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Distinct Patterns of the Second Demographic Transition in Southern and Eastern Europe: 3D Plots Analysis

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Abstract: This article provides a quantitative analysis of Second Demographic Transition (SDT) dynamics in Southern and Eastern European countries, addressing the need to quantify its pace and regional variations. We analyse transition trajectories by measuring Euclidean distances between country data points in two 3D scatter plots (based on fertility characteristics and socioeconomic population structure indicators) in ten-year intervals. Our study reveals comparable dynamics across both regions, with simultaneous or slightly delayed changes in key indicators. However, the timing of the transition varied substantially, occurring later in Eastern Europe. The findings confirm the SDT as a broadly universal process in Europe, shaped to a considerable degree by contrasting starting conditions and cultural contexts. Finally, the 3D scatter plot methodology proves to be an effective tool for illustrating and quantifying these complex transition trajectories.

Keywords: Second Demographic Transition • Fertility • Population structures • 3D scatter plot

1 Introduction

Fertility trends in Europe since the late 20th century have often been discussed within the framework of the Second Demographic Transition (SDT). Originally formulated by *van de Kaa* (1987), the SDT attributes fundamental shifts in family formation and fertility to a broad societal shift towards individualism and self-realisation. Specifically, fertility decline below replacement levels, marriage postponement, and the rise of non-marital cohabitation are key empirical signs of this transition. Although initially observed in Northern and Western Europe, the SDT's universality remains widely debated, particularly as regards its applicability to other parts of the continent (*Zaidi/Morgan* 2017; *Lesthaeghe* 2020).

Although the general outcome (lowest-low fertility and structural change) appears to be similar across Europe, the pathways to these outcomes in Southern and Eastern Europe differed significantly from the respective pathway in the West and from each other. In Southern Europe, the transition began later (in the

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1970s) but led to a persistent "lowest-low" fertility trap (*Billari* 2008). This region experienced a "conservative" transition: despite rapid fertility declines, traditional family structures proved more resilient, characterised by lower divorce rates and a slower uptake of non-marital cohabitation compared with the North (*Sobotka* 2017). Conversely, Eastern Europe followed a distinct trajectory shaped by the sudden collapse of socialist regimes. While fertility remained relatively high until the late 1980s, the 1990s saw a rapid, shock-induced contraction in fertility and a swift transformation of family norms (*Rychtaříková* 1999). Furthermore, Eastern Europe entered the transition with a historically high level of female labour force participation, in contrast to the traditionally lower rates found in Southern Europe (*UNIFEM* 2006; *Barbieri et al.* 2015).

To explain these different pathways, recent research views the SDT not as a single uniform shift, but as a multidimensional process of distinct and often asynchronous transitions across different subpopulations (*Marshall/Shepherd* 2022). The relationship between societal changes, shifting attitudes, and demographic indicators, together with the geographical variation in the relative pace of these changes, appears to be key to explaining similarities and differences within the context of the European SDT experience (*Han/Brinton* 2022). For example, while rising education widely drives fertility postponement (*Graff* 1979; *Ciganda/Villavicencio* 2016), it does not always synchronise with changes in family formation, which are also typical of the SDT (*Balbo et al.* 2013). The timing of these structural shifts compared with demographic outcomes varies greatly by region, and are often modulated further by different institutional contexts and family policies (*Gauthier* 2007; *Lazzari et al.* 2021).

Despite acknowledging this decoupling, current literature lacks macro-level quantitative approaches that simultaneously measure the asynchronicity between structural and demographic changes across countries. While some studies explore these dynamics within individual nations (*Blanco Iglesias* 2023), cross-national comparisons mostly examine indicators in isolation (*Marshall/Shepherd* 2022) or focus on specific changes in societal attitudes (*Han/Brinton* 2022). Therefore, our primary aim is to empirically quantify the relative pace of structural and demographic changes in order to determine whether they evolved together or decoupled over time. The key question remains unexplored: Did Southern and Eastern European countries follow a parallel demographic trajectory merely separated by time, or did they experience fundamentally different structural-fertility dynamics?

If the first scenario is true, the Second Demographic Transition (SDT) represents a universal, linear process in which mainly Eastern Europe is simply lagging in time due to its history and collapses of communist regimes (*Lesthaeghe* 2010). Conversely, if the second scenario holds, the relationship between societal structures and demographic outcomes is highly context-dependent. This implies that the demographic shift in at least one of these regions was not a standard SDT progression, but rather a unique trajectory driven by different factors, such as the sudden post-socialist structural shock in Eastern Europe (*Rychtaříková* 2000; *Sobotka* 2008).

Current macro-level research struggles to distinguish between these two scenarios because most comparative analyses rely on observing static data points. They typically measure net overall changes between two distant years (*Kuijsten* 1996;

Lesthaeghe 2010, 2020; *Zaidi/Morgan* 2017) or apply cross-sectional clustering at a single point in time (*Rychtaříková* 1999; *Marshall/Shepherd* 2022). While some studies have mapped spatial differences or tracked individual-level life course sequences (*Billari/Liefbroer* 2010), macro-level research rarely focuses on the "clustering of changes over time" or the continuous multidimensional shape of developmental trajectories across entire regions. The closest methodological exception to this is the SDT Index introduced by *Sobotka* (2008), which was later adopted by other authors (notably *Lesthaeghe* 2010, 2020). This index measures societal changes and correlates them with shifts in fertility characteristics. However, it remains a composite indicator that expresses the overall state of a society at a given moment. It does not examine in detail how individual populations evolve step-by-step, what the main indicator of these changes is, or how their specific pathways differ on a fundamental level.

To address this gap, we apply a multi-dimensional distance analysis. Drawing on methods from complex systems analysis (e.g. *Pulselli et al.* 2015), we use 3D scatter plots and apply distance-based measurements within the created analytical space to calculate Euclidean distances between data points over time. This approach allows us to quantify the exact pace of the transition in ten-year intervals, integrating fertility indicators with structural proxies (education, marriage intensity, and labour market participation). This study thus provides a novel quantitative perspective on the pace, magnitude, and the specific nature of convergence or divergence during the Second Demographic Transition in Southern and Eastern Europe. Ultimately, our findings reveal that while both regions progressed at a comparable overall pace, their respective internal pathways and structural drivers were fundamentally different. This suggests that the SDT can be viewed as a universal transition in terms of its general direction of changes, but the actual process and pathways of change vary.

2 Data

The analysis focuses on the development of six core indicators, divided into two distinct groups: fertility characteristics (three indicators) and indicators reflecting structural changes (three indicators).

Throughout this article, we refer to this second group as "population structure." While this term typically denotes the composition of a population by age and sex when used in traditional demographic research, in this article it is used to describe the socioeconomic composition of a population linked to the societal shifts associated with the SDT. The choice of these specific structural indicators is based on the consensus among demographers that three fundamental dimensions are closely linked to fertility trends, namely economic activity, family status, and education (*Zakharov* 2008; *Cygan-Rehm/Maeder* 2013; *Barbieri et al.* 2015). The investigated indicators are therefore:

- share of economically active women aged 15 years and over
- share of married women aged 15-49 years
- share of women aged 25-34 with at least a university degree

The selection of specific age groups was primarily driven by data availability, ensuring longitudinal consistency across all countries for the entire period. Detailed information regarding the primary data sources is provided in the Supplementary Material.

While fertility is traditionally described in terms of intensity and timing, we included a third dimension in the context of the SDT – fertility by family status – due to its substantial transformation during this period (*Lesthaeghe* 2020). The investigated indicators are therefore:

- total fertility rate
- mean age of the mother at first birth
- share of children born outside marriage

All indicators refer exclusively to the female population, as is typical in fertility studies. Data for all six indicators were collected at ten-year intervals from 1970 to 2020. The dataset covers selected European countries representing diverse SDT trajectories; details regarding country selection are provided in the Methods section.

Compiled from 14 different sources, the dataset relies primarily on national censuses, birth statistics, and publicly available demographic databases. The complete dataset and a detailed list of sources are available in the Supplementary Material.

3 Methods

The analytical core of this study uses sociodemographic indicators as coordinates in a Euclidean space, allowing us to measure the distances between points representing specific countries and years. This approach draws on fundamental statistical methods, such as cluster analysis or regression, which also rely on Euclidean distance metrics (e.g. *Kaufman/Rousseeuw* 1990). Although similar to cluster analysis, our objective is to interpret these spatial positions to quantify the dynamic trajectories of countries over time. Following the methodology of *Pulselli et al.* (2015), we construct a multidimensional space where a point's position represents a country's general attributes, effectively using this method as a spatial variation of descriptive statistics.

To operationalise and visualise this concept, we utilise three-dimensional (3D) scatter plots. While purely visual applications of 3D scatter plots are uncommon in scientific research due to potential depth perception issues (*Bauer et al.* 2021; *Han/Cho* 2023), they serve here as a necessary analytical environment. The 3D space allows for the simultaneous integration of three distinct indicators, enabling the visualisation of the distance-based analysis itself rather than just descriptive statistics. Although the use of 3D plots to display pre-calculated distances (*Rosenfield et al.* 1984; *Terasaki Hart et al.* 2021) or to visualise both the method and the underlying data is not new (*Piringer et al.* 2004; *Kosara et al.* 2004; *Kumar/Benbasat* 2004), practical applications remain rare. Throughout this study, we use specific 3D scatter plot terminology to provide a clear framework for describing the numerical expression of the transition dynamics.

As a first step, we created two 3D scatter plots. One is based on fertility characteristics and the other on population structure, with both plots using the indicators described in the Data section. To standardise the scales, all values were normalised to a range of zero to one. This procedure places all data points within or on the surface of two unit cubes. Animated versions of both 3D scatter plots are available for visualisation in the Supplementary Material.

Each data point in the 3D scatter plot represents a specific combination of values for the three indicators within a Cartesian coordinate system. We calculated the Euclidean distance between any two points using the standard Pythagorean formula. Geometrically, this distance corresponds to the diagonal of a cuboid, where the length of each side equals the absolute difference between the indicator values on the respective axis:

$$distance\ between\ points\ A\ \&\ B = |AB| = \sqrt{x^2 + y^2 + z^2}$$

Note: *x,y,z* = the distance between the data points along a given axis

To analyse the development of demographic and structural characteristics over time, we compare the positions of country data points in both 3D spaces at successive time points. Specifically, we divided the 1970-2020 period into five ten-year intervals, measuring each country's position at the start and end of every decade. The distance between these two points reflects the extent of change during that specific decade. By calculating these decadal distances, we can track the exact pace at which the transition unfolded. This approach focuses exclusively on comparisons between consecutive time points to capture the step-by-step dynamics of the transition process.

Following the calculation of the overall Euclidean distance, we assessed the contribution of each indicator in our second analytical step. To determine which indicator drove the most change during each ten-year interval, we decomposed the total distance along the three axes. Because the total distance is derived from the sum of squared differences, we calculated each indicator's contribution based on its specific squared difference. The relative share of each indicator was then expressed as the ratio of its squared difference to the total sum of squared differences. For example, the contribution along the x-axis was calculated as:

$$DEC_x = impact\ of\ indicator\ on\ x - axis = \frac{\sqrt{x^2 + y^2 + z^2}}{x^2 + y^2 + z^2} * x^2$$

Note: *x,y,z* = the distance between the data points along a given axis

Together, these three proportional contributions account for the total measured distance. This approach quantifies each dimension's share of the observed change, enabling a more detailed interpretation of the transition dynamics. For example, if the contribution along the x-axis accounted for the majority of the distance, it indicated that its corresponding indicator drove the transition between those two time points, with the other indicators contributing proportionally less. We use this decomposition throughout our analysis to identify which specific aspects of fertility and structural change influenced the overall trajectory most.

This analysis focuses on Southern and Eastern Europe, with country selection grounded in established welfare state typologies. For Southern Europe, we rely on *Esping-Andersen's* (1990) foundational framework, as later refined by *Rhodes* (1996) to identify a distinct Southern European welfare regime. The selection of Eastern European countries follows the framework of *Frejka* and *Gietel-Basten* (2016), who link empirical fertility development to post-communist family policies. Due to data availability constraints across the entire period under observation, we selected ten representative countries based on data reliability and population size: Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia, Greece, Spain, Italy, and Portugal.

For our analysis in SAS, we supplemented our own custom code with code from *Wu* (2022). This provided the foundation for generating the 3D scatter plots (Fig. 1) and calculating the spatial coordinates of individual data points. Additionally, the 3D scatter plots provided in the Supplementary Material were created and exported using the plotly package in R (*Sievert* 2020).

4 Results

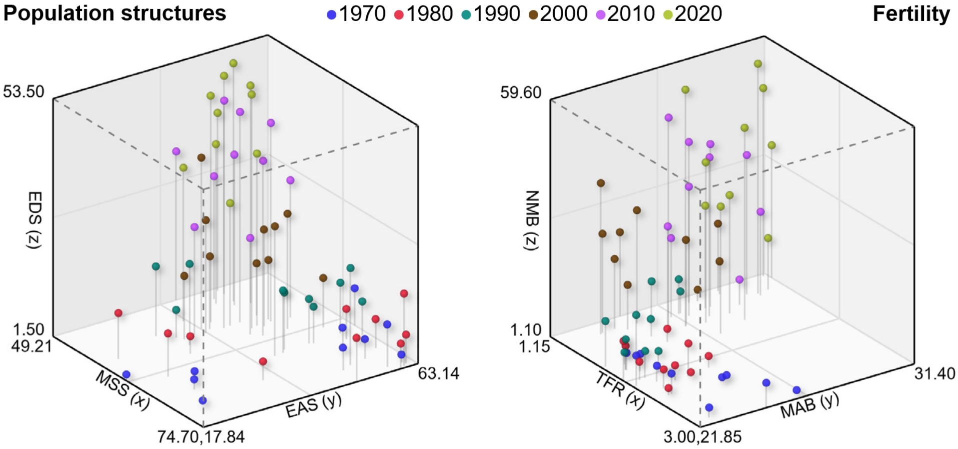
The visualisation of constructed 3D scatter plots – one representing fertility characteristics and the other population structure (Fig. 1, animated versions in the Supplementary Material) – immediately reveals that significant and similar transitions occurred within all observed populations across both analytical dimensions. However, the data points do not form distinct clusters, suggesting considerable heterogeneity in their developmental trajectories. Furthermore, individual country-level 3D scatter plots (all animated versions available in the Supplementary Material) highlight several fundamental characteristics of the examined transition.

The primary analytical objective was to quantify the trends of the observed transition by measuring the distances between time points. This approach quantifies the transition across two sets of indicators, five time intervals, and ten countries (Fig. 2).

The 1990s and 2000s stand out as periods of marked transformation in Eastern Europe. Bulgaria, Czechia, Hungary, and Slovakia experienced significant changes in both structural conditions (particularly women's education and marital status) and fertility behaviour, characterised by a sharp decline in total fertility rates and an increase in non-marital births. Romania exhibited a steep transition in both domains even before 1990. Poland also underwent strong shifts, though its core transformation occurred in the 2000s, driven primarily by changes in the mother's age at first birth and the female educational structure.

Southern European countries followed more gradual trajectories. In Italy, demographic shifts were moderate and population structures changed slowly, constrained by stagnation in the proportion of economically active women. Spain and Portugal displayed significant changes in both domains. This substantial and relatively constant pace of change was maintained throughout the entire period, as shifts in individual indicators were closely interconnected. Greece recorded only minor changes overall, with two notable exceptions: a decline in the total fertility rate during the 1980s and a sharp increase in the share of university-educated women in the 2000s.

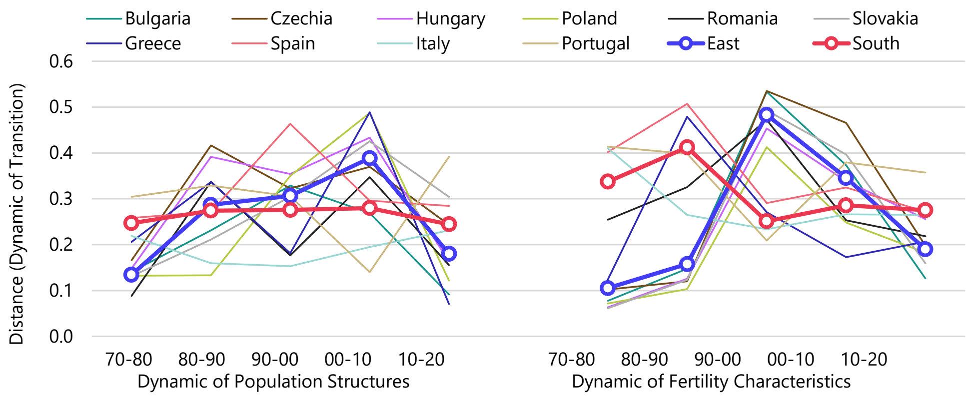
Fig. 1: 3D scatter plots for all the observed countries, divided by the type of indicator



Notes: TFR = total fertility rate; MAB = mean age at first birth; NMB = share of children born outside marriage; MSS = share of married women aged 15-49; EAS = share of economically active women aged 15 and over; EDS = share of women aged 25-34 with at least a university degree

Source: Own calculation

Fig. 2: Time development of the measured distances, by country and region



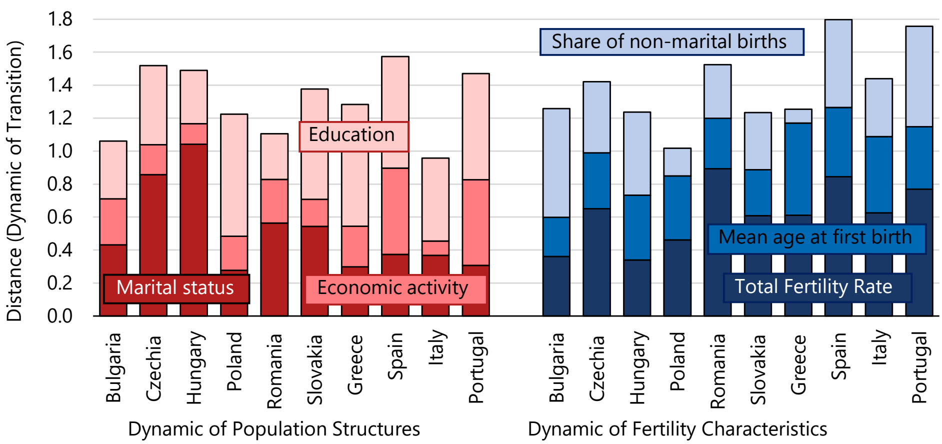
Source: Own calculation

Next, we compared the shifts in population structure and fertility characteristics. The sum of distances across all five ten-year intervals (Fig. 3) revealed that Spain experienced the most significant transition dynamics in both domains. Conversely, the lowest dynamics were observed in Italy for population structure and in Poland for fertility characteristics. Approximately two-thirds of these total distances fell within a range of 1.2 to 1.6 points. Only a few outliers fell outside this range: Bulgaria, Romania, and Italy (below 1.2 in population structure), Poland (below 1.2 in fertility), and Spain and Portugal (above 1.6 in fertility). This suggests that most of the countries analysed exhibited comparable total measured distances in both domains, indicating substantial and similar overall transition dynamics.

However, there were significant differences in terms of the indicators contributing most to this overall change. With regard to population structure, Eastern European countries witnessed more fundamental shifts in marital status, whereas Southern European states experienced more dynamic changes in economic activity. The drivers of fertility transition also varied: while the shift towards non-marital fertility was crucial in some countries (Bulgaria, Hungary, Spain, and Portugal), it was almost non-existent in others (Poland and Greece). Similarly, changes in total fertility were pivotal to the transition in Romania and Spain but remained marginal in Bulgaria and Poland.

The analysis of specific drivers reveals distinct temporal shifts (Table 1). With regard to population structure, shifts in marital status were the primary driver for most countries during the first half of the observed period. In Czechia and Hungary, for instance, this factor remained dominant for three consecutive decades leading up to 2000. By contrast, the trajectories of Poland and Portugal were driven more by changes in female economic activity. During the second half of the period, a

Fig. 3: Sums of the distances for all the ten-year steps between 1970 and 2020 for each country and the decomposition of the influence of the indicators on the total distance



Source: Own calculation

Tab. 1: The indicators exerting the greatest influence on the total measured distance, by decade and by country

Time step	1970 1980	1980 1990	1990 2000	2000 2010	2010 2020	1970 1980	1980 1990	1990 2000	2000 2010	2010 2020
Indicator type	Population structure					Fertility characteristics				
Bulgaria	EDS	EAS	MSS	EDS	MSS	TFR	TFR	NMB	NMB	NMB
Czechia	MSS	MSS	MSS	EDS	EDS	TFR	TFR	TFR	NMB	NMB
Hungary	MSS	MSS	MSS	EDS	MSS	TFR	NMB	TFR	MAB	NMB
Poland	EAS	EAS	EDS	EDS	EDS	MAB	TFR	TFR	MAB	MAB
Romania	EDS	MSS	MSS	EAS	EDS	TFR	TFR	NMB	MAB	MAB
Slovakia	EAS	MSS	MSS	EDS	EDS	TFR	TFR	TFR	MAB	NMB
Greece	MSS	EAS	EDS	EDS	MSS	TFR	TFR	MAB	TFR	MAB
Spain	MSS	EAS	EDS	EAS	MSS	TFR	TFR	MAB	NMB	NMB
Italy	MSS	MSS	EDS	EDS	EDS	TFR	MAB	MAB	NMB	NMB
Portugal	EAS	EAS	EDS	EDS	EDS	TFR	TFR	MAB	NMB	NMB

Notes: MSS = share of married women aged 15-49; EAS = share of economically active women aged 15 and over; EDS = share of women aged 25-34 with at least a university degree; TFR = total fertility rate; MAB = mean age at first birth; NMB = share of children born outside marriage;
The colouring of the fields served for purposes of clarity (in accordance with Fig. 3).
Source: Own calculation

universal shift in dynamics occurred as rising educational attainment (specifically the share of women with university degrees) became the decisive driver of structural change.

In terms of fertility characteristics, the total fertility rate (TFR) was the primary driver of change in most countries during the early decades. Subsequent periods saw a shift in influence towards a rising mean age at birth, followed by the growing significance of non-marital childbearing towards the end of the observed period. This evolution must be considered in the context of TFRs falling significantly below the replacement level of 2.1. While an upward shift is theoretically also possible, such a recovery did not happen in most of the countries analysed.

To maximise the interpretative value of the three-dimensional visualisation, we generated comprehensive graphical outputs for every country analysed. While these are not included in the main text due to their interactive nature, they are provided in the Supplementary Material in two formats: interactive HTML files (via Plotly), which allow for user-controlled rotation, and GIF animations (via SAS), which offer standardised automatic rotation along a specific axis. Furthermore, the Supplementary Material includes the two aggregate 3D models representing the complete fertility and structural datasets. A comprehensive Excel file is also provided, containing the raw data, primary sources, and a detailed breakdown of the calculated Euclidean distances and their axial decompositions. All supplementary files are hosted in a dedicated GitHub repository, with access instructions provided in the section following the Conclusion.

5 Discussion

In this study, we interpret the Euclidean distance between sequential data points as a direct measure of the pace and intensity of the demographic transition. Unlike static comparisons, this metric captures the dynamic momentum of social change. By applying this framework, we address our core research objectives concerning regional convergence. Specifically, this distance-based analysis allowed us to: (i) quantify the specific dynamics of empirical changes associated with the SDT in Southern and Eastern Europe; (ii) delineate the relationship and synchronicity between shifts in population structures (reflecting underlying values) and fertility characteristics; and (iii) compare these trajectories to determine the extent of developmental parallelism between the two regions.

Our analysis confirms that substantial shifts occurred in both sets of indicators between 1970 and 2020. Most countries experienced a marked decline in traditional family patterns alongside increasing individualisation, as predicted by Second Demographic Transition (SDT) theory (*van de Kaa* 1987). However, the timing and intensity of these trends varied considerably. For instance, in Romania and Italy, the dynamics captured by fertility indicators were more pronounced than those reflected by structural indicators; conversely, in Hungary and Poland, structural shifts proved more significant. Ultimately, these results support the notion that SDT-related changes have unfolded in all of the countries that were observed, but at different paces and through distinct developmental pathways.

Our findings suggest a strong link between structural and fertility changes. Declines in fertility rates, often occurring alongside delayed childbearing, coincided with shifts in the population structures under analysis. In particular, rising female education and the increasing mean age at birth evolved in parallel, suggesting that the expansion of education and the postponement of motherhood are closely interconnected processes. In contrast, the relationship between female economic activity and fertility was less uniform. These shifts often preceded or overlapped with different stages of fertility decline, depending on the decade and the specific national context. For example, in Greece, certain indicators (such as the share of non-marital births) remained relatively stable. This shows that structural shifts do not always progress at the same speed, nor do they share identical associations with fertility across all regions.

Summarising the temporal development of these distances was challenging due to the considerable differences between individual countries. Nevertheless, a comparison of the two regions reveals key distinctions. The share of economically active women was already high at the beginning of the period and declined over time in Eastern Europe. This is in stark contrast to the rapid upward trend seen in Southern Europe. This divergence reflects distinct historical contexts, in particular the socialist policies that promoted female labour force participation in Eastern Europe (*Ferge* 1997). Furthermore, while Southern European countries like Italy showed greater momentum in fertility changes than in structural shifts, several Eastern European populations followed the opposite pattern. Timing also differed. Whereas population structures in Southern Europe evolved smoothly and consistently, Eastern Europe experienced more volatile shifts, particularly around the turn of the century. Ultimately, the transition in Eastern Europe was both faster and more intensive than in Southern Europe.

These findings highlight that while the overall speed and scale of the transition were similar in both regions, their internal drivers and the order of changes were fundamentally different. By tracking continuous pathways rather than just static points in time, our analysis confirms that the SDT is not a simple, uniform process where one region is merely delayed compared with another. Importantly, these results align with and complement existing demographic literature. They do not contradict the overarching framework of the SDT, but rather expand upon it by demonstrating that while the general transition has a common start and end point, the actual routes depend to a considerable extent on specific historical and institutional contexts (*Lesthaeghe* 2020). For example, the rapid and turbulent structural changes in Eastern Europe directly reflect the sudden post-socialist shock (*Rychtaříková* 1999). Meanwhile, the transition in Southern Europe was driven more by shifts in economic activity and strong traditional family ties, which created a unique "lowest-low" fertility environment alongside the transition (*Billari* 2008; *Sobotka* 2017). Ultimately, our approach bridges a crucial research gap, confirming the broad destination of the SDT while empirically mapping the diverse journeys taken to reach it.

6 Limitations

The use of distance measurement in 3D scatter plots provides an innovative way to examine the SDT. However, using distance as a metric for quantitative information has its limitations and requires careful interpretation.

First, it is important to place this approach within the broader context of multidimensional demographic analysis. Traditional methods, such as factor analysis, have been used effectively to identify latent dimensions of the demographic transition, as seen in *Rychtaříková's* (1999) analysis of Eastern Europe. While factor analysis is particularly strong at reducing dimensionality and identifying underlying correlation structures, our distance-based approach focuses on visualising and quantifying the temporal trajectory and the actual pace of change. Unlike models based on latent variables, our method preserves the direct visibility of the chosen indicators, which allows for specific structural shifts over time to be interpreted geometrically.

Another critical limitation is the sensitivity of Euclidean distance to the different scales and variances of the input variables. Without proper pre-processing, any dimension with a wider numerical range would disproportionately dominate the calculation, effectively masking changes in other dimensions. Beyond the impact of extreme values, this bias can arise when comparing populations in which indicator values remain at vastly different levels throughout the period. To achieve unit invariance, the data must be normalised. We addressed this by applying min-max normalisation, scaling all indicators to the <0, 1> interval. While alternative techniques like Z-score standardisation are also common, both approaches effectively prevent scale distortion in same way and ensure that all dimensions contribute equally to the aggregate distance metric.

Our method treats the analytical space as linear, assuming that a unit change in an indicator represents a constant magnitude of difference regardless of its position on the scale. While this assumption can be problematic for unbounded ratios, where the substantive meaning of a change varies across the spectrum, we addressed this through the careful selection of input variables. We prioritised indicators defined as shares and rates, which align naturally with the linear logic of Euclidean distance. Unlike complex ratios that might require logarithmic transformation to remain spatially meaningful, these shares provide a direct and intuitive interpretation of distance as a shift in structural composition.

Additionally, when interpreting temporal trends, analysts must distinguish between net displacement (the distance between start and end points) and total path length (the sum of distances across consecutive time steps). A country's trajectory may exhibit a non-linear or "zigzagging" pattern with fluctuations due to short-term shocks, which increases the total distance travelled without leading to significant long-term structural change. Ignoring this distinction could result in an overestimation of the transition's actual magnitude. Finally, extreme outliers on a single axis can compress the visualisation of other dimensions, potentially obscuring subtler dynamics in countries with more stable indicators.

To overcome the limitations of a fixed viewing angle, we included animated versions of the 3D scatter plots in the Supplementary Material. These animations allow for a more intuitive exploration of country trajectories by providing a dynamic view of the underlying spatial structure.

7 Conclusion

This study analysed the demographic shifts and structural changes in the socioeconomic composition of the populations associated with the Second Demographic Transition (SDT) in Southern and Eastern Europe. By quantifying these transitions in ten-year intervals, we revealed that both regions exhibited comparable overall paces of change, albeit with different internal dynamics. Although significant shifts in fertility and population structure occurred in both regions, the primary drivers of these changes varied. The main wave of transformation in Southern Europe was driven more by shifts in economic activity and fertility intensity, while Eastern Europe was shaped primarily by rapid structural realignments following the post-socialist shock.

The results suggest that while the SDT is a broadly universal process in Europe, it is not a uniform one. The transition unfolded through distinct pathways depending on the starting conditions and historical contexts of each region. This confirms that the SDT should be viewed as a common direction of change that is filtered through the specific characteristics of the populations under observation. Specifically, by mapping the continuous shape of these trajectories rather than relying on isolated, static data points, our approach fills a crucial gap in current macro-level research. We were able to empirically demonstrate that Eastern Europe is not merely lagging behind Southern Europe in a universal timeline, but is following a distinct structural pathway towards the same SDT outcomes.

From a methodological perspective, the use of animated 3D scatter plots proved essential for capturing this complexity. By moving beyond static, one-dimensional comparisons, this approach allowed us to visualise the asynchronicity between indicators. These tools offer an effective way to communicate complex demographic trends to both academic and non-specialist audiences, especially as interactive data sharing becomes the professional standard.

On the whole, this research advances our understanding of inter-population differences within the SDT by moving from descriptive narratives to a quantifiable, multidimensional assessment. It highlights the fact that the shift towards individualisation may itself be universal but the interaction between structural drivers and fertility outcomes is heavily path-dependent. For policymakers designing modern family policies, these distinct regional trajectories underscore the insufficiency of uniform approaches. To further consolidate the theoretical framework of the SDT as a general theory, future research should apply this multidimensional methodology to other populations currently undergoing the transition, such as those in Latin America or Eastern Asia. Expanding this spatial approach to newly transitioning macro-regions will be crucial for determining the extent to which diverse, context-specific pathways are a fundamental feature of the global demographic transition.

Supplementary Material

All data, analytical code, and supplementary 3D visualisations are openly available in the dedicated GitHub repository: https://github.com/Lukas-the-Demographer/Second-Demographic-Transition-in-Southern-and-Eastern-Europe

The repository includes the following resources:

- Dataset (Excel): A comprehensive file containing all raw indicator values, a detailed list of primary data sources, and the calculated Euclidean distance matrices with axial decomposition for every country and time interval.
- 3D visualisations:
  - GIF animations: Auto-rotating visualisations of country-specific trajectories and aggregate models, viewable in any standard media player or browser.
  - Interactive plots (HTML): Fully interactive 3D scatter plots generated via Plotly. Viewing instructions: To access the interactive features (rotation, zooming, and data inspection), these .html files must be downloaded to a local drive and opened using a standard web browser (e.g. Google Chrome, Mozilla Firefox, or Microsoft Edge).

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