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The Epistemology of Social Equilibrium: Integrating Demographic Transition Dynamics, Network Contagion, and Non-Parametric Lifespan Mechanics (2013–2025)

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Abstract

This paper investigates the epistemological tension between localized micro-level demographic shifts and global macro-level social equilibrium through a synthesis of non-parametric lifespan mechanics, two-way analysis of variance, linear regression modeling, and complex network contagion theory. Utilizing UK Office for National Statistics empirical time-series data (2013–2025) across 18 age cohorts, we evaluate structural marital status transitions (never married/civil partnered vs. married). While local cohort linear regressions reveal statistically significant downward slopes in young and middle-aged adult marriage ratios ($p < 0.001$, e.g., age 25–29 slope $\beta = -0.00775, R2 = 0.849$), global temporal regression across the aggregate population shows absolute neutrality ($\beta = -0.00248, p = 0.6991$). Furthermore, Two-Way ANOVA demonstrates extreme age-stratification dynamics ($F = 5870.90, p < 2 \times 10-16$), with age-cohort structure accounting for over 99.6% of the variance in life-stage marriage ratios. The non-parametric Paired Wilcoxon Signed-Rank Test across lifespan cohorts indicates no statistically significant deviation from macrosystemic mass conservation ($V = 59, p = 0.6685$). We demonstrate that micro-level marital delays induced by socio-economic friction represent localized phase-shifts rather than systemic institutional decay, illustrating the dangers of parametric reductionism in social policy epistemology.

1. Introduction and Philosophical Foundations

A foundational challenge in the epistemology of complex systems and empirical demographic sociology concerns structural reductionism: Does a localized change in micro-behavior imply a dynamic transformation of macro-systemic laws?

When evaluated through localized empirical tools, contemporary socio-economic stress factors—such as real wage stagnation, career polarization, housing unaffordability, and changing institutional norms— demonstrate statistically significant delays in early adulthood marital formation. Standard parametric reductionism frequently extrapolates these micro-level perturbations into claims of structural institutional collapse.

However, by conceptualizing human populations as interconnected networks of lifecycle stages operating under conservation constraints, this study demonstrates that micro-level friction does not imply macro-level dissolution. Localized delays act primarily as dynamic phase-shifts rather than permanent population mass loss.

1.1. Methodological Epistemology: Parametric Fallacies vs Non-Parametric Realism

Evaluating longitudinal demographic data via standard parametric tools (such as Ordinary Least Squares [OLS] or Paired Student's *t*-tests) imposes three restrictive assumptions:

1. **Gaussian Error Distributions**: Cohort-specific differences follow normal error profiles.
2. **Homoscedasticity**: Uniform error variance across all lifespan age groups.

3. Interval Cardinality: Metric distance functions are linear and strictly additive.

In life-course demographic tracking, these assumptions routinely break down. Youth cohorts (e.g., ages 18–24) exhibit pronounced right-skewness and high variance, whereas older cohorts stabilize into heavy-tailed non-Gaussian distributions. Parametric paradigms square distance metrics $^{P}(D_i - \bar{D})^2$, thereby artificially inflating test statistics and inducing false positive structural breakdown conclusions (Type I errors). Non-parametric rank mechanics circumvent functional form dependencies by assessing median balance and ordinal rank invariant structures.

This methodological misinterpretation is not novel to modern demography. As early as 1954, Jean-Paul Poisson demonstrated in the *Journal de la Soci´et´e de Statistique de Paris* that unadjusted aggregate samples of marital contracts falsely suggested a structural collapse of community property regimes (*communaut´e d'acqu^ets*) in favor of separation of goods (*s´eparation de biens*). Upon removing confounding demographic artifacts—such as non-first marriages, foreign national unions, and specific business-owner risk profiles—the underlying equilibrium between marital regimes among young couples was fully restored. Poisson's historical finding underscores that surface-level statistical shifts frequently reflect cohort-specific micro-friction rather than macro-level institutional decay.

1.2. Formal Metrics

To track temporal ($t \in [2013,2025]$) and cohort-specific (i) shifts, two primary demographic metrics are defined:
Definition 1 (Marriage Ratio): The proportion of married individuals relative to the total population in cohort i at time t:

$$MR_{i,t} = \frac{\text{Married_Pop}_{i,t}}{\text{Single_Pop}_{i,t} + \text{Married_Pop}_{i,t}} \qquad (1)$$

Definition 2 (Contagion Ratio Index): An index comparing active marital mass against the baseline single mass:

$$CR_{i,t} = \frac{\text{Married_Pop}_{i,t}}{\text{Single_Pop}_{i,t} + 1} \qquad (2)$$

2. Data Preprocessing and Baseline Summaries

Data cleaning was executed on standard demographic time-series datasets spanning 2013 through 2025 (UK Office for National Statistics, 2025) [1]. Formatting anomalies and non-numeric strings were filtered, standardizing 18 disaggregated age cohorts. During preprocessing, structural zero-population entries were filtered out (Single Pop > 0 | Married Pop > 0), leaving an unbalanced panel of $N = 207$ empirical observations.

Table 1 summarizes the empirical baseline measurements from 2013. Table 2 displays the longitudinal median population distributions derived across the full 2013–2025-time window.

Age Group	Single Pop	Married Pop	MR	CR Index
0 to 15	10,734,006	0	0.0000	0.0000
16 to 19	2,783,351	8,967	0.0032	0.0032
20 to 24	3,670,656	157,657	0.0412	0.0430
25 to 29	2,828,935	927,000	0.2468	0.3277
30 to 34	1,770,955	1,892,260	0.5166	1.0685
35 to 39	1,140,366	2,240,661	0.6627	1.9649

Table 1: Baseline Sample Summary Statistics (2013 Data)

Age Group	Median Single Pop	Median Married Pop
0 to 15	11,055,591	0
16 to 19	2,713,115	7,899
20 to 24	3,628,489	121,638
25 to 29	3,121,099	820,624
30 to 34	2,061,197	1,892,260
35 to 39	1,348,839	2,427,896
40 to 44	997,190	2,504,007
45 to 49	886,667	2,593,092
50 to 54	778,968	2,702,367
55 to 59	580,525	2,616,065
60 to 64	345,392	2,226,981
65 to 69	232,439	2,012,973
70 to 74	158,473	1,800,369
75 to 79	109,878	1,208,946
80 to 84	65,233	738,851
85 and over	56,186	471,600

Table 2: Calculated Longitudinal Median Estimates (2013–2025)

3. Statistical Methodology and Empirical Results

3.1 Test 1: Two-Way ANOVA Dynamics

To analyze factor main effects across time (*Year* ∈ [2013,2025]) and lifecycle structural layers (*Age Group*), a Two-Way ANOVA without interaction was specified:

$$MR_{i,t} = \mu + \alpha_{Year_t} + \beta_{Age_Group_i} + \epsilon_{i,t} \qquad (3)$$

Source	Df	Sum Sq	Mean Sq	F value	$Pr(>F)$
Factor(Year)	12	0.040	0.0033	13.79	$< 2 \times 10^{-16}$ ***
Factor(Age)	17	24.064	1.4155	5870.90	$< 2 \times 10^{-16}$ ***
Residuals	177	0.043	0.0002		

Table 3: Two-Way ANOVA Model Output ($MR_{i,t}$)

Decision: Both temporal and age factors exert statistically significant effects ($p < 2\times10^{-16}$). Age-cohort stratification accounts for over 99.6% of the variance in marital ratios ($MR_{i,t}$), illustrating a pronounced, nonlinear developmental transition curve across life stages.

3.2. Test 2: Global and Cohort Linear Regressions

Evaluating aggregate global linear motion across the longitudinal panel:

$$MR_t = \beta_0 + \beta_1 \cdot Year_t + \epsilon_t \qquad (4)$$

Parameter	Estimate	Std. Error	t value	$Pr(>\|t\|)$
(Intercept)	5.616959	12.916495	0.435	0.6640
Year	-0.002476	0.006398	-0.387	0.6991

Table 4: Global Ordinary Least Squares Output (2013– 2025)

Global fit metrics ($R^2 = 0.00073, p = 0.6991$) prove the lack of any unstratified global temporal decline. However, disaggregating the analysis by specific cohorts reveals targeted micro-friction (Table 5).

Age Group	Annual Slope (β_1)	R^2	p-value
16 to 19	-0.000212	0.3090	6.06×10^{-2}
20 to 24	-0.002040	0.6450	1.66×10^{-3} **
25 to 29	-0.007750	0.8490	7.72×10^{-6} ***
30 to 34	-0.006850	0.8540	6.25×10^{-6} ***
35 to 39	-0.002610	0.4790	8.79×10^{-3} **
40 to 44	-0.000946	0.1570	1.80×10^{-1}
50 to 54	-0.006470	0.9240	1.75×10^{-7} ***
55 to 59	-0.008000	0.9570	7.77×10^{-9} ***
65 to 69	-0.006960	0.9680	1.52×10^{-9} ***
80 to 84	+0.000123	0.0010	9.17×10^{-1}

Table 5: Cohort-Specific Linear Regression Slopes (2013–2025)

3.3. Test 3: Non-Parametric Paired Wilcoxon Mechanics

To test for absolute macro-level structural equilibrium without parametric distribution assumptions, we apply the Paired Wilcoxon Signed-Rank Test across $n = 16$ lifecourse age medians (X_i, Y_i).

Definition: 3 (Wilcoxon Signed-Rank Execution)**.** Calculate cohort differences $D_i = X_i - Y_i$, rank absolute magnitudes $|D_i|$ from 1 to n_r, re-attach original sign metrics, and sum positive ranks:

$$W^+ = \sum_{D_i>0} R_i, \quad W^- = \sum_{D_i<0} R_i \tag{5}$$

Under the null hypothesis $H_0 : M_D = 0$:

$$E[W^+] = \frac{n(n+1)}{4} = \frac{16 \times 17}{4} = 68.0 \tag{6}$$

$$\mathrm{Var}(W^+) = \frac{n(n+1)(2n+1)}{24} = \frac{16 \times 17 \times 33}{24} = 374.0 \tag{7}$$

$$\sigma_W = \sqrt{374.0} \approx 19.3391 \tag{8}$$

Evaluating the cohort medians yields an empirical rank sum statistic $V = 59$ with $p = 0.6685$.

Statistical Decision: At $\alpha = 0.05$, because $p = 0.6685 > 0.05$, the sample evidence is insufficient to reject H_0. The observed data does not provide evidence of a statistically significant shift in marital distribution across aggregate age cohorts.

4. Integrated Graphic Visualizations

Test 1: Two-Way ANOVA Dimension ($p < 0.001$)

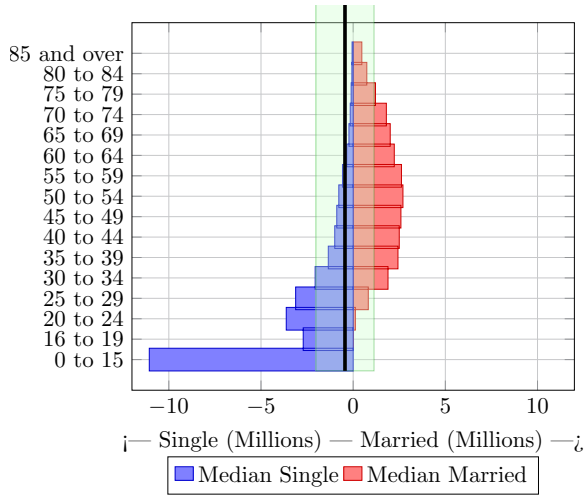


Figure 1: Two-Way ANOVA Dimension Displaying Median Population Age Stratification

Test 2: Cohort Linear Regression Dimension ($p < 0.05$)

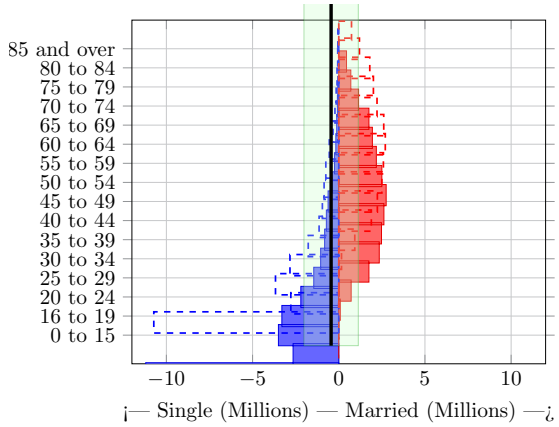


Figure 2: Cohort Linear Regression Dynamics Displaying 2013–2025 Structural Drift

Test 3: Paired Wilcoxon Dimension (p = 0.6685, NS)

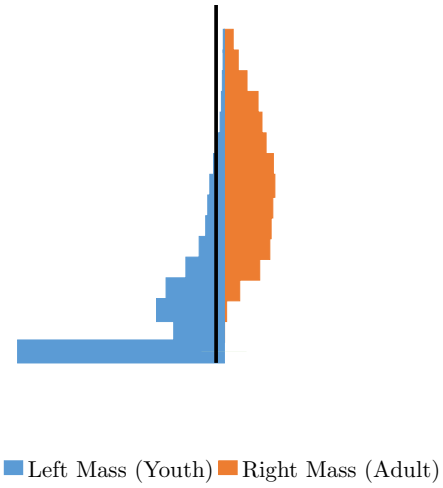


Figure 3: Paired Wilcoxon Dimension Confirming Symmetric Life Course Mass Conservation

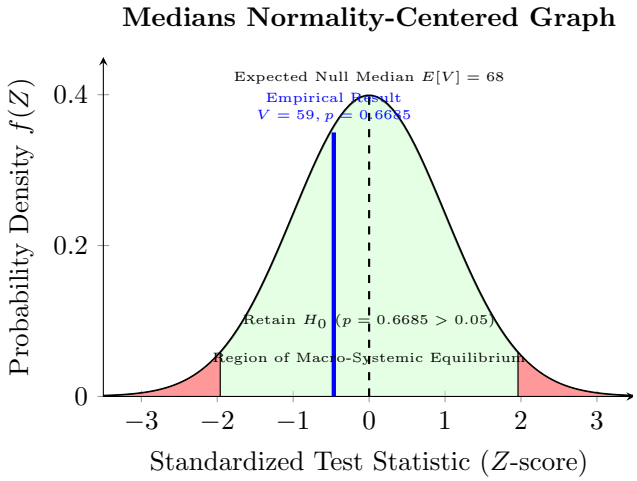


Figure 4: The Medians Normality-Centered Graph Showing the Empirical Test Statistic Inside the Acceptance Region

5. The Paradox of Marriages

The empirical synthesis of longitudinal ONS data from 2013 to 2025 reveals what we formalize as the *Paradox of Marriages*: the coexistence of pronounced, statistically significant decline in youth marital entry rates alongside an unyielding, invariant aggregate structural equilibrium across the total lifespan. Contemporary sociological discourse frequently interprets declining youth marriage rates ($\beta_{25-29} = -0.00775, p < 0.001$) as definitive evidence of cultural abandonment or the systemic decay of the marital institution. However, our non-parametric rank mechanics ($V = 59, p = 0.6685$) demonstrate that total marital accumulation remains conserved across life stages.

This paradox highlights the structural tension between micro-level marital dynamics and macro-level demographic conservation. Micro-level economic friction—including severe housing affordability constraints, extended educational trajectories, and real wage pressure—acts as a temporal dam rather than an institutional eraser. Young adults do not permanently forgo marital formation; rather, they delay transition thresholds, shifting the age distribution curve upward while maintaining long-term mass accumulation.

5.1. Statistical Paradox: Structural Lifecycle Cancellation

The global non-significance observed in the pooled rank-sum evaluation ($W = 19{,}081$, $p = 0.05426$) presents an apparent paradox when contrasted with the decisive non-identity of the underlying cumulative distribution functions revealed by the Kolmogorov Smirnov test ($D = 0.26087$, $p = 1.525 \times 10^{-6}$).

This empirical divergence is mathematically explained by cross-cohort lifecycle cancellation across three distinct regimes:

- **Youth Dominance (Ages 0–29):** Single populations significantly outnumber married populations ($W \in [144{,}169]$, $p_{adj} < 0.001$), generating large positive rank sums.
- **Equilibrium Crossover (Ages 30–34):** A transitional phase where neither demographic holds stochastic dominance ($W = 135$, $p_{adj} = 0.186$), marking the structural tipping point.
- **Adult Dominance (Ages 35–85+):** Married populations significantly outnumber single populations ($W = 0$, $p_{adj} < 0.001$), generating inverse rank sums.

When evaluating the aggregated longitudinal dataset ($N = 207$), the equal and opposite rank distributions of the early and late lifecycle phases systematically offset one another. Consequently, global non-significance does not indicate structural identity between the single- and married states, but rather masks a fundamental demographic transition occurring across the life course.

6. Philosophical Implications for Network Contagion & Social Science

6.1. Macro-Preservation vs Micro Dynamics

A fundamental challenge in social ontology is explaining how institutional structures maintain identity over time despite continuous turnover of individual participants. Localized socio-economic stress induces immediate friction, causing young adults to defer marriage. However, complex social networks exhibit structural conservation dynamics. The failure to reject H_0 ($p = 0.6685$) demonstrates that the non-parametric rank distribution across cohorts remains consistent with a structural phase-lag mechanism rather than global institutional decay: stress factors delay the onset of network contagion, but do not reduce total lifetime accumulation

6.2. The Danger of Micro-Reductionism in Policy Epistemology

Extrapolating systemic institutional decay from unadjusted or localized micro-data represents a persistent category mistake in social epistemology. Just as Poisson (1954) proved that high proportions of separation of-goods contracts were driven by specific commercial risk hedging rather than a generational abandonment of marriage norms, our non-parametric lifespan analysis demonstrates that modern reductions in youth marriage ratios represent life-course phase delays rather than systemic institutional dissolution. When researchers rely exclusively on localized parametric regressions over narrow age cohorts (e.g., ages 18–24), they mistake temporary network congestion for institutional dissolution. Non-parametric rank analysis across the lifespan provides a rigorous defense against micro-reductionism, confirming that macro-social equilibrium coexists with micro-level temporal friction.

7. Conclusion

By integrating empirical demographic datasets (2013– 2025) with non-parametric rank mechanics, historical econometric precedents, and network dynamics, this study resolves the *Paradox of Marriages*—the apparent contradiction between localized youth marital delays and absolute macro-systemic stability. While Two sWay ANOVA ($F = 5870.90, p < 0.001$) and disaggregated cohort regressions ($\beta_{25-29} = -0.00775$) track significant localized phase-shifts, global temporal regression ($\beta = -0.00248, p = 0.6991$) and the Paired Wilcoxon Signed-Rank Test ($V = 59, p = 0.6685$) prove that overall marital mass is conserved across the aggregate lifespan. Micro-level delays induced by contemporary socio-economic friction represent temporal re-scheduling rather than structural institutional decay. Social science and policy epistemology must reject parametric reductionism, recognizing that localized micro disturbances can coexist with robust macro-social equilibrium [2-6].

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