. Prov.	40	20	32	40	20	32	40	20	32

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