On the Socio-Economic Factors affecting Fertility Rate Decline in a Small Island Developing State

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Abstract—This study examines the drivers and trajectory of fertility decline in a Small Island Developing State (SID) through a generational lens, highlighting the country's transition from high to sub-replacement fertility levels. Using a Data Science based approach, we investigate how factors including education, income, religion, ethnicity, marital status, and birth year have influenced reproductive outcomes across three generational cohorts. National fertility data reveal a steady decline to a stabilized rate below the replacement threshold of 2.1 around the late 1990s. Regression analysis shows that while fertility in the traditional generation was uniformly high, the transitional cohort displayed emerging variation. In the modern generation, fertility patterns became uniformly low with higher education significantly reducing fertility. These findings suggest a shift from culturally driven fertility norms to more individualized reproductive behaviour. The study contributes to understanding fertility transitions in postcolonial contexts and offers insight into the demographic implications.

Index Terms—Exploratory Data Analysis, Education and fertility, Fertility Decline, Generational analysis, Regression Analysis, Socio-cultural Determinants

I. INTRODUCTION

Although our study is applicable to many Small Island Developing States, we use one specific country, Trinidad and Tobago, for our study. Trinidad and Tobago is undergoing a decline in its fertility rate, with the current fertility rate estimated at 1.5, well below the replacement threshold of 2.1 children per woman [1]. This trend reflects a broader demographic paradox, despite widespread access to education, healthcare, and institutional birth services, and rising levels of public awareness, the number of children born per woman continues to fall [2]. Originally observed in industrialized nations such as Japan, Australia, and the Tiger economies of Southeast Asia, the decline in fertility has become a near-universal phenomenon [2]. Projections indicate that by the close of the 21st century, 183 out of 195 countries will exhibit fertility rates below replacement levels [3].

The Total Fertility Rate (TFR) is a widely used demographic indicator that measures the average number of live births a woman is expected to have over her reproductive lifetime. It is a critical measure for assessing population dynamics and long-term demographic sustainability [4]. As outlined by the Demographic Transition Model, nations initially experience high fertility and infant mortality rates. However, as prosperity rises and access to healthcare and education improves, fertility tends to decline [4]. Reference [5] explained that sub-

replacement fertility leads to a shrinking share of the workingage population, posing risks of slower economic growth. As the population ages, the fiscal burden on governments increases, with rising health and pension costs due to lower support ratios and higher per capita medical expenditures [5]. Hence, fertility rates intersect directly with national priorities such as labour force sustainability, health system planning and old-age social protection.

Fertility trends cannot be extrapolated from global patterns alone as they are shaped by local dynamics influenced by the legacies of slavery, indenture-ship, and colonial family structures. For example, marriage remains more prevalent among Indo-Caribbean families, while visiting and common-law unions are more frequent among mixed-heritage and Afro-Caribbean populations, patterns that reflect deeply entrenched socio-cultural histories [6]. Additionally, religious doctrines ranging from Hinduism to Christianity, shape family formation and also perceptions of contraception, gender roles and ideal family size [7]. Therefore, understanding fertility trends in Trinidad requires an appreciation of the country's unique cultural, historical, and social landscape.

This study examines the drivers of fertility decline through the lens of Trinidad and Tobago's unique socio-cultural land-scape. The core research objective is to assess how variables such as education, income, ethnicity, religion, and age have contributed to the sustained decrease in fertility rates, and to explore the underlying socioeconomic reasons behind these shifts. To address this, the study employs exploratory data analysis (EDA) on nationally collected demographic data and applies regression to model intergenerational trends.

II. LITERATURE REVIEW

Fertility decline is a complex demographic process shaped by a convergence of structural, behavioural, and socioeconomic factors. As [8] explains, education reduces fertility through increased opportunity costs, improved maternal and child health, and enhanced knowledge and use of contraception. Furthermore, [9] demonstrated that contraceptive prevalence the adoption of modern contraceptive methods has a direct impact on fertility reduction, especially in the Caribbean where fertility fell from six to four births per woman in less than two decades. In addition, a range of behavioural factors also influence TFR such as, age at marriage, the effectiveness and availability of contraception, abortion rates, and spousal separation due to migration or employment [9].

A growing body of research has turned to Exploratory Data Analysis (EDA) to investigate demographic trends, especially in the field of fertility. In one notable study EDA played a central role by facilitating descriptive analysis, before advancing to predictive analytics using linear regression [10]. EDA is a technique used to investigate datasets and summarize their key characteristics. While EDA was the foundation, the study also incorporated correlational techniques under the broader umbrella of quantitative methods. By adopting this layered approach the study aligns with established best practices in fertility research.

Complementing EDA approaches, Ordinary Least Squares (OLS) regression remains a widely used method in fertility research due to its simplicity and interpretability. For example, an econometric analysis of 108 countries by [11] employed OLS regression to evaluate the impact of variables such as income, inflation, urbanization, and education on fertility. It was chosen for its ability to generate best-fit estimates by minimizing residuals and satisfying diagnostic conditions for unbiased-ness and efficiency. The study also acknowledging OLS's limitations, such as sensitivity to outliers and omitted variable bias.

Further supporting the use of OLS in demographic research, [12] investigated the relationship between environmental sustainability and fertility by applying OLS and static panel models to data from 31 countries. Ecological footprint indicators such as carbon use along with socio-economic controls like HDI and GNI per capita were examined for their influence on TFR. The OLS model offered valuable baseline insights, however the authors noted limitations such as non-normality and skewness in the data but reaffirmed the relevance of OLS as an analytical method in fertility research.

III. METHODOLOGY

A. Data Collection via Online Survey

We created an online survey to collect local, recent data but also used historical data in our study. Table I provides the questions asked together with the options provided and the corresponding percentage of the answers for each option. We obtained a total of 96 samples.

To understand the trends and demographic patterns within the fertility dataset, an exploratory data analysis was conducted across two integrated sources, annual national fertility rates and a respondent-level dataset including socio-demographic information. Exploratory Data Analysis (EDA) involves applying a range of analytical and visualization techniques to better understand a dataset and uncover meaningful patterns [15]. When applied to time-series data, visual exploratory methods are particularly effective in revealing interpretable insights [15]. First, the datasets were cleaned to ensure consistency in column formatting and chronological order and the data was sorted by year for uniform numerical analysis. The national fertility trend was visualized through a line graph showing births per woman over time with a reference line at the

replacement-level fertility rate. The respondent dataset was analysed to examine the distribution of number of children across different religions. This EDA provided a foundational understanding of fertility trends and their variation across individual-level characteristics. These insights informed the modelling and interpretation of the subsequent analysis.

B. Regression

To model the generational decline in fertility, a segmented linear regression approach was employed based on generations. The dataset was partitioned into three generational groups that align with historical and demographic shifts. Firstly, the traditional generation (1910–1950) which represented pre-modern fertility patterns typically characterised by high birth rates. The transition generation (1951–1980) which captured the period of demographic transition marked by declining fertility and lastly the modern generation (1981–2010). For each group, an OLS regression was fit with the number of children as the dependent variable and birth year as the independent variable.

A constant term was included to capture baseline fertility levels. The segmented model specification allowed each period to have its own slope and intercept, capturing unique fertility dynamics over time. To further isolate the drivers of fertility decline, multivariate OLS regressions were performed separately for each of the three generations. This segmentation allowed for the estimation of distinct fertility determinants within each period. The dependent variable in each model was the reported number of children. Independent variables included birth year and a set of categorical factors: religion, education, income level, employment status, marital status, and ethnicity. These categorical variables were one-hot encoded, excluding the first level to avoid multicollinearity and a constant term was added to the model.

IV. RESULTS AND ANALYSIS

A. Exploratory Data Analysis (EDA)

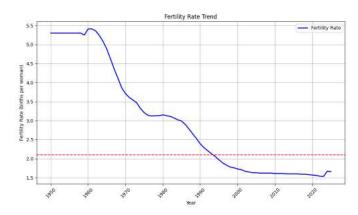


Fig. 1. Graph showing trajectory of fertility rates from 1950 to 2025 and the replacement-level fertility threshold of 2.1 births per woman.

Figure 1 illustrates a steep and uninterrupted decline in fertility beginning in the late 1960s until 1990s. The the dashed

TABLE I
DATA COLLECTED THROUGH ONLINE SURVEY

Question	Options Provided with Respondent Percentage
Entry ID	User provides a unique ID which can be used to edit the entry
Year of Birth	Ranging from 1910-2010
Number of Children	0-15
Religion	Christian(48), Hindu(37), Muslim(10), Other(5)
Highest Education Level	None(5), Primary(13), Secondary(37), Tertiary(45)
Income Level (at birth of first child or at age 20 if no children)	Unknown(3), Low(45), Middle(51), High(1)
Employment (at birth of first child or at age 20 if no children)	Unknown(3), Employed(53), Self-Employed(8), Unemployed(36)
Marital Status (at birth of first child or at age 20 if no children)	Single(35), Married(64), Divorced(1)

red line denotes the replacement-level fertility threshold of 2.1 births per woman. The graph reveals the rate falling from above 5.0 to below the replacement level. Since then, fertility has hovered between 1.5 and 2.0 births per woman, indicating a global demographic shift toward smaller families. From an exploratory standpoint, this visualization confirms that the dataset is well-suited for time series modelling as it displays both trend and level shifts over time. Additionally, the post-replacement-level plateau aligns with demographic transitions, substantiating the relevance of analysing predictors of fertility decline. This trend line justifies further predictive modelling and regression-based exploration, validating the hypothesis that fertility behaviour has undergone sustained change and is now entering a phase of low or even negative population growth momentum.

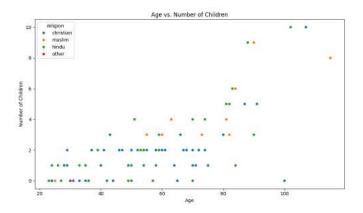


Fig. 2. Scatter plot of respondent age versus number of children, colour-coded by religion.

Exploratory analysis of respondent data in Figure 2, reveals a negative relationship between age and number of children. Respondents over age 70 reported typically 4–10 children while those under 40 rarely exceed three. The generational drop-off in family size supports the hypothesis of a fertility transition occurring over time, confirming that the dataset

is suitable for modelling temporal fertility dynamics. Additionally, the plot highlights plausible socio-cultural drivers of fertility. Respondents identifying as Hindu or Muslim appear more frequently at higher parity levels in older age groups, while others tend to cluster at lower parity. The clear stratification by age and religion indicates that cultural variables may influence fertility outcomes. These insights confirm that the dataset is well-aligned with the study's objectives.

B. Regression

The fitted trend lines in Figure 3 demonstrate a clear downward trajectory in the average number of children per respondent across cohorts, reinforcing the central hypothesis of generational fertility decline. The traditional generation starts with the highest fertility levels, with some individuals reporting between 8 to 10 children. The steep negative slope reflects a rapid decline in childbearing as the cohort progresses toward the 1950s. The transitional generation exhibits a more moderate decline stabilizing around 1 to 3 children, while the modern generation shows the most uniform pattern converging toward sub-replacement fertility levels, with many respondents reporting zero or one child. This visual confirms fertility patterns not only declined over time but also did so with different rates and intensities across generations. The graph supports the broader argument that cultural, economic, and educational transformations likely accelerated the transition from high to low fertility. The smoothing of the curve over time also suggests a shift from irregular, large-family patterns to more planned family sizes.

The multiple linear regression model aimed at explaining the number of children born to respondents in the traditional cohort (1910-1950) produced a relatively high R^2 value of 0.892, suggesting that the model accounts for approximately 89.2% of the variance in fertility outcomes within the sample. However, this apparent explanatory power is misleading due to the adjusted R^2 of -0.403, which turns negative, often associated with small sample sizes and over-fitting. In total, the model included 13 predictors across demographic categories:

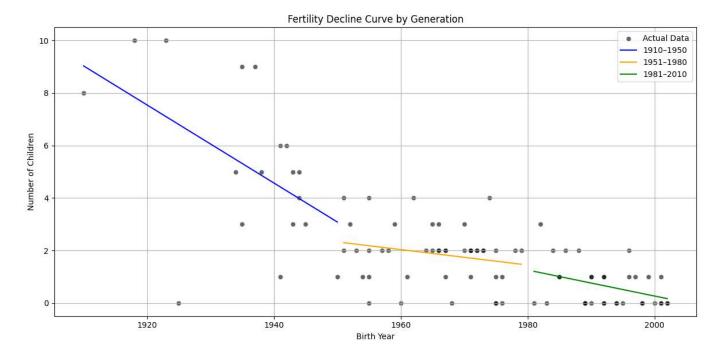


Fig. 3. Fertility decline across three generations: the traditional (1910-1950), transitional (1951-1980), and modern (1981-2010) generations.

religion, education, income level, employment status, ethnicity, and birth year.

None of these variables were statistically significant (all p-values > 0.60), indicating that the null hypothesis cannot be reject that their coefficients are equal to zero. The F-statistic was 0.6888 (p=0.749) confirming that the model as a whole is not statistically significant. Additionally, a warning on multicollinearity is justified given the extremely small sample size (n=14) relative to the number of predictors (13). This suggests that the model is over-fitted, with insufficient data to produce reliable coefficient estimates.

The multiple linear regression model for the transitional generation (1951-1980) explained a moderate proportion of the variance in fertility outcomes, with an R^2 of 0.587 and an adjusted R^2 of 0.444. This suggests that approximately 58.7% of the variability in the number of children can be explained by the demographic and socioeconomic predictors included in the model. The model was statistically significant overall (F(11,32)=4.127, p=0.000813), indicating that the independent variables contribute meaningfully to the model's explanatory power. Among the predictors, only two were statistically significant at the 5% level.

Being of the Muslim religion was associated with a higher number of children, while being single (as opposed to married) was associated with fewer children. All other predictors, including education level, income, employment status, ethnicity, and birth year, were not statistically significant (p>0.1), though the coefficient for birth year was negative and approached significance, suggesting a slight downward trend in fertility over time.

The multiple linear regression model for the modern cohort

(1981-2010) yielded a strong R^2 value of 0.799 and an adjusted R^2 of 0.661, indicating that approximately 80% of the variance in the number of children can be explained by the demographic and socioeconomic predictors. The model was statistically significant overall $(F(13,19)=5.809,\ p=0.000321)$ suggesting substantial explanatory power. Among the predictors tertiary education was statistically significant at the 5% level and negatively associated with fertility ($\beta=-0.911,\ p=0.037$), suggesting that respondents with higher education tend to have fewer children.

Being married was also significant ($\beta=1.375,\ p=0.024$), indicating that marital status continues to be an important determinant of childbearing. Birth year was marginally significant ($\beta=-0.0366,\ p=0.082$), suggesting a continuing downward trend in fertility over time. Notably, Muslim affiliation and low or medium income categories exhibited positive associations with fertility ($p\approx0.076$ –0.078), which may warrant further investigation in studies with larger samples.

V. DISCUSSION

A. Traditional Generation

The Traditional Generation came of age during a period of social transition marked by the slow unravelling of rigid colonial control. Although the indentureship system had imposed strict labour regimens and pervasive surveillance on Indian immigrants, its grip had loosened by the late 19th and early 20th centuries [16]. The decline of rise of cocoa cultivation offered new economic avenues, enabling labourers to settle permanently and assert greater cultural agency. In particular, Indo-Trinidadians were able to retain and reconstruct their religious and cultural traditions. However, Trinidad remained

deeply structured by the racial and ethnic hierarchies institutionalized during the plantation era.

While the sample size for this generation was too small to support a statistically valid regression analysis, the exploratory data analysis revealed a clear pattern, Muslim and Hindu respondents in this group appeared more often among individuals reporting larger numbers of children. This visual trend points to historically larger family sizes within these communities, consistent with the presence of traditional or religious norms that likely shaped fertility decisions in earlier generations. According to [17] during the early to mid-20th century for Indo-Trinidadians large families were often seen as blessings and childbearing was considered both a spiritual and social obligation.

A woman who bore many children, especially sons, was seen as fulfilling a biological role while enacting religious duty and familial honour. Having children within a "proper" Hindu marriage was also seen as a way to protect the community's traditions and keep religious identity intact. Additionally, [17] notes that Hindu community life was deeply enmeshed in cooperation, kinship, and sharing. Therefore, larger families enabled more expansive kin networks and greater participation in communal functions, religious festivals, and labor sharing arrangements. In these rural plantation-descended societies, fertility was as much about sustaining the cultural commons as about individual family size.

For Muslims, this period was marked by a strong emphasis on religious retention and community identity, often maintained in distinction from both Hindus and Afro-Trinidadians [17]. Fertility was closely linked to notions of family duty, religious piety and moral legacy which are all highly valued teachings within Islam. According to [17] Muslim leaders sought to preserve religious purity and distinguish their practices from perceived Hindu or Western influences hence the community centred around core values that prioritized continuity, modesty and reproduction. Additionally, families who demonstrated their commitment to Islamic values through gendered roles that encouraged women to prioritize motherhood and home life, were respected [17].

B. Transitional Generation

The transitional generation marks the onset of the fertility transition in Trinidad and Tobago, this generation came of age during a pivotal moment in Trinidad and Tobago's history. Following independence in 1962, the nation experienced rapid economic growth, social modernization, and the rollout of various public initiatives [18]. Educational reforms expanded access to secondary schooling, family planning services were institutionalised and urbanisation accelerated. These historical shifts help contextualize the observed fertility patterns among the transitional generation, whose average family sizes fell to between 1 to 3 children a clear departure from the high-parity norms of their parents' generation.

In 1967, the state formalized its commitment to population control with the launch of the National Family Planning Programme (NFPP), supported by international agencies [19].

The NFPP offered contraceptives, reproductive education, and outreach services, especially to rural and lower-income populations, but uptake remained uneven due to persistent cultural norms and mistrust of modern methods. Concurrently, the expansion of the education system under the Fifteen-Year Education Plan (1968–1983) increased access to secondary schooling [20]. The timing of the fertility decline, beginning in the late 1960s, closely mirrors the rollout of state-led family planning programs and expanded access to education which likely delayed childbearing and reduced overall parity. Meanwhile, economic restructuring led to urban migration and the decline of agriculture loosening traditional family and community structures that once sustained high fertility [18].

The statistically significant association between Muslim affiliation and higher fertility aligns with research showing that traditional religious communities [17] maintained more pronatalist values during this transitional period. The finding that single individuals had significantly fewer children may also reflect the enduring influence of religious and cultural norms that emphasized marriage as a prerequisite for child-bearing. Despite the broader modernization underway, such values continued to shape reproductive behavior. Overall, the variability captured in the data reflects the uneven reach and uptake of new policies and opportunities, some families embraced modern reproductive norms, while others held on to traditional ideals.

C. Modern Generation

The modern generation represents the culmination of Trinidad and Tobago's fertility transition. Respondents from this cohort reported the lowest and most uniform fertility levels across the dataset, with the majority having zero to one child. This generational shift is further underscored by fertility rates that remained consistently below the replacement threshold of 2.1 births per woman, marking a decisive break from earlier patterns of high and variable fertility. The fertility outcomes observed among the modern generation reflect a demographic shaped by the evolving structure of Trinidad and Tobago's tertiary education system.

Since the 1990s, the country has witnessed an expansion in access to higher education. This growth was driven by public initiatives like the Government Assistance for Tuition Expenses (GATE) which allowed for a more diverse student population. According to [21] enrollment surged with the number of GATE-funded students nearly doubling between 2004 and 2010. Crucially, women emerged as strong academic performers during this period, with girls consistently outperforming their male counterparts in national assessments at the pre-tertiary level [21]. This academic momentum translated into greater female representation in tertiary institutions.

Research also suggests that women were often motivated to pursue higher education as a means of career change, a pathway less frequently chosen by men [21]. The regression analysis showed that tertiary education was a statistically significant and negative predictor of fertility, confirming that women with higher education levels tended to have fewer

children as they pursued extended education before or instead of childbearing. The strong positive association between being married and higher fertility in this cohort further supports this interpretation that childbearing has become increasingly tied to deliberate marital and economic planning and not traditional expectations.

VI. CONCLUSION

This study confirms that Trinidad has undergone a consistent decline in birth rates across generations, culminating in a modern generation marked by sub-replacement fertility. The exploratory data and regression analyses reveal that fertility decline is not a uniform process but one shaped by the intersection of education, religion, marital status, and evolving cultural norms. The modern generation stands out with the lowest and most uniform fertility levels strongly linked to expanded access to tertiary education and the growing decoupling of reproduction from traditional social expectations. The data also affirm that marriage remains a powerful predictor of childbearing, highlighting the continued cultural and religious association between family formation and formal union.

Importantly, these findings underscore the complex interplay between macro-level policy shifts, such as the implementation of the National Family Planning Programme and the GATE initiative and micro-level fertility choices. Fertility outcomes today are less dictated by communal or religious norms and more by individual aspirations, especially among women who delay or forgo childbearing in pursuit of higher education and professional goals. Trinidad now faces the broader demographic challenge of maintaining workforce sustainability, addressing population ageing and rethinking social policies for a post-transition society. Future research and policy must consider how to balance reproductive autonomy with national development priorities in this new demographic reality.

While this study provides a robust analysis of fertility decline, it also highlights several areas for future research. Firstly, expanding the respondent-level dataset with a larger and more representative sample would enhance the statistical power of intergenerational comparisons. Further research could also deepen understanding of the cultural and personal motivations behind reproductive decisions, particularly among those who remain childless. Finally, comparative regional studies across the Caribbean could also determine on whether Trinidad and Tobago's transition is unique or part of a broader pattern influenced by similar post-colonial, socio-religious, and economic forces.

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