

Understanding The Fertility Patterns Of Italian And Foreign Women In Italy's Macro-Regions: Insights From Joinpoint Regression And Discriminant Analysis

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Abstract

The study analyses the evolution of reproductive behaviour among Italian and foreign women in Italy between 2002 and 2023, in a context of a persistent decline in fertility, and territorial heterogeneity. Using data from the Italian National Institute of Statistics on total fertility rate (TFR) and average age at childbirth (MAC), the study adopts two complementary approaches: joinpoint regression to identify significant changes in temporal trends, and discriminant analysis to ¹distinguish reproductive profiles between macro-regions and between citizenships (Italian and foreign women). The results show that TFR is declining for all women, albeit at different rates and intensities: for Italian women there is a reversal of the trend midway through the period, while for foreign women there is an earlier and more marked decline. The MAC is growing in all groups, indicating a general postponement of motherhood, with a trend towards convergence between the two groups of women. Discriminant analysis reveals clear territorial gradients for Italian women and less separation between foreign women, confirming processes of behavioural convergence in fertility among these women.

Keywords: *fertility trends and profiles, Italian macro-regions, Italian and foreign women, classification statistical methods.*

Introduction and Context

In Europe, shifts in the intensity and timing of reproductive behaviours have played a pivotal role in demographic dynamics, although their patterns have differed widely across countries and historical periods (Balbo et al., 2013; Frejka & Sobotka, 2008). The persistent decline in fertility stands out as one of the most significant features of the contemporary demographic change. Italy exemplifies this trend clearly, emerging as a paradigmatic case in which the reduction in births has been particularly pronounced and has exerted a substantial effect on demographic growth (Billari, 2008). Birth rates have fallen steadily since the 1970s, with only a modest rebound in the early 2000s, which was driven by a recovery in the number of postponed births among cohorts born in the 1960s and the growing contribution of foreign mothers (Mencarini et al., 2021; Vignoli & Paterno, 2025). This long-term decrease reflects both a lower average number of children per woman and shrinking cohorts entering reproductive age groups (Mencarini & Vignoli, 2018). By 2023, the total fertility rate (TFR) had fallen to 1.2 children per woman, while the mean age at

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childbearing (MAC) reached 32.5 years—about three years more than in 1990 (ISTAT, 2024).

In parallel, since the early 2000s Italy has undergone a substantial increase in births involving at least one foreign parent, with a rise from a marginal share of less than 4% in the late 1990s to 21.3% by 2023 (ISTAT, 2024). Foreign women initially contributed to a slowing down in the decrease of births observed nationwide (Giannantoni & Strozza, 2015; Stranges et al., 2025). Nevertheless, their fertility has also trended downward—especially after the 2008 crisis—as their reproductive behaviour has increasingly converged with those of Italian women as their durations of stay have lengthened (Carella et al., 2021; Mussino & Strozza, 2012, Ortensi, 2015). In 2023, foreign women's TFR (1.82) remained above that of Italian women (1.14) but far below the replacement figure and substantially down from the figure of 2.67 in 2008 (ISTAT, 2024).

Italy's fertility patterns have also historically displayed strong territorial heterogeneity, characterized by higher fertility in the south and lower levels in the north, at least until the late 1980s (Carboni & Caltabiano, 2025; Vitali & Billari, 2017). While regional disparities have not disappeared, the old pattern has been substantially reshaped over time. In the 1990s, regional fertility differentials narrowed and, since 2008, they have even reversed: the 2000s marked an inversion in reproductive behaviours, with the north overtaking the south in fertility levels. This inversion reflects profound structural and behavioural changes, with northern regions—reinforced by internal and international migration—responding more quickly to economic recessions than southern ones, where out-migration, population aging, and structural disadvantages reduced responsiveness to economic downturns (De Rose & Strozza, 2021; Garcia Pereiro & Paterno, 2025; Zambon et al., 2020).

The main objective of this study is to undertake a comparative analysis of reproductive behaviours among Italian and foreign women in Italy over the past two decades (2002–2023), with particular attention to macro-regional differences. Adopting a citizenship-differentiated perspective, the research investigates how fertility patterns and timing have evolved across the country's five macro-regions—the North-West, the North-East, the Centre, the South, and the Islands—while highlighting territorial heterogeneity.

To accomplish these aims, the study focuses on two key fertility indicators, TFR and MAC, and applies a two-step methodological framework. First, joinpoint regression analysis is employed to detect statistically significant changes in temporal trends, modelling shifts through segmented linear functions (Kim, 2001; Rea et al., 2017). Second, discriminant analysis is used to classify, and differentiate between, the reproductive behaviours of Italian and foreign women across the macro-regions, based on TFR and MAC.

By combining these approaches, our study not only identifies turning points in fertility trends but also evaluates the extent to which macro-regional and citizenship-based differences persist or shrink. This dual perspective contributes to a deeper understanding of fertility dynamics in Italy and demonstrates the value of integrating time-series and spatial analysis with classification techniques in demographic research.

Data and Methods

The analyses are based on fertility data provided by the Italian National Institute of Statistics (ISTAT), covering annual periods from 2002 to 2023. The dataset includes: (i) TFR, defined as the average number of children per woman; and (ii) MAC. All analyses are conducted at the level of the Italian macro-regions, corresponding to the official territorial divisions: the North-West, the North-East, the Centre, the South, and the Islands. This allows us to capture regional heterogeneity in reproductive behaviour among Italian and foreign women.

Two complementary statistical approaches are employed. First, joinpoint regression analysis is applied using the Joinpoint Regression Program (2021) developed by the US National Cancer Institute. Within this methodological framework, time is treated as the

independent variable, and the dependent variable can correspond to any indicator whose temporal evolution is being assessed (Z Dyvesether et al., 2018; Wilson et al. 20217; Zafeiris, 2023). This method identifies statistically significant changes in trends by fitting a series of connected linear segments to the data. Each segment is joined at a “joinpoint”, which represents a turning point in the trend. The model uses a Monte Carlo permutation test to assess whether additional joinpoints improve the fit, assuming constant variance and uncorrelated errors (Kim et al., 2001). For each segment, the annual percentage change (APC) quantifies the rate of increase or decrease in the indicators, and significance is denoted by an asterisk. Comparability tests (Kim et al., 2004) are used to verify whether the trends for Italian and foreign women are parallel or identical. Through this approach, we detect statistically significant inflection points encompassing accelerations, decelerations, and periods of stability for both the fertility indicators (TFT and MAC) and for both the citizenship groups (Italian and foreign women). This enables a nuanced interpretation of shared and divergent temporal trajectories in their fertility patterns across macro-regions (Zaferiris et al., 2024)

Second, discriminant analysis (DA) is performed to classify and differentiate between the reproductive behaviours of Italian and foreign women across the macro-regions. DA is a multivariate statistical technique designed to identify linear combinations of predictor variables—known as discriminant functions—that maximize the ratio of between-group variance to within-group variance, thereby achieving the greatest possible separation among predefined groups (Hair et al., 2019; Huberty & Olejnik, 2006). In this study we use DA to find linear combinations of the fertility variables (TFR and MAC) that maximize the separation between the macro-regions (predefined classes/groups). By examining the discriminatory power of the fertility indicators—TFR and MAC—this methodological framework allows us to identify the territorial profiles of fertility by citizenship and enables an assessment of whether these profiles diverge or exhibit tendencies towards convergence.

Classification accuracy was evaluated through multiple tests and cross-validation procedures to assess the robustness of the group assignments. The tests were Pillai’s Trace test, the Lawley–Hotelling Trace test, Roy’s Largest Root (Criterion), the Box test (Chi-square asymptotic approximation), the Box test (Fisher’s F asymptotic approximation), all of them being statistically significant. A multicollinearity test was also performed, and the Variance Inflation Factor revealed no problem with multicollinearity (less than 10).

Through the joint application of trend detection (joinpoint regression) and classification (discriminant analysis), the methodological strategy adopted in this study provides a robust analytical approach for capturing the complexity of fertility patterns across Italian macro-regions.

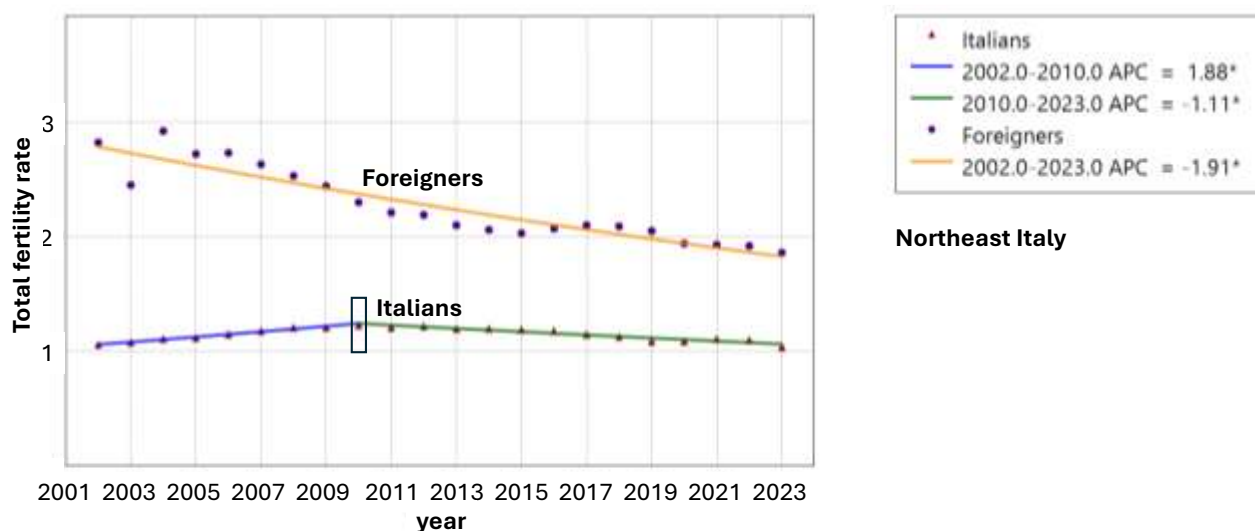
Results

Joinpoint Regression Analysis

The following figures show the results of the joinpoint regression applied to TFR and MAC across the Italian macro-regions. The analyses were performed separately for Italian women and foreign women, with the APC estimated within the segments defined by the joinpoints.

In the North-East (Figure 1: Panel A), Italian women’s fertility shows one joinpoint in the mid/late 2010s, with a shift from moderate growth (APC = +1.88%) to decline (APC = -1.11%). For foreign women, TFR declines progressively (APC = -1.91%) with no joinpoints. This suggests a stable downward trend among foreign women, while Italian women experienced a clear mid-period reversal.

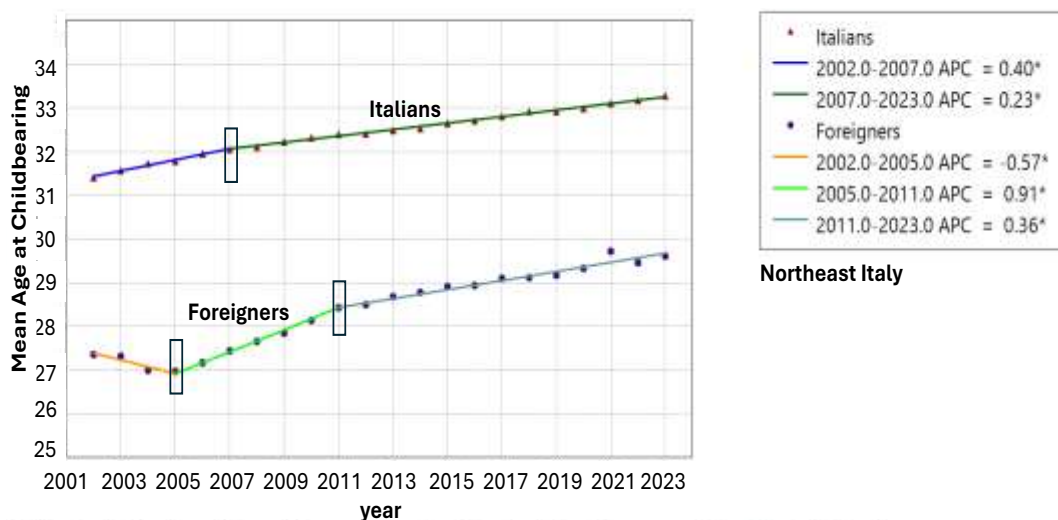
Figure 1 (Panel A): Northeast – TFR



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level. Final Selected Model: Italians - 1 Joinpoint, Foreigners - 0 Joinpoints. Rejected Parallelism.

For MAC (Figure 1: Panel B), the trend for Italian women exhibits a single joinpoint in 2007, marking a transition from an initial phase of faster increase (APC = +0.40%) to growth at a slower pace (APC = +0.23%). Among foreign women, two joinpoints (2005 and 2011) segment the trend into three phases: an early decline (APC = -0.57%), followed by a sharp rise (APC = +0.91%), and then a moderate increase (APC = +0.36%). This configuration indicates stable postponement of having a child among Italian women, and a pronounced catch-up among foreign women beginning in the mid-2000s. After 2011 the slopes are closer, suggesting converging timing behaviour, although a persistent gap remains, with Italians consistently older when they give birth.

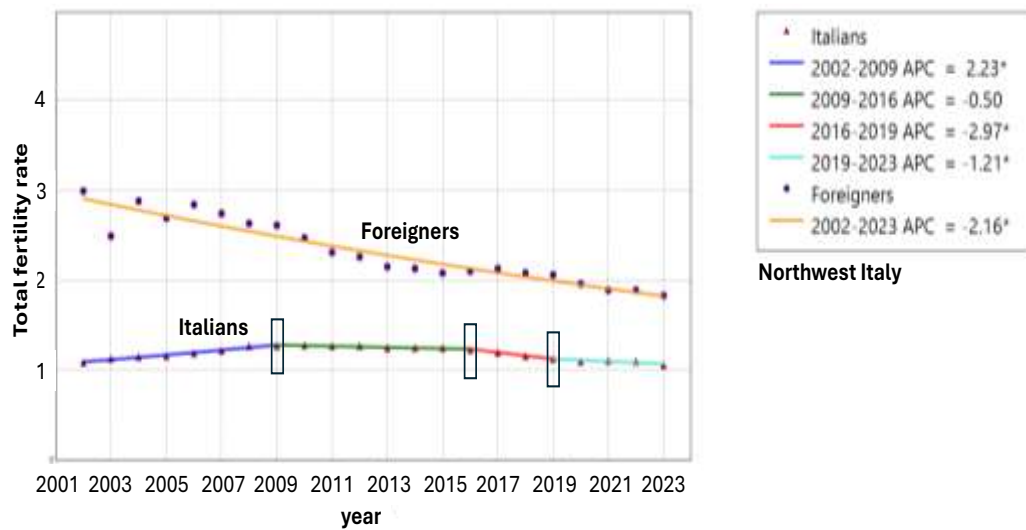
Figure 1 (Panel B) North-East - MAC



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level. Final Selected Model: Italians - 1 Joinpoint, Foreigners - 2 Joinpoints. Rejected Parallelism.

In the North-West (Figure 2: Panel A), the fertility of Italian women shows three joinpoints that segment the trends in four periods characterized by a growth (2002–2009, APC = +2.23%), a slight decline (2009–2016, APC = -0.50%), and then a sharper decrease distinct in two phases (2016–2019, APC = -2.97% and 2019-2023=-1.21). Foreign women display a steady decline (APC = -2.16%) with no joinpoints. These findings suggest fertility transition patterns in this area that are very similar to those observed in the North-East and are characterized by a stable downward trend among foreign women and a shift from early growth to a sustained decline among Italian women.

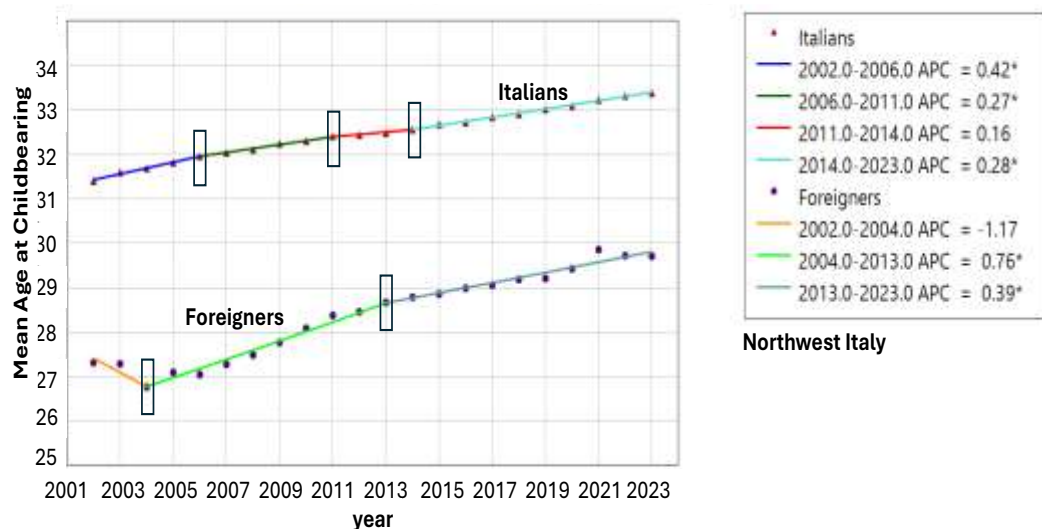
Figure 2 (Panel A): North-West – TFR



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
 Final Selected Model: Italians - 3 Joinpoints, Foreigners - 0 Joinpoints, Rejected Parallelism.

In this macro-region, Italian women show a steady rise in MAC (Figure 2: Panel B) with three joinpoints (2006, 2011, and 2014): growth slows after 2006, flattens in around 2011, and then accelerates after 2014. Foreign women follow a more dynamic path, with MAC exhibiting two joinpoints: an early decline until 2004, then strong growth until 2013 and a moderate increase thereafter. As in the North-East, from 2013 onward the MAC in the North-West for both groups of women (nationals and foreigners) shows similar upward slopes, displaying convergence in postponement behaviours.

Figure 2 (Panel B): Northwest - MAC



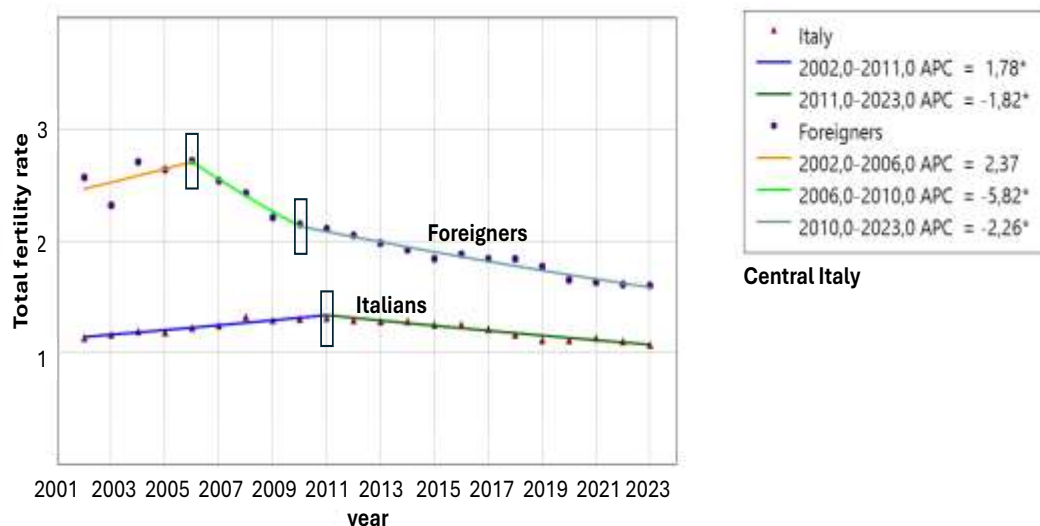
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
 Final Selected Model: Italians - 3 Joinpoints, Foreigners - 2 Joinpoints, Rejected Parallelism.

Moving to the Centre (Figure 3: Panel A), Italian women’s TFR exhibits a single joinpoint in 2011, marking a transition from a moderate growth (APC = +1.78%) to a sharp decline (APC = -1.82%). The foreign women’s TFR displays two joinpoints (2006 and 2011), segmenting the trend into an initial increase (APC = +2.37%), a marked contraction (APC = -5.82%), and a steady post-2010 decline (APC = -2.26%).

Italian women’s MAC (Figure 3: Panel B) in this macro-region is characterized by three joinpoints (2009, 2014, and 2017), indicating a segmented but consistently upward

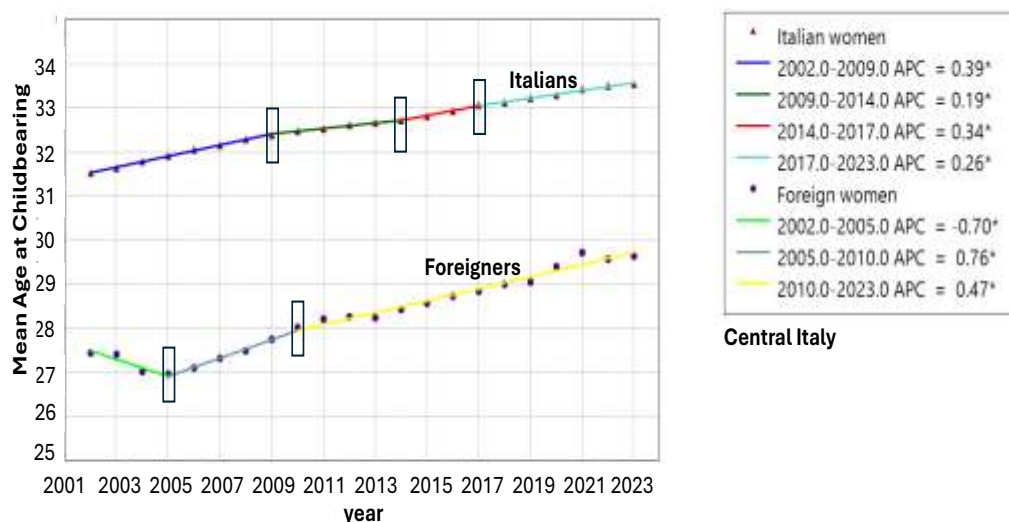
trajectory and a temporary slowdown bracketed by two periods of upward momentum. Foreign women's MAC shows two joinpoints (2005 and 2010), with a longer, faster, rise after each of them. The slope differential points to faster postponement of childbirth among foreign women, shrinking the timing gap.

Figure 3 (Panel A): Centre - TFR



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italy - 1 Joinpoint, Foreigners - 2 Joinpoints. Rejected Parallelism.

Figure 3 (Panel B): Centre - MAC



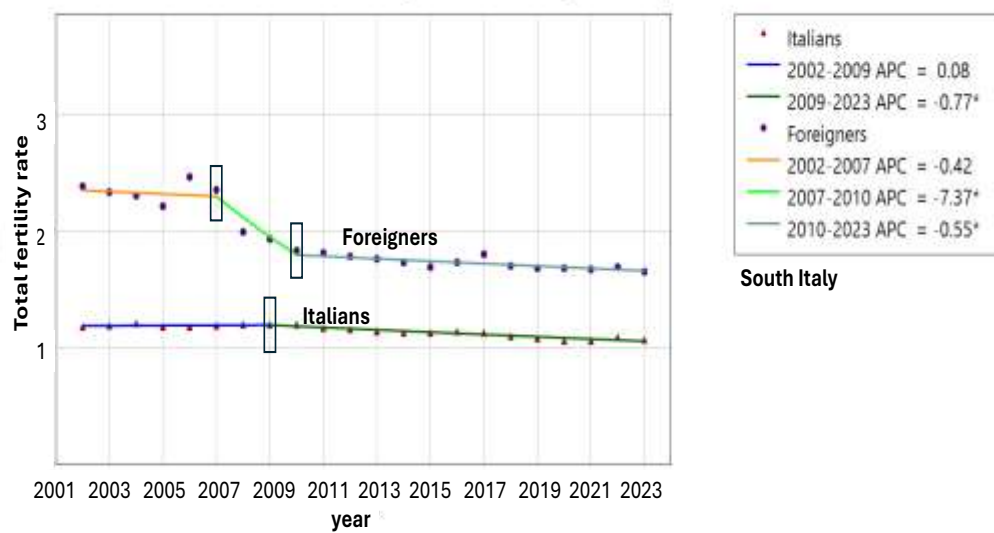
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italian women - 3 Joinpoints, Foreign women - 2 Joinpoints. Rejected Parallelism.

Regarding the South (Figure 4: Panel A), Italian women's TFR shows one joinpoint in 2009, with a shift from near stability (2002–2009, APC = +0.08%) to a decline (2009–2023, APC = -0.77%). Foreign women's TFR exhibits two joinpoints (2007 and 2010), with a mild early decrease (APC = -0.42%), a sharp contraction (2007–2010, APC = -7.37%), and a moderate decline thereafter (APC = -0.55%). The downturn for foreigners is earlier and more abrupt, while Italian women follow a smoother trajectory. After 2010, the two groups converge to a sustained further decline.

In the South, the trend for Italian women's MAC (Figure 4: Panel B) is a steady rise, with one joinpoint in 2009 (APC = +0.45% before 2009; APC = +0.34% after). The timing for the fertility of foreign women follows a fragmented path, with four joinpoints, shifting from decline to sharp growth, stagnation, brief acceleration, and moderate rise. This high short-

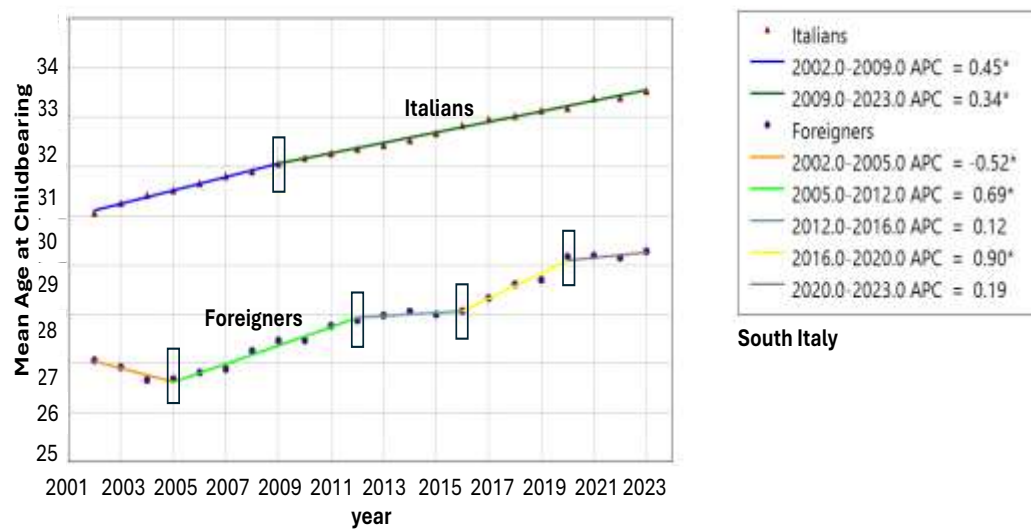
term volatility for foreign women contrasts with the postponement of childbirth among Italians that continues to increase steadily.

Figure 4 (Panel A): South TFR



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italians - 1 Joinpoint, Foreigners - 2 Joinpoints. Rejected Parallelism.

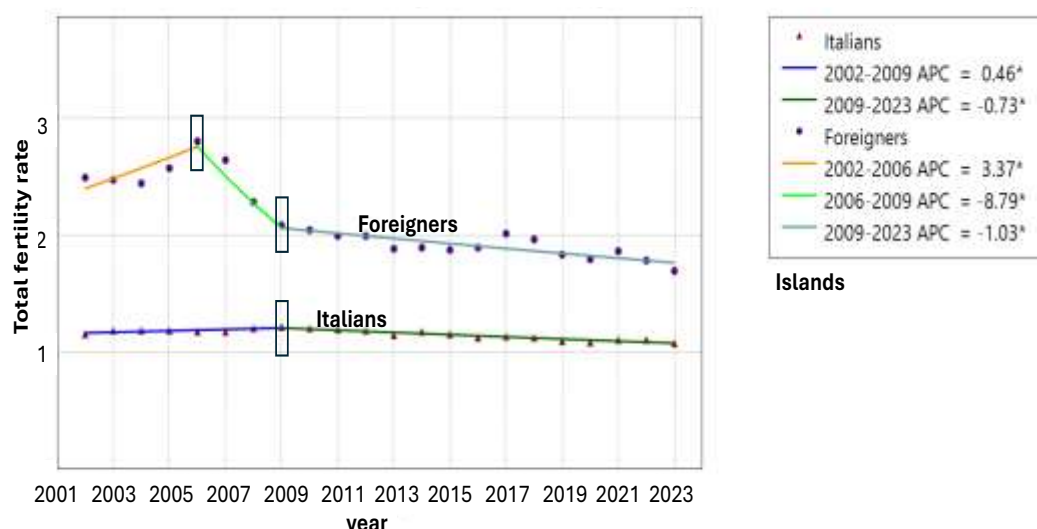
Figure 4 (Panel B): South MAC



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italians - 1 Joinpoint, Foreigners - 4 Joinpoints. Rejected Parallelism.

Finally, in the Islands (Figure 5: Panel A) Italian women’s fertility shows one joinpoint in 2009, separating a 2002–2009 period of modest increase (APC = +0.46%) from a prolonged decline (APC = -0.73%), while foreign women’s TFR exhibits two joinpoints (2006 and 2009) and three distinct phases: strong early growth (APC = +3.37%), a sharp contraction (APC = -8.79%), and moderate long-run decrease (APC = -1.03%).

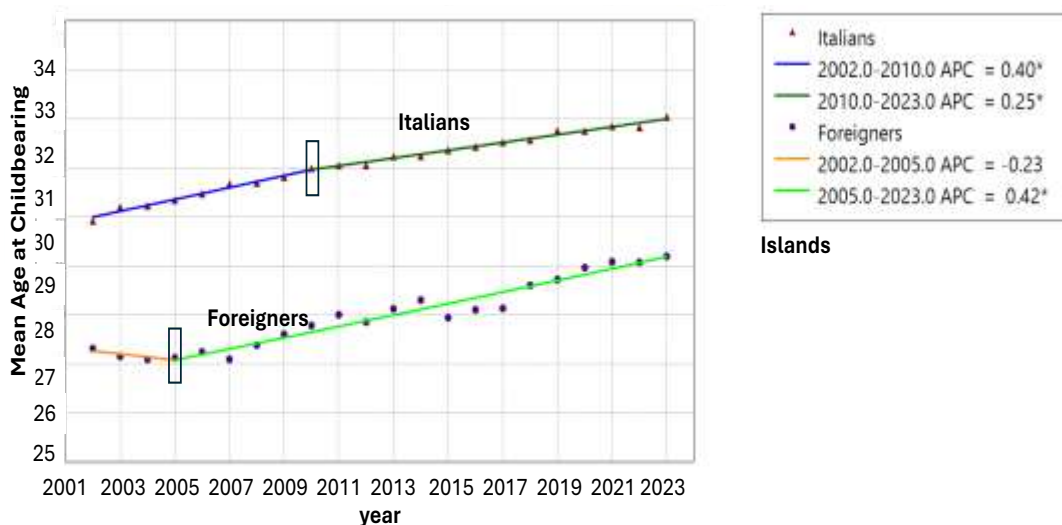
Figure 5 (Panel A): Islands TFR



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italians - 1 Joinpoint, Foreigners - 2 Joinpoints. Rejected Parallelism.

In this context, Italian women's MAC (Figure 5: Panel B) shows one joinpoint (2010), with growing trend. Foreign women exhibit one joinpoint in 2005 that separate an initial decline (APC = -0.234%) to growth (APC = +0.42%). The Islands thus reveal an initial instability among foreign women, while Italian women maintain a gradual postponement trajectory.

Figure 5 (Panel B): Islands MAC



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: Italians - 1 Joinpoint, Foreigners - 1 Joinpoint. Rejected Parallelism.

Across the macro-regions, the joinpoint analysis for the TFR indicates heterogeneous temporal dynamics but also similarities and differences by citizenship and macro-region:

- (i) Nationality differences: foreign women consistently exhibit sharper and earlier downturns than Italian women, reflecting higher sensitivity to structural and socio-economic shocks, while Italian women experience more gradual adjustments linked to long-term fertility transition.
- (ii) Regional divergences: the northern regions (the North-East and North-West) display more stable trends in the fertility of foreign women and smoother transitions for Italian women, whereas the Centre, the South, and the Islands reveal greater and more sudden contractions and multiple turning points, especially among foreign women.
- (iii) Shared patterns: All the macro-regions converge to a sustained fertility decline after the early 2010s, with Italian women typically showing an initial growth phase followed by

reversal, while foreign women generally maintain a downward trajectory over the whole period.

Concerning MAC, the joinpoint analysis reveals three key patterns: (i) a consistent increase in maternal age for both Italian and foreign women, reflecting the ongoing postponement of childbearing; (ii) more frequent structural shifts among foreign women, especially in the South; and (iii) gradients becoming closer, suggesting converging timing behaviours, although the average age for childbearing remains different (Italian MAC ~32–33 years vs foreign MAC ~29–30 by 2023).

Discriminant Analysis

The discriminant analysis applied here to the Italian macro-regions (IS=Islands, S=South, C=Centre, NE=North-East, NW=North-West) uses TFR and MAC as explanatory variables. Its purpose is to identify linear combinations of these variables—known as discriminant functions (F1, F2)—that maximize the separation between the macro-regions. In the F1–F2 discriminant space each original observation is transformed into a point by applying the discriminant function coefficients. Points belonging to the same group tend to cluster together because DA seeks to minimise within-group scatter. The spatial arrangement visually reflects how well the discriminant functions separate the groups. For each group, the centroid (or group mean) is also plotted. The centroid represents the average discriminant score of all observations in that group. Centroids provide for the interpretation of group separation; indeed, the distance between centroids reflects how distinct the groups are in the discriminant space.

In this section each of the Figures (Figures 6, 7, and 8) represents the data in an F1–F2 space, where the points correspond to observations (year × macro-region) and the centroids represent the mean scores of all observations for each group that correspond to geographic macro-areas. The greater the distance between the centroids, the stronger the discrimination achieved by the model, indicating that the macro-regions differ more clearly in terms of the selected indicators (TFR and MAC). The ellipses surrounding each centroid illustrate the dispersion of the observations belonging to that group in the discriminant space. If ellipses overlap, it means the groups may share similar characteristics.

Figure 6 shows the results of the DA for Italian women. The centroids are far apart, indicating that the model separates the macro-regions well. More precisely, the DA reveals that both TFR and MAC contribute to the class separation, with the clusters separated on F1–F2 plane, and that there are clear territorial patterns among Italian women: S It and IS It cluster on one side, NE It, NW It, C It on the other, and IT It (which includes all macro-regions) sits in between. F2 adds a finer differentiation: the South lies slightly higher (positive F2), the Islands lower (negative F2), while North-West, North-East, and Centre cluster are very close to one another and close to zero, indicating limited differences in their TFR–MAC profiles. In detail, Italian women show a distinct territorial gradient: MAC is higher in the northern regions (≈ 32.4 years) and lower in the South and the Islands (≈ 31.1 – 31.4), and TFR is slightly higher in the South (≈ 1.29 vs 1.22 in the north). Over time, TFR slightly declines and MAC rises everywhere.

Figure 6: Centroids Discriminant analysis: TFR and MAC. Italian women

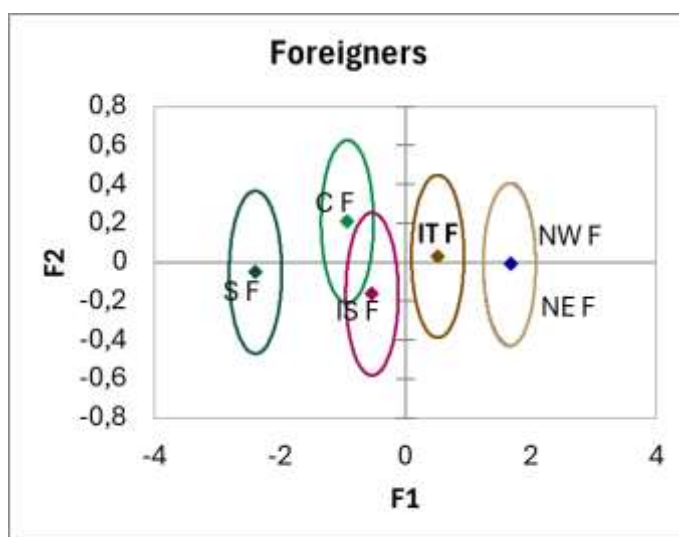


Figure 7 presents the results of the DA for foreign women. On the F1–F2 plane, the foreign-women centroids reveal a marked North–South gradient along F1: NE/NW at positive F1, S F is the most distant group along F1 (far left). C F and IS F are intermediate on F1 and moderately separated on F2 (C F slightly higher, IS F lower), while Italy as a whole (IT F) lies just to the right of zero. Here, the clusters are less distinct, especially the NE/NW clusters that compress and overlap: the clouds for NE and NW are very close to each other (small F2 difference). Foreign women have a high but declining TFR and a low but rising MAC (2002–2023). This behavioural convergence over time shrinks the distances between the northern macro-regions, explaining the overlap. Indeed, in the model discrimination is driven by MAC while TFR is nearly redundant.

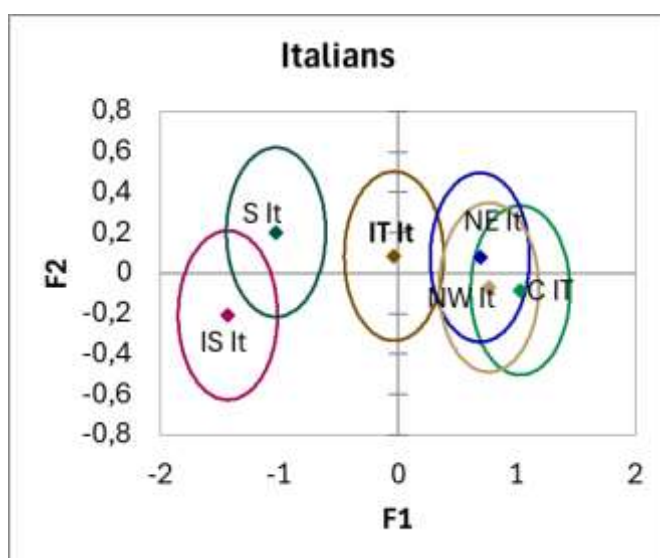


Figure 7: Centroids in Discriminant analysis: TFR and MAC. Foreigner women

In the combined model (Figure 8), the real cutting edge is citizenship rather than macro-region. Indeed, the centroid map on the two discriminant functions shows a pronounced citizenship divide along F1: all foreign groups lie to the left (negative F1), all Italian groups to the right (positive F1) with no overlap, indicating systematically different TFR–MAC profiles (higher TFR/lower MAC among foreigners and lower TFR/higher MAC among Italians). Within each citizenship, F2 reveals a North–South gradient: NW/NE tend to be higher, S/IS lower. Visualization details these patterns: among Italians, NW and C form a

compact cluster with NE adjacent near the F2 midline, whereas S and especially IS lie lower on F2; among foreigners, NE and NW occupy the upper part of F2, C is intermediate, S and IS are lower. Overall, citizenship emerges as the primary axis of differentiation in the joint TFR–MAC space, and geography refines it through a consistent North–South gradient within each group.

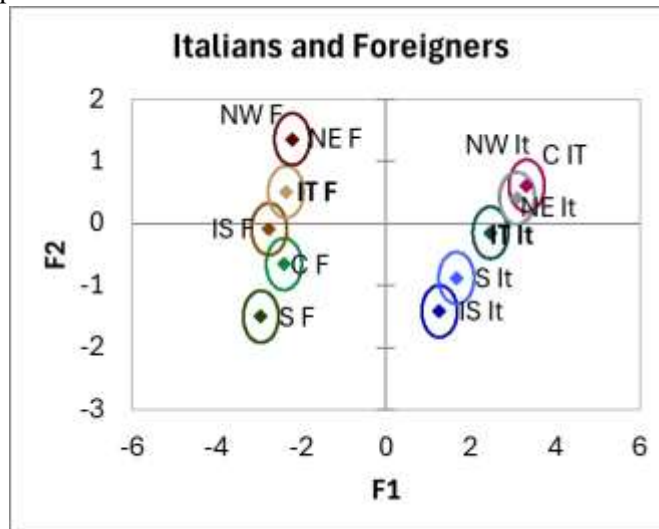


Figure 8: Centroids in Discriminant analysis TFR and MAC. Italian and Foreign women

Conclusions

This study examined fertility transitions among Italian and foreign women over the last two decades (2002–2023) at the macro-regional scale, employing two complementary statistical approaches to detect shifts in fertility trends and to identify territorial patterns of reproductive behaviour.

The joinpoint regression analysis revealed marked disparities in the evolution of TFR and MAC among Italian and foreign women across the country’s macro-regions. While a general decline in fertility emerges as a common trend, its timing and intensity vary substantially.

In the North-East and the North-West, the Italian women experience a mid-period reversal from moderate growth to decline, whereas the foreign women follow a steady downward path from the outset. Moving to the Centre, the patterns become more complex: both groups show marked shifts, but the foreign women exhibit sharper oscillations and earlier downturns, indicating heightened sensitivity to structural shocks. In the South and the Islands, the instability is even more pronounced, with the foreign women’s fertility undergoing abrupt contractions after an initial growth, while the Italian women’s fertility declines more gradually. Despite these differences, all the regions converge to a sustained fertility reduction after the early 2010s, albeit a reduction accompanied by heterogeneous temporal dynamics.

Consistent with previous research (Benassi & Carella, 2023; Vitali & Billari, 2017; Zambon et al., 2019), these findings indicate that, although fertility decline is widespread across all groups, it does not follow a uniform or linear trajectory. Fertility among Italian women remains lower in the north than in the south; however, immigration has contributed to fertility resilience in the northern regions, where foreign women continue to record higher TFR—despite a downward trend—than in other areas. Notably, in the North-East and the North-West, fertility appears more responsive to economic cycles, particularly during recessions, exhibiting quicker adjustments than the adjustments observed in the South and the Islands.

These findings were clearly reflected in the discriminant analysis, which, on the one hand, captured the geographical variations in fertility and the parameters related to it, as described here, and, on the other hand, showed the significant differentiation of the foreign population relative to the Italian one.

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