

Predicting Fertility Intentions Among Young Adults Using Machine Learning: The Relative Importance of Family Expectations, Housing Insecurity, Gender Ideology, Career Uncertainty, Relationship Quality, and Cultural Values

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ABSTRACT

Objective: This study aimed to predict positive fertility intentions among young adults in Germany and determine the relative importance of family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values.

Methods and Materials: A cross-sectional predictive study was conducted with 1,284 adults aged 18–35 years residing in Germany. Participants completed measures of fertility intentions, family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values. The dataset was divided into an 80% training set and a 20% independent test set. Logistic regression, elastic-net regression, random forest, extreme gradient boosting, support vector machine, and multilayer perceptron models were developed using nested stratified cross-validation. Model performance was evaluated through the area under the receiver operating characteristic curve, precision–recall area, balanced accuracy, sensitivity, specificity, F1 score, and Brier score. Predictor importance was assessed using permutation importance and Shapley additive explanation values.

Findings: Extreme gradient boosting produced the strongest predictive performance, with an area under the receiver operating characteristic curve of .846, precision–recall area of .799, balanced accuracy of .784, sensitivity of .764, specificity of .803, F1 score of .753, and Brier score of .159. Its discrimination was significantly greater than that of standard logistic regression and elastic-net regression. Relationship quality was the most influential predictor domain, accounting for 24.8% of total SHAP importance, followed by housing insecurity at 21.6%, cultural values at 18.9%, career uncertainty at 15.7%, family expectations at 11.6%, and gender ideology at 7.4%. Severe housing and career uncertainty reduced the probability of positive fertility intentions, whereas high relationship quality and family-centered cultural values increased it. Family expectations showed a nonlinear pattern, and gender ideology was more influential when combined with supportive relationships and expectations of shared caregiving.

Conclusion: Fertility intentions among young adults in Germany are best predicted through an integrated assessment of relational, residential, cultural, and occupational

conditions, with relationship quality and housing security representing the most influential domains.

Keywords: *fertility intentions; machine learning; relationship quality; housing insecurity; gender ideology; career uncertainty; cultural values; Germany*

1 Introduction

Fertility intentions occupy a central position in demographic research because they connect broad social conditions with individual decisions about whether and when to have children. Although intentions do not always translate directly into births, they represent a critical stage through which people interpret their opportunities, constraints, relationships, and anticipated futures. For young adults, reproductive decision-making increasingly occurs amid prolonged education, delayed entry into stable employment, high housing costs, changing partnership patterns, and expanding expectations regarding personal development and gender equality. These developments have made fertility planning less dependent on age or marital status alone and more responsive to the perceived feasibility and desirability of parenthood. Research on young adults in Hungary has shown that intentions regarding future parenthood are embedded in wider transitions involving partnership formation, economic independence, and expectations about adulthood (Erát & Bognár, 2024). Evidence from Romania has likewise linked delayed fertility to the incomplete transformation of gender relations and the uneven progression of the second gender revolution, suggesting that reproductive postponement may persist when women's participation in education and employment advances more rapidly than men's participation in unpaid care (Voicu & Papuc, 2023). Fertility intentions should therefore be understood as multidimensional judgments shaped by the interaction of material security, intimate relationships, gender arrangements, family norms, and cultural values.

The normative environment surrounding parenthood is one of the most influential contexts in which fertility intentions are formed. Families transmit expectations about the appropriate timing of marriage, the desirability and number of children, and the obligations of younger generations to continue the family line. Such expectations may operate through encouragement, anticipated grandparental support, repeated questioning, or direct pressure. Their effects are not necessarily uniform. Supportive expectations may make parenthood appear more attainable, whereas controlling expectations may undermine autonomy and provoke resistance. Experimental evidence on

normative fertility attitudes indicates that evaluations of childbearing are sensitive to social context and to the characteristics of the individuals whose reproductive choices are being judged (Miao, 2026). Research on attitudes toward the fertility decisions of wives and husbands also shows that the perceived legitimacy of refusing parenthood is gendered, reflecting unequal assumptions about marital obligation and reproductive responsibility (Oslawski-Lopez & Tabor, 2024). Family expectations may consequently influence fertility intentions not only through the strength of perceived norms but also through whether those norms are experienced as supportive, obligatory, or intrusive.

Family expectations are embedded in broader cultural narratives about religion, collective identity, demographic continuity, and the social value of parenthood. National identity has been associated with fertility intentions in Hungary, illustrating how reproductive preferences may become connected to belonging and national continuity (Erát, 2026). Religiosity and ideology have similarly been linked to fertility-related behavior and preferences across social settings (Kumo & Perugini, 2023). Recent work on Christian nationalism has further distinguished general pronatalism from selective support for producing particular kinds of children, demonstrating that pronatalist beliefs may be structured by political and moral boundaries rather than by a uniform valuation of fertility (Perry, 2026). Political orientation also matters at the individual level. Left-right self-placement has been associated with fertility intentions across European societies (Arpino & Mogi, 2024), while political identity has been related to fertility desires among younger populations (Rackin & Gibson-Davis, 2024). These findings suggest that reproductive aspirations may form part of broader identity configurations involving family, religion, nation, and political values.

Cultural influences are especially relevant in diverse societies such as Germany, where young adults differ in migration histories, religious affiliations, political orientations, and conceptions of intergenerational obligation. Evidence from France has shown that fertility ideals vary by gender and by Muslim or non-Muslim immigrant background and may also change across generations (Ng, 2025). Comparative research on Indian and Chinese women likewise demonstrates that attitudes toward family, childbearing, and gender norms are shaped by

distinct institutional and cultural environments, even when societies face similar pressures related to modernization and changing women's roles (Zhou, 2025). Culture should therefore not be treated as a fixed ethnic attribute. It is more appropriately conceptualized through directly measured orientations toward family centrality, intergenerational duty, personal autonomy, religion, acceptance of childlessness, and social continuity. Such measurement makes it possible to determine whether cultural values predict fertility intentions beyond migration background or demographic classification.

Gender ideology is another major determinant because the anticipated costs and rewards of parenthood depend heavily on how paid work, domestic labor, and childcare are expected to be distributed. Egalitarian attitudes may strengthen fertility intentions when they imply that partners will share caregiving and employment responsibilities. However, egalitarian beliefs may also expose a gap between desired equality and the institutional or relational conditions available to achieve it. Research in Nordic countries has challenged the assumption that gender equality and fertility are connected through a simple linear continuum, showing that micro-level combinations of attitudes and behavior produce a more complex nexus (Begall & Hiekel, 2024). Subsequent evidence on the gender equality–fertility paradox indicates that egalitarianism may support fertility only when equality is realized across relevant domains of family life rather than endorsed abstractly (Begall & Hiekel, 2025). Studies of gender and family attitudes in East Asia similarly identify aligned, competing, and blurred configurations, in which support for women's employment may coexist with traditional expectations of motherhood (Han & Oh, 2024). Women's intrahousehold decision-making power further conditions the relationship between gender attitudes and fertility intentions, because formal endorsement of equality has limited practical value when women lack influence over household decisions (Yang et al., 2025). At the macro level, demographic processes may themselves constrain the global diffusion of gender egalitarianism by shaping the reproduction of populations with different value orientations (Akaliyski et al., 2026).

The lived experience of inequality may be as important as ideological endorsement. Institutional sexism and discriminatory everyday interactions can influence childbearing timing by shaping women's assessments of education, employment, safety, and the expected burdens of motherhood (Su & Musick, 2024). Gendered experiences also influence preferences concerning the sex of children,

showing that reproductive attitudes develop through cumulative encounters with unequal opportunities and expectations (Zhou, 2024). Perceived gender conflict can reduce favorable attitudes toward marriage and childbearing when intimate relationships are interpreted as arenas of competition, unfairness, or incompatible expectations (Lee et al., 2025). Digital media may intensify these concerns by circulating narratives about unequal domestic labor, maternal sacrifice, relationship risk, and the economic costs of children. Evidence from China suggests that media use may influence fertility intentions through gender-role attitudes and related mediating processes (Fu et al., 2026). Social media research has also documented the coexistence of fertility anxiety and anti-fertility anxiety among women, reflecting simultaneous fears about becoming a mother and about rejecting motherhood (Li, 2025). Gender ideology should therefore be examined as a framework through which young adults anticipate the practical and emotional consequences of parenthood.

Material insecurity constitutes another central dimension of fertility decision-making. Parenthood generally requires confidence that adequate housing, income, employment, and time will remain available over a sufficiently long period. Housing insecurity may weaken fertility intentions because high expenditure burdens reduce disposable income, unstable tenure makes future residence unpredictable, overcrowding limits the feasibility of raising a child, and anticipated relocation can disrupt employment and support networks. Research on young female migrants has shown that housing-expenditure pressure is negatively connected to reproductive willingness and interacts with gender preference, underscoring the joint influence of material constraints and cultural expectations (Wu et al., 2025). Housing insecurity may be particularly consequential for young adults in Germany who face competitive rental markets, delayed residential independence, and regional inequalities in access to suitable family housing. Even when current income is adequate, uncertainty about future rent, tenure security, or residential space may encourage postponement. Housing conditions are therefore not merely background socioeconomic indicators but concrete assessments of whether parenthood can be accommodated spatially and financially.

Career uncertainty operates alongside housing insecurity but represents a distinct form of anticipated instability. Temporary contracts, occupational transitions, further training, uncertain advancement, and possible relocation can discourage fertility when individuals fear unemployment,

career stagnation, or long-term penalties associated with parental leave. These concerns are gendered because women may anticipate greater career interruption, while men may experience pressure to establish a stable provider role before parenthood. The psychological meaning of career uncertainty may also exceed the effect of contract type alone, as individuals with similar employment conditions may differ in perceived control and confidence that work and family can be combined. Research on women's desire for children has emphasized the combined role of psychological, relational, and sociocultural fears and desires, supporting the view that fertility motivation reflects both attraction to parenthood and apprehension about its consequences (Arici, 2026). Research on evolving gender attitudes and fertility preferences among young women likewise shows that preferences change in relation to social transformation and perceived life possibilities rather than remaining fixed across cohorts (Vestel & Gadeyne, 2026). Career uncertainty should therefore be analyzed together with gender ideology and housing security.

Relationship quality provides the immediate interpersonal setting in which many fertility intentions are negotiated. Emotional closeness, trust, communication, commitment, conflict resolution, and agreement about long-term goals can increase confidence that the demands of parenthood will be managed cooperatively. Conversely, instability or disagreement about children may weaken reproductive plans even when economic conditions are favorable. A theory-of-planned-behavior approach has linked fertility intentions to family functioning, fertility anxiety, and marriage–fertility views, emphasizing that intentions emerge through the interplay of attitudes, perceived norms, and perceived control (Peng et al., 2025). Relationship quality may also moderate external insecurity: a supportive partnership may partially buffer housing or career uncertainty, whereas conflict may intensify the same pressures. Nevertheless, general relationship functioning should be distinguished from direct agreement about having children, because partner agreement is both a relational condition and a proximal component of fertility planning.

Although previous research has identified numerous correlates of fertility intentions, much of the literature evaluates predictors separately or relies on linear models that assume additive and relatively uniform associations. These approaches may underrepresent thresholds and interactions. Housing insecurity may matter most after affordability reaches a critical level; family expectations may be beneficial when supportive but harmful when coercive;

egalitarian gender ideology may encourage fertility only in relationships characterized by genuinely shared responsibilities; and career uncertainty may become especially influential when combined with unstable housing. Machine-learning methods are suited to these complexities because they can compare algorithms, accommodate nonlinearities, identify higher-order interactions, and assess out-of-sample prediction. They also permit the relative importance of predictor domains to be estimated through procedures such as permutation importance and Shapley additive explanations. Predictive importance does not establish causality, but it can reveal which variables most improve accurate classification and whether their contributions remain stable across groups and model specifications.

A comprehensive predictive analysis is particularly valuable in Germany, where young adults make fertility decisions within a context of high educational participation, diverse partnership forms, cultural pluralism, regional housing inequalities, and continuing debates about gender equality and work–family reconciliation. Existing evidence indicates that fertility intentions are related to national identity (Erát, 2026), religion and ideology (Kumo & Perugini, 2023), gendered institutional conditions (Su & Musick, 2024), housing pressure (Wu et al., 2025), family functioning (Peng et al., 2025), and changing norms concerning marriage and childbearing (Lee et al., 2025). However, these domains are rarely examined within a single predictive framework that directly compares their relative importance among young adults. Integrating them can clarify whether intentions are most strongly associated with intimate relationship conditions, material feasibility, cultural meaning, family pressure, or gender-role expectations.

Accordingly, the aim of the present study was to use machine-learning models to predict positive fertility intentions among young adults in Germany and to determine the relative importance of family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values.

2 Methods and Materials

2.1 Study Design and Participants

This study employed a cross-sectional, predictive research design to examine the relative importance of family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values in predicting fertility intentions among young adults living in

Germany. A machine-learning framework was selected because fertility intentions are shaped by multiple interconnected personal, relational, economic, and sociocultural factors whose associations may be nonlinear and may involve complex interactions. The target population consisted of young adults residing in Germany who were within the principal age range for educational completion, labor-market establishment, partnership formation, and family-planning decisions. Participants were recruited between September 2025 and January 2026 through a nationwide online research panel, digital advertisements distributed through universities and vocational education centers, social media platforms, community organizations, and professional networks. Stratified recruitment procedures were used to obtain participants from all 16 German federal states and to improve representation across sex, age group, educational attainment, employment status, migration background, urban–rural residence, and geographical region. Recruitment quotas were applied to prevent excessive concentration of participants from large metropolitan areas or university populations.

A total of 1,463 individuals accessed the online survey. Of these, 92 discontinued the questionnaire before completing the principal study measures, 31 did not meet the age or residency criteria, 18 failed at least two embedded attention-check items, and 38 submitted responses that were identified as potentially invalid because of duplicate digital identifiers, implausibly short completion times, or invariant response patterns across the principal scales. After applying the predefined eligibility and data-quality criteria, the final analytical sample consisted of exactly 1,284 young adults. Participants ranged in age from 18 to 35 years, with a mean age of 27.14 years and a standard deviation of 4.82 years. The sample included 645 women, 606 men, and 33 participants who identified as nonbinary, gender-diverse, or another gender identity. All participants had resided in Germany for at least 12 months and were able to read and respond to the questionnaire in German. Individuals were eligible regardless of citizenship, migration background, current parenthood status, or marital status because fertility intentions may be relevant to both childless adults and individuals considering additional children. However, participants were required to indicate that having a biological, adopted, foster, or socially parented child remained a personally meaningful or conceivable future option. Individuals who reported that a medically confirmed condition made future parenthood impossible and that they had definitively excluded all alternative pathways to

parenthood were not included, because the primary outcome concerned the intention to have or raise a child in the future.

The inclusion criteria were being between 18 and 35 years of age, currently residing in Germany, having sufficient German-language proficiency to complete the questionnaire independently, providing informed consent, and completing at least 90% of the principal study measures. Participants who were currently single were retained because relationship status itself may influence fertility intentions and because excluding single adults would have limited the generalizability of the findings. For participants who were not currently involved in a romantic relationship, relationship quality items were coded as structurally unavailable rather than interpreted as poor relationship quality. A separate relationship-status indicator was therefore included in the predictive models, and relationship-quality scores were used only for participants reporting a current romantic relationship of at least three months. This approach allowed relationship quality to be evaluated without conflating the absence of a partner with dissatisfaction in an existing relationship. Participants who were currently pregnant or whose partner was pregnant were retained, but pregnancy status was recorded and entered as a control variable because an ongoing pregnancy could substantially influence reported fertility intentions.

The minimum sample size was determined before data collection using both conventional statistical and machine-learning considerations. For conventional multivariable analysis, the study was designed to provide adequate statistical power to detect small associations after adjustment for demographic and socioeconomic covariates. For machine-learning analysis, the planned sample size was selected to provide a sufficiently large number of participants in both fertility-intention classes, permit separation of training and independent test datasets, and support repeated cross-validation without producing unstable validation folds. The final sample of 1,284 participants exceeded the predefined minimum requirement of 1,100 cases and was considered sufficient for comparing multiple classification algorithms, tuning model hyperparameters, estimating out-of-sample performance, and calculating model-agnostic variable-importance indices.

Participation was voluntary and anonymous. Before accessing the survey, participants viewed an electronic information sheet explaining the study objectives, eligibility criteria, expected completion time, confidentiality procedures, potential discomfort associated with questions about family formation and economic insecurity, and the

right to discontinue participation without penalty. Electronic informed consent was obtained from all participants. No directly identifying information was stored with questionnaire responses. Internet protocol information and panel identifiers used for duplicate detection were converted into nonreversible codes and deleted after data-quality screening.

2.2 Measures

Data were collected through a structured German-language online questionnaire consisting of demographic and background questions, a measure of fertility intentions, and standardized multi-item measures assessing family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values. All items were presented in a fixed thematic order, while item order within each multi-item scale was randomized to reduce order effects and patterned responding. The complete questionnaire required approximately 20 to 25 minutes to complete. Before the main study, the questionnaire was pilot-tested with 42 German-speaking young adults representing different educational, occupational, and family backgrounds. Cognitive interviews were conducted with 12 members of the pilot group to evaluate item clarity, cultural appropriateness, interpretation of fertility-related terminology, and the usability of the online survey. Minor wording changes were made to improve clarity without changing the conceptual meaning of the measures.

Fertility intention was the primary outcome variable. It was assessed through three questions addressing the participant's desire, intention, and perceived likelihood of having a first or additional child within the next three years. Participants indicated whether they wanted to have a child, whether they intended to take concrete steps toward parenthood, and how likely they believed it was that they would have or begin raising a child during the specified period. Responses were recorded on five-point scales ranging from strong rejection or very low likelihood to strong intention or very high likelihood. The three items were averaged to create a continuous fertility-intention score, with higher scores indicating stronger intentions. For the primary machine-learning classification analysis, participants were categorized as having a positive fertility intention when their mean score was 3.50 or higher and they did not explicitly indicate that they definitely did not want a child during the next three years. Participants with scores below 3.50 were categorized as having an uncertain or

negative fertility intention. The threshold was defined before model development and was selected to distinguish participants expressing a reasonably clear intention from those reporting ambivalence, postponement, or rejection. Sensitivity analyses were also planned using the continuous fertility-intention score and an alternative three-category outcome representing negative, uncertain, and positive intentions.

Family expectations were measured using an eight-item scale assessing the extent to which participants perceived direct and indirect expectations from parents, grandparents, relatives, and other significant family members concerning marriage, parenthood, the preferred timing of childbearing, and the continuation of the family line. Items addressed perceived encouragement, pressure, anticipated approval, anticipated disappointment, and the frequency with which family members raised the issue of having children. Responses were provided on a five-point scale ranging from strongly disagree to strongly agree. After reverse coding where required, item scores were averaged, with higher values representing stronger perceived family expectations regarding parenthood. To distinguish supportive expectations from coercive pressure, two supplementary items assessed whether family involvement was experienced as emotionally supportive or controlling. These items were examined descriptively and in sensitivity analyses but were not included in the principal composite score.

Housing insecurity was assessed with nine items covering residential instability, unaffordable housing costs, overcrowding, risk of displacement, temporary accommodation, inability to obtain suitable family housing, uncertainty about future residence, and concern that current housing conditions would be inadequate for raising a child. Participants indicated the frequency or intensity of each experience during the previous 12 months on a five-point response scale. Items relating to objective circumstances, such as repeated residential moves or absence of a stable rental agreement, were combined with subjective concerns about affordability and future housing access because both material instability and perceived insecurity may influence family-planning decisions. Scores were averaged after standardizing items with different response anchors. Higher scores indicated greater housing insecurity. Additional housing characteristics, including tenure status, monthly housing-cost burden, number of persons per household, size of municipality, and whether the participant expected to move within the next year, were collected as background variables.

Gender ideology was measured using a 12-item instrument assessing attitudes toward gender roles in paid employment, unpaid domestic work, childcare, parental leave, financial provision, and decision-making within intimate relationships. The scale included traditional statements, such as the expectation that mothers should assume primary responsibility for young children, as well as egalitarian statements concerning the equal distribution of childcare, household labor, career opportunities, and parental responsibilities. Responses were recorded on a five-point agreement scale. Traditional items were reverse-coded so that higher total scores reflected a more egalitarian gender ideology. In addition to the overall score, exploratory subscale scores were calculated for beliefs about employment and caregiving, division of domestic labor, and gender equality in parental responsibilities. Because the implications of gender ideology may differ across genders and partnership arrangements, interaction terms between gender ideology, participant gender, employment status, and current relationship status were considered during model development.

Career uncertainty was evaluated using eight items assessing perceived instability in employment, uncertainty about career direction, concern about unemployment, limited prospects for advancement, anticipated occupational relocation, conflict between career development and parenthood, and fear that having a child would reduce future professional opportunities. Participants responded on a five-point scale ranging from not at all applicable to completely applicable. The items were averaged to produce a composite career-uncertainty score, with higher values indicating greater occupational and career-related uncertainty. Objective employment indicators were recorded separately, including current employment status, contractual arrangement, weekly working hours, occupational sector, student status, monthly household income, and experience of unemployment during the preceding year. Separating subjective career uncertainty from objective employment conditions made it possible to determine whether perceived unpredictability contributed to fertility intentions beyond formal labor-market status.

Relationship quality was assessed among participants who reported a current romantic relationship of at least three months. The measure contained ten items addressing emotional closeness, mutual trust, communication, conflict resolution, satisfaction, commitment, perceived partner support, agreement about future goals, perceived stability, and agreement regarding parenthood. Responses were

provided on a five-point scale, and negatively worded items were reverse-coded. Higher mean scores represented better perceived relationship quality. Because agreement about having children may be conceptually close to the fertility-intention outcome, the item assessing reproductive agreement was excluded from the principal relationship-quality score and analyzed separately as a partner-agreement variable. This decision reduced the risk of artificially inflating predictive performance through conceptual overlap between the predictor and outcome. Participants without a current partner did not complete the relationship-quality measure and were assigned a separate relationship-status category during model preprocessing.

Cultural values were assessed using a 16-item measure designed to capture value orientations relevant to family formation in contemporary Germany. The measure examined familism, intergenerational obligation, individual autonomy, religious or moral valuation of parenthood, pronatalist beliefs, acceptance of voluntary childlessness, preference for self-realization, and the perceived social importance of marriage and family continuity. Participants rated each statement on a five-point agreement scale. Following reverse scoring, higher overall values indicated stronger endorsement of family-centered and pronatalist cultural values. Because cultural values are multidimensional, four conceptually derived subdomains were also calculated: family centrality, intergenerational obligation, personal autonomy, and acceptance of diverse family and childlessness choices. Participants additionally reported religious affiliation, frequency of religious participation, country of birth, parents' countries of birth, citizenship, language primarily spoken during childhood, and self-identified migration background. These variables were collected to contextualize cultural-value scores and were not used as substitutes for directly measured values.

The questionnaire also included demographic, socioeconomic, relational, and reproductive variables that could function as potential confounders or supplementary predictors. These variables comprised age, gender identity, sexual orientation, educational attainment, current student status, employment status, contract type, personal income, household income, federal state, urban or rural residence, migration background, religious affiliation, relationship status, relationship duration, cohabitation, marital status, number of existing children, preferred number of children, self-rated health, caregiving responsibilities, pregnancy status, and previous experience of infertility or pregnancy loss. Participants could select "prefer not to answer" for

sensitive questions. These responses were treated as missing rather than being assigned to substantive categories.

Content validity of the questionnaire was evaluated by a multidisciplinary panel consisting of two family sociologists, two psychologists specializing in close relationships and reproductive decision-making, one demographer, one labor-market researcher, and one machine-learning specialist. Panel members assessed the relevance, clarity, and conceptual coverage of each item. Items judged to be ambiguous, redundant, or excessively similar to the fertility-intention outcome were revised or removed. Construct validity was evaluated through confirmatory factor analysis before predictive modeling. Internal consistency was examined using Cronbach's alpha and McDonald's omega, with coefficients of .70 or higher considered acceptable for multi-item measures. Scale scores were calculated only when participants had answered at least 80% of the relevant items. When this requirement was satisfied, occasional missing item responses were replaced by the individual's mean score on the remaining items from the same scale.

2.3 Data Analysis

Data analysis was conducted using Python, with the pandas and NumPy libraries used for data management, scikit-learn used for preprocessing and model development, XGBoost used for gradient-boosting classification, and the SHAP library used to interpret model predictions. Preliminary psychometric and conventional statistical analyses were conducted using R. All analytical procedures were specified before inspection of the independent test-set results. The primary objective was to develop and compare machine-learning models for predicting positive fertility intentions and to estimate the relative contribution of family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values to the predictions. The analysis was explicitly predictive rather than causal; therefore, variable-importance values were interpreted as indicators of contribution to out-of-sample prediction and not as evidence that a predictor caused stronger or weaker fertility intentions.

Initial data screening included examination of duplicate records, completion time, attention-check responses, missingness, univariate distributions, impossible values, and multivariate response patterns. Cases meeting the predefined invalid-response criteria were removed before model development. Descriptive statistics were calculated for all

variables. Means and standard deviations were reported for approximately normally distributed continuous variables, medians and interquartile ranges were used for skewed variables, and frequencies and percentages were calculated for categorical variables. Differences between participants with positive and uncertain or negative fertility intentions were explored using independent-samples tests, nonparametric tests, or chi-square tests as appropriate. These comparisons were considered descriptive and were not used to select predictors for the machine-learning models.

Missing data were handled within the machine-learning pipeline to prevent information leakage. Continuous predictors were imputed using the median calculated from the relevant training fold, while categorical predictors were imputed using the most frequent category or an explicit missing category when nonresponse could carry substantive meaning. For relationship quality, structurally missing values among participants without a current partner were imputed within the pipeline and accompanied by a binary indicator distinguishing participants with and without an eligible relationship-quality score. Continuous predictors were standardized for algorithms sensitive to feature scale, including logistic regression, support vector machines, and neural-network models. Categorical variables were transformed through one-hot encoding. Tree-based algorithms were trained on the same harmonized predictor set but did not require standardization. All preprocessing steps were estimated exclusively from the training data and applied unchanged to validation and test data.

The complete dataset was divided into a training set containing 80% of participants and an independent test set containing 20%. Stratified random sampling was used to preserve the proportion of participants with positive and uncertain or negative fertility intentions in both subsets. The test set was isolated before model tuning and was not examined until the final model specifications had been selected. Within the training set, nested stratified cross-validation was used for model development. The outer loop consisted of five folds and was used to estimate validation performance, while the inner loop consisted of five folds and was used to optimize model hyperparameters. Cross-validation was repeated three times using different random seeds to reduce the influence of a single partition of the data.

Six predictive algorithms were compared. These included standard logistic regression as an interpretable benchmark, elastic-net penalized logistic regression, random forest classification, extreme gradient boosting, support vector classification with a radial basis function kernel, and a

multilayer perceptron neural network. Logistic regression provided a conventional linear reference model, whereas the remaining algorithms allowed varying degrees of regularization, nonlinearity, threshold effects, and interactions. Hyperparameters were optimized using randomized search within the inner cross-validation loop. The tuning process considered the regularization strength and penalty mixture for elastic-net regression; number and depth of trees, minimum node size, and number of candidate variables for random forest; learning rate, tree depth, subsampling rate, column-sampling rate, and regularization parameters for extreme gradient boosting; cost and kernel-width parameters for the support vector machine; and hidden-layer size, regularization strength, and learning rate for the neural network.

Class imbalance was evaluated before model training. When the ratio between outcome categories exceeded 1.5 to 1, class-weighted loss functions were applied so that errors in the smaller class received greater weight. Synthetic oversampling was not used in the primary analysis because generating artificial observations could distort the joint distributions of sensitive sociocultural and relational variables. A supplementary analysis using synthetic minority oversampling within the training folds was conducted only to assess the robustness of the findings. No resampling procedure was applied to the independent test set.

Model performance was evaluated using the area under the receiver operating characteristic curve as the primary discrimination metric. Additional performance indicators included the area under the precision–recall curve, accuracy, balanced accuracy, sensitivity, specificity, positive predictive value, negative predictive value, and F1 score. Because fertility-intention predictions may be used as probabilities rather than simple classifications, calibration was assessed using the Brier score, calibration intercept, calibration slope, and graphical calibration curves. The classification threshold was selected within the training data by maximizing the Youden index while also considering the balance between sensitivity and specificity. The threshold was fixed before evaluation on the independent test set. Differences in the areas under the receiver operating characteristic curves of competing models were evaluated using bootstrap confidence intervals based on 2,000 resamples of the test data.

The best-performing model was selected using a combination of cross-validated discrimination, calibration, stability across folds, and interpretability. A model was not

selected solely because it produced the highest area under the curve when the improvement over a simpler model was negligible. After selecting the final algorithm, it was refitted using the complete training dataset with the optimal hyperparameters and evaluated once on the untouched test set. To examine potential overfitting, training, cross-validation, and test performance were compared. Calibration correction using isotonic regression or Platt scaling was applied only when the model demonstrated meaningful miscalibration during cross-validation, and the calibration method was fitted exclusively within the training data.

The relative importance of the six principal predictor domains was estimated using complementary model-interpretation methods. First, permutation importance was calculated by randomly shuffling each predictor in the independent test set and quantifying the resulting decrease in predictive performance. Greater reductions in the area under the receiver operating characteristic curve indicated greater predictive importance. Second, SHAP values were calculated for the final model to quantify the contribution of each predictor to individual predictions and to summarize its overall importance across participants. Absolute SHAP values were averaged across the test sample to rank individual variables. Predictor-level importance values were then aggregated within the six predefined domains so that family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values could be compared on a common scale. Domain importance was expressed both as the mean absolute SHAP value and as the percentage of the total absolute SHAP contribution attributable to each domain.

SHAP dependence plots and partial dependence analyses were used to examine whether associations were linear, nonlinear, or characterized by thresholds. Interaction analyses focused on theoretically relevant combinations, including housing insecurity with household income, career uncertainty with gender, gender ideology with relationship status, relationship quality with partner agreement about children, and cultural values with migration background. These analyses were considered explanatory interpretations of the predictive model rather than confirmatory causal tests. To evaluate the stability of the importance rankings, the complete model-development process was repeated across 500 bootstrap samples. For each principal domain, the median rank and 95% bootstrap interval were calculated. A predictor was considered robustly important when it retained a high rank across resamples and showed consistent results under both permutation importance and SHAP analysis.

Several sensitivity analyses were conducted. The first repeated the modeling procedure using fertility intention as a continuous outcome and compared elastic-net regression, random forest regression, gradient boosting regression, support vector regression, and neural-network regression. The second used a three-category outcome distinguishing negative, uncertain, and positive fertility intentions. The third excluded participants who were currently pregnant, whose partner was pregnant, or who already had two or more children. The fourth restricted the analysis to childless participants. The fifth restricted the analysis to participants currently involved in a romantic relationship so that relationship quality could be assessed without structurally missing observations. The sixth applied alternative cutoffs for defining positive fertility intention. The seventh compared models with and without demographic and socioeconomic covariates to determine whether the six focal domains contributed predictive information beyond basic background characteristics.

Fairness and subgroup performance were evaluated because fertility-intention models may perform differently across demographic groups. Model discrimination, calibration, sensitivity, and specificity were therefore examined separately by gender, age group, migration background, parental status, relationship status, and geographical region. Large performance differences between subgroups were interpreted as evidence of limited generalizability rather than as inherent group differences. Protected demographic characteristics were included primarily to evaluate model fairness and adjust for confounding, not to assign normative reproductive profiles to individuals. Statistical uncertainty was reported using 95% confidence intervals, and all hypothesis-based supplementary analyses used two-sided significance tests with an alpha level of .05. To reduce false-positive findings in multiple exploratory interaction analyses, the Benjamini–Hochberg procedure was applied to control the false discovery rate.

3 Findings and Results

The final analytical sample consisted of 1,284 young adults residing in Germany. Participants ranged in age from 18 to 35 years, with a mean age of 27.14 years and a standard deviation of 4.82 years. Of the total sample, 645 participants identified as women (50.2%), 606 identified as men (47.2%), and 33 identified as nonbinary, gender-diverse, or another gender identity (2.6%). Regarding age distribution, 326

participants were between 18 and 23 years of age (25.4%), 518 were between 24 and 29 years of age (40.3%), and 440 were between 30 and 35 years of age (34.3%). Participants were recruited from all 16 German federal states. A total of 824 participants lived in large or medium-sized urban areas (64.2%), 275 lived in small towns (21.4%), and 185 lived in rural municipalities (14.4%). Moreover, 371 participants reported a migration background, defined as either having been born outside Germany or having at least one parent born outside Germany (28.9%).

In terms of educational attainment, 420 participants had completed secondary school or vocational education as their highest qualification (32.7%), 590 held or were currently completing a bachelor's degree or an equivalent tertiary qualification (46.0%), and 274 held a postgraduate degree or were enrolled in postgraduate education (21.3%). A total of 602 participants were employed full-time (46.9%), 224 were employed part-time (17.4%), 297 were primarily students or vocational trainees (23.1%), and 161 were unemployed, temporarily out of the labor market, or classified in another employment category (12.5%). Among employed participants, 342 reported having a temporary, fixed-term, probationary, or otherwise insecure employment contract, representing 41.4% of employed respondents. Approximately 37.1% of the total sample reported that their monthly housing costs exceeded 35% of their available household income.

With respect to relationship status, 382 participants were single and not currently involved in a romantic relationship (29.8%), 327 were in a noncohabiting romantic relationship (25.5%), 313 were cohabiting with a romantic partner without being married or in a registered civil partnership (24.4%), and 262 were married or in a registered civil partnership (20.4%). Among the 902 participants who reported a current romantic relationship of at least three months, the mean relationship duration was 4.26 years, with a standard deviation of 3.39 years. Most participants were childless, including 1,089 respondents representing 84.8% of the sample. A total of 132 participants had one child (10.3%), and 63 had two or more children (4.9%). Forty-three participants reported that they or their partner were currently pregnant at the time of data collection (3.3%).

Based on the predefined classification threshold, 548 participants were classified as having a positive fertility intention within the next three years (42.7%), whereas 736 were classified as having an uncertain or negative fertility intention (57.3%). Positive fertility intentions were more common among participants who were married or

cohabiting, those reporting higher relationship quality, those with more stable housing conditions, and those who endorsed stronger family-centered cultural values. In contrast, uncertain or negative intentions were more frequent among participants reporting substantial housing insecurity,

temporary employment, pronounced career uncertainty, or disagreement with a partner regarding future parenthood. These descriptive differences were examined more systematically through the correlational and predictive analyses reported below.

Table 1

Descriptive statistics, internal consistency coefficients, and correlations among the principal study variables

Variable	Mean	SD	Cronbach's α	McDonald's ω	1	2	3	4	5	6	7
1. Fertility intention	2.91	1.08	.88	.89	—						
2. Family expectations	3.12	0.91	.86	.87	.31***	—					
3. Housing insecurity	2.74	0.94	.89	.90	-.39***	.12***	—				
4. Gender ideology	3.79	0.73	.84	.85	.14***	-.18***	-.05	—			
5. Career uncertainty	2.88	0.88	.87	.88	-.35***	.09**	.46***	-.08**	—		
6. Relationship quality	3.91	0.70	.92	.93	.43***	.08*	-.27***	.11**	-.31***	—	
7. Cultural values	3.08	0.82	.88	.89	.37***	.42***	-.07*	-.29***	-.12***	.19***	—

As presented in Table 1, all multi-item measures demonstrated satisfactory to excellent internal consistency. Cronbach's alpha coefficients ranged from .84 for gender ideology to .92 for relationship quality, while McDonald's omega coefficients ranged from .85 to .93. These coefficients indicated that the items within each measure consistently represented their intended constructs and supported the use of composite scores in the subsequent analyses. The mean fertility-intention score was 2.91, indicating that the overall sample was positioned slightly below the midpoint separating uncertain from clearly positive intentions. However, the relatively large standard deviation of 1.08 demonstrated considerable heterogeneity in participants' reproductive plans.

Relationship quality showed the strongest positive bivariate association with fertility intention, $r = .43, p < .001$. Participants who described their romantic relationships as emotionally close, stable, supportive, and oriented toward shared future goals were therefore more likely to express an intention to have a first or additional child within the next three years. Housing insecurity had the strongest negative association with fertility intention, $r = -.39, p < .001$, indicating that difficulties involving affordability, residential instability, overcrowding, inadequate space, and uncertainty about future housing were associated with weaker or postponed fertility plans. Cultural values were positively associated with fertility intention, $r = .37, p < .001$, suggesting that participants who placed greater

importance on family centrality, intergenerational continuity, and the social value of parenthood were more likely to report positive fertility intentions. Career uncertainty was negatively related to fertility intention, $r = -.35, p < .001$, while perceived family expectations showed a moderate positive association, $r = .31, p < .001$.

Gender ideology had a smaller but statistically significant positive association with fertility intention, $r = .14, p < .001$. Because higher scores represented more egalitarian beliefs, this finding suggested that participants who endorsed a more equal distribution of employment, childcare, parental leave, and domestic responsibilities were somewhat more likely to anticipate having a child. The magnitude of this association was nevertheless substantially smaller than those observed for relationship quality, housing insecurity, cultural values, and career uncertainty. Housing insecurity and career uncertainty were moderately correlated, $r = .46, p < .001$, demonstrating that economic and residential instability frequently occurred together. Relationship quality was negatively related to both housing insecurity, $r = -.27, p < .001$, and career uncertainty, $r = -.31, p < .001$. Family expectations were positively associated with family-centered cultural values, $r = .42, p < .001$, but the correlation was not sufficiently large to indicate that the two constructs were interchangeable. The variance-inflation factors calculated before model development ranged from 1.12 to 1.76, indicating that multicollinearity among the principal predictors was not problematic.

Table 2

Performance of the classification models in the independent test sample

Model	AUROC (95% CI)	AUPRC	Accuracy	Balanced accuracy	Sensitivity	Specificity	F1 score	Brier score
Logistic regression	.782 (.726–.836)	.724	.724	.713	.674	.752	.684	.192
Elastic-net logistic regression	.797 (.744–.847)	.743	.739	.728	.691	.765	.703	.184
Random forest	.816 (.767–.861)	.761	.755	.746	.718	.774	.727	.176
Extreme gradient boosting	.846 (.802–.886)	.799	.786	.784	.764	.803	.753	.159
Support vector machine	.824 (.776–.868)	.774	.763	.754	.727	.781	.736	.171
Multilayer perceptron	.809 (.758–.855)	.752	.747	.739	.709	.769	.717	.180

The predictive-performance results presented in Table 2 showed that all six models identified meaningful patterns differentiating participants with positive fertility intentions from those with uncertain or negative intentions. Standard logistic regression produced an AUROC of .782, demonstrating acceptable discrimination and indicating that the predictors contained substantial information even when their effects were modeled as linear and additive. Elastic-net regularization modestly improved discrimination, calibration, and overall accuracy, producing an AUROC of .797 and a Brier score of .184. This improvement suggested that controlling coefficient magnitude and reducing the effects of correlated or weak predictors increased the generalizability of the conventional regression model.

The nonlinear machine-learning algorithms generally outperformed the two regression-based approaches. The random forest achieved an AUROC of .816, while the support vector machine achieved an AUROC of .824. The multilayer perceptron demonstrated an AUROC of .809 but did not outperform the tree-based or support vector models. Extreme gradient boosting produced the strongest overall predictive performance, with an AUROC of .846 and an AUPRC of .799. At the probability threshold selected exclusively within the training data, the extreme gradient-boosting model correctly classified 78.6% of participants in the independent test sample. Its balanced accuracy was .784, indicating that the model performed comparably across the positive and uncertain or negative fertility-intention classes rather than achieving high overall accuracy by disproportionately predicting the larger outcome group.

The sensitivity of the final extreme gradient-boosting model was .764, indicating that approximately three-quarters of participants with positive fertility intentions were correctly identified. Its specificity was .803, showing that slightly more than four-fifths of participants with uncertain or negative intentions were also correctly identified. The F1 score of .753 demonstrated a favorable balance between the precision and sensitivity of positive-intention predictions. The model also produced the lowest Brier score of all tested algorithms, at .159, indicating that its estimated probabilities

were more accurate than those generated by the alternative models. Calibration analysis showed a calibration intercept of .02 and a calibration slope of .97 in the independent test set, suggesting that predicted probabilities were closely aligned with observed outcomes and that the model exhibited limited systematic overestimation or underestimation.

Bootstrap comparison of model discrimination showed that the AUROC of the extreme gradient-boosting model was significantly higher than that of standard logistic regression, with a mean AUROC difference of .064 and a 95% bootstrap confidence interval ranging from .019 to .109. Its advantage over elastic-net logistic regression was also statistically meaningful, with a mean difference of .049 and a 95% confidence interval from .008 to .091. Differences between extreme gradient boosting and the random forest or support vector machine were smaller, although the extreme gradient-boosting model retained the highest mean AUROC, AUPRC, accuracy, and calibration performance. On the basis of its discrimination, calibration, performance stability across cross-validation repetitions, and compatibility with SHAP-based interpretation, extreme gradient boosting was selected as the final predictive model.

The final model continued to perform consistently across the principal demographic subgroups. AUROC values were .851 for women, .839 for men, and .817 for gender-diverse participants, although the estimate for the gender-diverse group was less precise because of its smaller sample size. The model achieved AUROC values of .837 among participants with a migration background and .849 among participants without a migration background. Discrimination was .842 among childless participants and .821 among participants who already had at least one child. Calibration differences between the subgroups were limited, and no subgroup showed a calibration slope below .88 or above 1.10. These findings suggested that the model's predictive performance was not restricted to one major demographic category, although the smaller number of gender-diverse participants limited the certainty of subgroup-specific conclusions.

Table 3*Domain-level importance of the principal predictors in the final extreme gradient-boosting model*

Predictor domain	Mean absolute SHAP value	Percentage of total SHAP importance	Permutation decrease in AUROC	Importance rank	Bootstrap rank interval	Predominant association with positive fertility intention
Relationship quality	.184	24.8%	.061	1	1–2	Positive
Housing insecurity	.160	21.6%	.052	2	1–3	Negative
Cultural values	.140	18.9%	.043	3	2–4	Predominantly positive
Career uncertainty	.116	15.7%	.036	4	3–5	Negative
Family expectations	.086	11.6%	.025	5	4–6	Positive but nonlinear
Gender ideology	.055	7.4%	.014	6	5–6	Weakly positive and subgroup-dependent
Total	.741	100.0%	—	—	—	—

The domain-level importance results presented in Table 3 demonstrated that relationship quality was the most influential predictor of fertility intentions in the final model. Relationship-quality variables accounted for 24.8% of the total absolute SHAP importance. Randomly permuting this predictor domain reduced test-set AUROC by .061, which was the largest deterioration observed for any of the six domains. High emotional closeness, mutual trust, relationship stability, constructive communication, partner support, and shared long-term goals consistently shifted model predictions toward a positive fertility intention. Conversely, low perceived stability, unresolved conflict, weak commitment, or limited agreement regarding the future shifted predictions toward uncertain or negative intentions. The effect of relationship quality was especially pronounced among cohabiting and married participants and among participants who had already discussed parenthood with their partner.

Housing insecurity was the second most important domain, accounting for 21.6% of total SHAP importance and producing a .052 decrease in AUROC when permuted. High housing-cost burden, anticipated relocation, unstable tenure, overcrowding, and the perception that the current residence was unsuitable for raising a child substantially reduced the predicted probability of positive fertility intentions. The effect was nonlinear. Relatively small differences were observed between participants with low and moderate housing-insecurity scores, but the predicted probability of positive intention declined sharply once the standardized housing-insecurity score rose above approximately 0.60 standard deviations from the sample mean. Housing insecurity remained important after household income,

employment status, federal state, urban–rural residence, and current housing tenure had been included in the model, indicating that perceived residential insecurity contributed information beyond conventional socioeconomic indicators.

Cultural values ranked third and explained 18.9% of total SHAP importance. Stronger endorsement of family centrality, intergenerational continuity, and the personal importance of parenthood was generally associated with a higher predicted probability of positive fertility intention. However, the effect was not uniform across all cultural-value dimensions. Family centrality and the personal valuation of parenthood showed clear positive associations, whereas strong intergenerational obligation produced a smaller and more variable contribution. In some participants, highly controlling or duty-oriented beliefs were associated with ambivalence rather than a stronger intention. Acceptance of voluntary childlessness and strong prioritization of individual autonomy were generally associated with lower short-term fertility intentions, although these variables did not necessarily indicate permanent rejection of parenthood.

Career uncertainty accounted for 15.7% of total SHAP importance and ranked fourth. Participants who expected unemployment, occupational relocation, contract termination, limited career progression, or substantial incompatibility between parenting and professional development were less likely to be classified as having positive fertility intentions. The negative effect of career uncertainty was particularly strong among participants aged 24 to 31 years, university graduates entering the labor market, employees with fixed-term contracts, and participants who anticipated changing occupations within

the next two years. The interaction between career uncertainty and housing insecurity was also influential. Participants experiencing high levels of both forms of uncertainty had substantially lower predicted probabilities of positive fertility intention than participants experiencing either form of uncertainty in isolation.

Family expectations accounted for 11.6% of total SHAP importance and ranked fifth. Moderate perceptions of encouragement and anticipated family support were generally associated with stronger fertility intentions. However, the association became weaker at very high levels of family pressure. Participants who perceived their families as supportive and available to provide emotional or practical assistance were more likely to express positive intentions, whereas participants who experienced repeated questioning, anticipated disappointment, or pressure to preserve the family line did not show an equivalent increase. In a smaller subgroup, very high family pressure was associated with lower predicted fertility intention, particularly among participants with strong autonomy values. The predictive relationship between family expectations and fertility intention was therefore nonlinear and depended partly on whether expectations were interpreted as supportive or controlling.

Gender ideology had the lowest overall importance, accounting for 7.4% of total SHAP importance, but it still improved model performance and was retained in the final model. More egalitarian beliefs were generally associated with a modestly higher probability of positive fertility intention, especially when participants also reported confidence that childcare and domestic labor would be shared fairly. The association was more pronounced among women than among men. Among women, traditional expectations that mothers should assume primary responsibility for childcare and reduce paid employment shifted predictions toward uncertain or negative fertility intentions. Among men, gender ideology had a smaller direct contribution, although egalitarian attitudes were positively associated with fertility intentions when accompanied by willingness to take parental leave and assume substantial caregiving responsibilities. Bootstrap analyses showed that relationship quality, housing insecurity, and cultural values consistently occupied the highest importance ranks, whereas gender ideology almost always ranked fifth or sixth.

The SHAP summary plot further illustrated the contribution of individual variables within the six principal domains. High scores for relationship stability, emotional support, communication quality, and shared future

orientation were concentrated on the positive side of the SHAP distribution, indicating that these variables increased the predicted probability of positive fertility intention. Partner agreement regarding having children produced one of the largest individual positive contributions, even though it was modeled separately from the principal relationship-quality score to minimize conceptual overlap. In contrast, low relationship stability and uncertainty regarding the partner's long-term commitment generated substantial negative SHAP values.

The figure also showed that high housing-cost burden, anticipated forced relocation, lack of adequate space for a child, and insecure rental arrangements consistently shifted predictions toward uncertain or negative fertility intentions. These housing variables produced larger contributions than residential location alone. Living in a large city was not uniformly associated with lower fertility intention after affordability, space, and tenure insecurity were considered. Rather, urban residence became negatively predictive primarily when it coincided with high costs, overcrowding, or limited access to suitable family housing.

Among career-related variables, fear that parenthood would restrict professional advancement and concern about unstable employment produced the strongest negative SHAP values. Temporary employment alone had a moderate contribution, but its effect became substantially stronger when accompanied by low perceived career control or expected occupational relocation. High household income produced a positive contribution in some cases, although income was less important than subjective housing security, career predictability, and relationship stability. This pattern indicated that perceived conditions and anticipated future stability carried predictive information beyond current financial resources.

The distribution of cultural-value variables showed that strong personal valuation of parenthood and high family centrality increased predicted fertility intentions, whereas acceptance of permanent childlessness and strong prioritization of unrestricted individual autonomy generally reduced short-term intentions. Nevertheless, the SHAP distributions overlapped considerably, demonstrating that no cultural orientation determined fertility intention in isolation. Several participants with highly autonomy-oriented values still had positive fertility intentions when they reported strong relationship quality, stable housing, and confidence in an egalitarian division of caregiving.

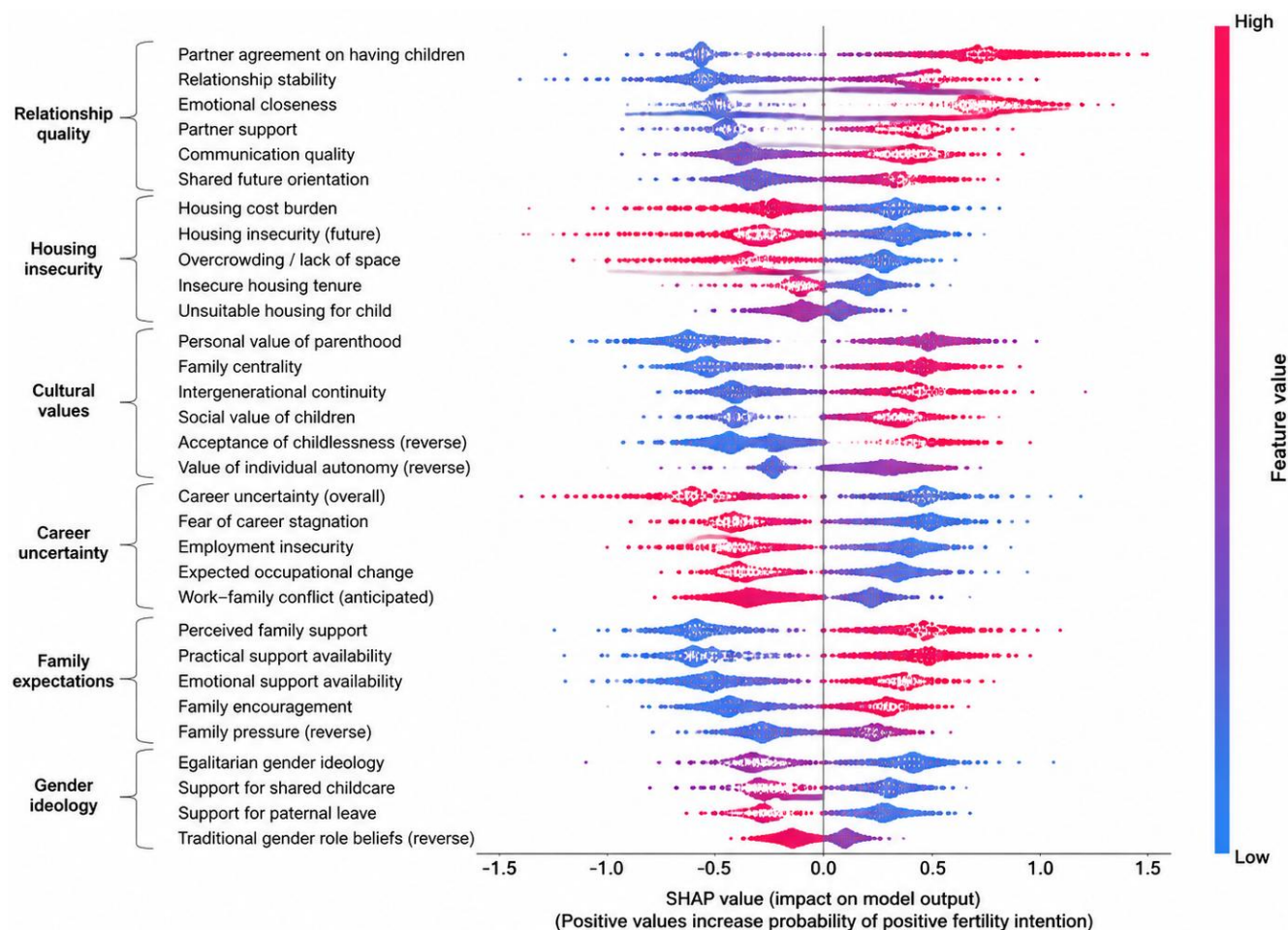
The most influential interaction identified by the model involved relationship quality and housing insecurity. High

relationship quality partly attenuated the negative contribution of moderate housing insecurity, but it did not fully compensate for severe housing instability. A second important interaction involved career uncertainty and housing insecurity. Participants who scored in the highest quartile of both domains had an estimated probability of positive fertility intention that was approximately 29

percentage points lower than that of participants in the lowest quartile of both domains, after averaging across the remaining predictors. A third interaction involved gender ideology and relationship quality. Egalitarian gender ideology was most positively predictive when participants also reported that their partner supported an equal division of paid work, childcare, and household responsibilities.

Figure 1

SHAP summary plot showing the direction and magnitude of individual predictor contributions to positive fertility intentions



Sensitivity analyses supported the robustness of the principal findings. When fertility intention was analyzed as a continuous outcome, gradient-boosting regression explained 43.8% of the variance in the independent test sample, and the ordering of the six predictor domains remained largely unchanged. Relationship quality retained the highest importance, followed by housing insecurity, cultural values, career uncertainty, family expectations, and gender ideology. When the outcome was divided into negative, uncertain, and positive categories, the multiclass gradient-boosting model achieved an overall accuracy of 71.2%, with the strongest discrimination observed between

clearly positive and clearly negative intentions. Classification of uncertain intentions was less accurate, reflecting the conceptual heterogeneity of ambivalence and postponement.

Restricting the analysis to the 1,089 childless participants produced an AUROC of .842, which was nearly identical to the primary analysis. Excluding participants who were currently pregnant or whose partner was pregnant reduced the sample but did not materially alter model performance or the feature-importance ranking. Among participants currently in a romantic relationship, the model achieved an AUROC of .853, and relationship quality became even more

dominant, accounting for 28.6% of total SHAP importance. In models excluding demographic and socioeconomic covariates, the six principal psychosocial and contextual domains still produced an AUROC of .821. Adding age, education, income, employment status, relationship status, parenthood status, migration background, and place of residence increased the AUROC to .846, demonstrating that demographic information improved prediction but did not replace the explanatory value of the focal variables.

Taken together, the findings showed that fertility intentions among young adults in Germany were predicted most accurately through a combination of relational, residential, cultural, and occupational factors. The strongest model was able to distinguish positive from uncertain or negative intentions with good discrimination and calibration. Relationship quality was the most important predictor, followed closely by housing insecurity. Cultural values and career uncertainty made substantial independent contributions, while family expectations exerted a smaller and nonlinear influence. Gender ideology had the lowest overall importance but remained relevant, particularly through its interaction with gender, relationship quality, and anticipated divisions of childcare and domestic labor.

4 Discussion

The present study used a machine-learning framework to predict fertility intentions among young adults in Germany and to compare the relative importance of family expectations, housing insecurity, gender ideology, career uncertainty, relationship quality, and cultural values. The findings showed that the extreme gradient-boosting model achieved the strongest predictive performance, with good discrimination, balanced classification, and satisfactory calibration in the independent test sample. Relationship quality emerged as the most influential predictor domain, followed by housing insecurity, cultural values, career uncertainty, family expectations, and gender ideology. The results also revealed nonlinearities and interactions that would have been difficult to identify through conventional additive models alone. In particular, severe housing insecurity produced a sharp reduction in the probability of positive fertility intention, the adverse effect of career uncertainty became stronger when combined with housing instability, and moderate family encouragement was more favorable than intense or controlling family pressure. Gender ideology had the smallest overall contribution, but its predictive relevance increased when considered in relation

to participant gender, relationship quality, and expectations regarding the division of childcare and domestic labor.

The strong performance of the extreme gradient-boosting model indicates that fertility intentions are not adequately explained by a single linear sequence of economic or attitudinal variables. Instead, they appear to result from configurations of relational, material, cultural, and occupational circumstances. The higher predictive accuracy of the nonlinear models compared with standard and penalized logistic regression supports the assumption that the relationships between fertility intentions and their determinants include thresholds, conditional effects, and interactions. Previous studies have similarly described fertility intention as the outcome of interconnected psychological, relational, and sociocultural influences rather than a simple response to demographic characteristics. Arici's analysis of women's desire to have children emphasized the simultaneous operation of fears, desires, interpersonal conditions, and cultural expectations (Arici, 2026). The theory-of-planned-behavior model examined by Peng and colleagues likewise connected fertility intention with family functioning, fertility anxiety, and views concerning marriage and childbearing (Peng et al., 2025). The present findings extend this literature by demonstrating that the relative predictive value of these domains can be estimated simultaneously and that their effects vary depending on the wider configuration in which they occur.

Relationship quality was the strongest predictor of fertility intention. Participants who reported greater emotional closeness, mutual trust, commitment, constructive communication, partner support, and shared future orientation were more likely to express positive intentions to have a first or additional child within the following three years. Agreement between partners concerning parenthood also had one of the largest individual contributions to model predictions. This result is consistent with the view that fertility intention is rarely an exclusively individual preference when parenthood is anticipated within an intimate relationship. A stable and supportive partnership can reduce uncertainty about how childcare, financial responsibilities, emotional demands, and long-term commitments will be managed. By contrast, relational conflict or uncertainty may make parenthood appear risky even when objective socioeconomic conditions are relatively favorable. The finding aligns with evidence that family functioning and marriage-fertility views are central components of fertility intention (Peng et al., 2025). It is also compatible with research showing that perceived gender

conflict can weaken young adults' attitudes toward marriage and childbearing by reducing confidence in intimate cooperation and fairness (Lee et al., 2025).

The importance of relationship quality should not be interpreted as evidence that partnership alone produces fertility intention. Rather, the findings suggest that the anticipated quality of cooperative parenthood matters more than formal relationship status. This distinction is relevant because individuals may be married or cohabiting while remaining uncertain about commitment, emotional support, or the division of caregiving. Attitudes regarding whether wives or husbands may legitimately refuse parenthood also reflect gendered assumptions about relational obligation and reproductive autonomy (Oslawski-Lopez & Tabor, 2024). In the present study, relationship quality became even more influential when analyses were restricted to partnered participants, indicating that differences within relationships were more informative than a simple partnered-versus-single distinction. This result supports approaches that examine negotiation, mutuality, and shared expectations rather than treating partnership status as a sufficient indicator of readiness for parenthood.

Housing insecurity was the second most important predictor and had the strongest negative bivariate relationship with fertility intention. High housing-cost burden, unstable tenure, overcrowding, anticipated relocation, and the perception that current housing was unsuitable for a child were associated with a lower probability of positive intention. The nonlinear pattern was particularly important: modest housing concerns were not associated with major changes in predicted intention, but the probability of positive fertility intention declined sharply once housing insecurity exceeded a moderate level. This suggests that young adults may tolerate some residential uncertainty while completing education or beginning their careers, but severe or persistent insecurity can make parenthood appear practically unmanageable. The result is consistent with evidence that housing-expenditure pressure reduces reproductive willingness among young women and interacts with gendered expectations (Wu et al., 2025). The present findings also showed that subjective housing insecurity remained important after accounting for income, employment, tenure, and residential location. Fertility planning may therefore depend not only on current economic resources but also on whether individuals believe they can maintain an adequate and stable home over time.

Career uncertainty was another substantial negative predictor. Participants who feared unemployment,

occupational displacement, career stagnation, or conflict between parenthood and professional advancement had weaker fertility intentions. This pattern was especially pronounced among participants who simultaneously experienced housing insecurity, supporting the idea that different forms of uncertainty accumulate rather than operate independently. Young adults may postpone parenthood not because they reject having children, but because they cannot identify a sufficiently predictable time at which work, income, and housing conditions will permit it. Research on fertility desires has shown that anticipated costs and fears can coexist with a positive valuation of parenthood (Arici, 2026). Changes in fertility preferences among young women have likewise been associated with evolving expectations concerning education, employment, and gender roles (Vestel & Gadeyne, 2026). The present results suggest that career uncertainty should be understood as perceived lack of control over future work trajectories, not merely as current unemployment or temporary employment.

Cultural values ranked third in predictive importance and were generally positively associated with fertility intentions. Participants who placed greater value on parenthood, family centrality, and intergenerational continuity were more likely to report positive intentions. This finding is compatible with evidence that fertility attitudes are embedded in ideological, religious, and collective identities. Religion and political ideology have been associated with fertility behavior and preferences (Kumo & Perugini, 2023), while national identity has been linked to fertility intentions in Hungary (Erát, 2026). Political self-placement and political identity have also been associated with fertility intentions and desires (Arpino & Mogi, 2024; Rackin & Gibson-Davis, 2024). Perry's distinction between general and selective pronatalism further indicates that the cultural valuation of fertility may depend on beliefs about which families or populations should reproduce (Perry, 2026). The present findings therefore support a multidimensional interpretation of cultural values rather than treating culture as a uniform pronatalist influence.

The relationship between cultural values and fertility intention was not entirely linear. Strong personal valuation of parenthood increased positive intentions, whereas highly obligation-oriented family values sometimes coincided with ambivalence, particularly among participants who strongly valued personal autonomy. This pattern is consistent with experimental evidence showing that normative evaluations of fertility decisions vary according to the social context in which choices are made (Miao, 2026). It also reflects the

diversity of fertility ideals observed across immigrant generations and religious groups in Europe (Ng, 2025). Comparative research has similarly shown that attitudes toward family, childbearing, and gender norms differ across cultural and institutional settings and cannot be reduced to a simple traditional–modern continuum (Zhou, 2025). Thus, family-centered values may encourage parenthood when they are integrated with personal preferences, but they may generate resistance when experienced as externally imposed duties.

Family expectations had a moderate and nonlinear predictive contribution. Supportive encouragement, anticipated practical assistance, and emotional availability were associated with stronger fertility intentions, whereas intense pressure did not produce an equivalent increase and occasionally predicted lower intention. This distinction suggests that the source and meaning of family influence are crucial. Family expectations can increase perceived social support and reduce anticipated childcare burdens, but controlling communication may threaten reproductive autonomy. Evidence concerning attitudes toward the rights of husbands and wives to refuse parenthood demonstrates that fertility decisions continue to be interpreted through unequal expectations of marital and family obligation (Oslawski-Lopez & Tabor, 2024). Research on young adults in Hungary has also indicated that fertility intentions develop within family and social transitions rather than solely through private preference (Erát & Bognár, 2024). The present findings clarify that perceived support and perceived pressure should not be combined into a single undifferentiated measure of family influence.

Gender ideology had the lowest overall importance but remained statistically and substantively relevant. More egalitarian attitudes were modestly associated with positive fertility intentions, particularly among women and among participants who expected childcare and domestic labor to be shared. This finding supports the gender-equity perspective, according to which fertility may be encouraged when equality in education and employment is accompanied by equality within households. However, the relatively low overall importance of gender ideology suggests that abstract attitudes alone may have limited predictive value unless they are connected to actual relational arrangements. Research from Nordic countries has demonstrated that the gender equality–fertility relationship is not a simple continuum and depends on combinations of attitudes and behavior (Begall & Hiekel, 2024, 2025). Similarly, gender and family attitudes may form aligned, competing, or ambiguous

configurations in which support for women's employment coexists with traditional expectations of caregiving (Han & Oh, 2024).

The subgroup patterns also support this interpretation. Among women, traditional beliefs assigning primary childcare responsibility to mothers reduced the predicted probability of positive fertility intention. Among men, egalitarian ideology became more relevant when it included willingness to take parental leave and participate substantially in care work. Women's intrahousehold decision-making power has been shown to condition the relationship between gender attitudes and fertility intentions (Yang et al., 2025). Institutional and interpersonal sexism may also shape early childbearing by altering the expected costs of motherhood (Su & Musick, 2024). Gendered lived experiences influence reproductive attitudes, including preferences concerning children and family formation (Zhou, 2024). These studies support the present finding that fertility intentions depend less on whether individuals endorse equality in principle than on whether they expect equality to be realized in everyday family life.

The identified interaction between relationship quality and gender ideology is particularly informative. Egalitarian attitudes were most positively associated with fertility intention when participants also described their relationships as supportive and stable. This suggests that egalitarian ideology may increase reproductive confidence when partners trust one another to implement shared responsibilities. Where relationship quality was low, ideological agreement alone did not compensate for uncertainty about future cooperation. Perceived gender conflict may similarly weaken marriage and childbearing attitudes when young adults doubt the possibility of fair partnerships (Lee et al., 2025). Digital media may reinforce either confidence or anxiety by circulating accounts of unequal caregiving, career sacrifice, marital conflict, and maternal burden. Media use has been connected to fertility intention through gender-role attitudes (Fu et al., 2026), and social-media discussions reveal simultaneous fertility and anti-fertility anxieties (Li, 2025). The present findings indicate that these ideological and mediated concerns may ultimately affect intentions through expectations about concrete relationship practices.

5 Conclusion

The results also have broader implications for understanding demographic change. Delayed fertility may

partly reflect the incomplete alignment of gender equality, employment systems, housing markets, and family-support arrangements. Evidence from Romania has attributed fertility postponement to delays in the second gender revolution (Voicu & Papuc, 2023). At the global level, demographic processes may constrain the diffusion of egalitarian attitudes, creating feedback between fertility patterns and value change (Akaliyski et al., 2026). The present German findings suggest that positive fertility intentions are most likely when young adults simultaneously perceive relational stability, housing feasibility, occupational predictability, and fair gender arrangements. Pronatalist values or family pressure alone are unlikely to offset severe structural and relational constraints.

Several limitations should be considered when interpreting these findings. First, the cross-sectional design did not permit causal conclusions or establish the temporal order among predictors and fertility intentions. Relationship quality, housing insecurity, and career uncertainty may influence fertility intentions, but fertility plans may also alter how participants evaluate their relationships and future conditions. Second, the outcome represented intentions within a three-year period rather than observed births, and intentions may change in response to partnership transitions, employment changes, infertility, pregnancy, or unexpected life events. Third, although the sample included participants from all German federal states, recruitment through an online panel and digital advertisements may have underrepresented young adults with limited internet access, low German-language proficiency, or highly unstable living conditions. Fourth, some constructs were measured through self-report and may have been affected by social desirability or shared-method variance. Fifth, relationship quality could be measured only among partnered participants, requiring explicit treatment of structural missingness. Finally, machine-learning variable importance reflects predictive contribution rather than causal effect and may vary across populations, time periods, and model specifications.

Future research should use longitudinal designs that follow young adults from the formation of fertility intentions through subsequent revisions, pregnancy attempts, and realized births. Repeated measurement would make it possible to distinguish stable preferences from temporary postponement and to test whether changes in housing, employment, or relationship quality precede changes in intentions. Future studies should also examine partners jointly because fertility decisions are frequently negotiated at the couple level, and disagreement between partners may

be more informative than either partner's individual score. Larger samples should be used to evaluate heterogeneity across gender-diverse groups, migration generations, regions, socioeconomic positions, and different pathways to parenthood. Research could further incorporate local housing-market indicators, employment histories, childcare accessibility, and family-policy exposure alongside subjective measures. The predictive models should be externally validated in other European countries and across different economic periods. Finally, qualitative interviews could clarify why moderate family encouragement is supportive while stronger pressure becomes counterproductive and how young adults interpret the practical meaning of egalitarian parenthood.

Programs intended to support voluntary family formation should address the conditions that make parenthood appear feasible rather than concentrating narrowly on changing attitudes or promoting pronatalist messages. Housing policy should improve access to secure, affordable, and adequately sized accommodation for young adults and couples considering children. Employment policies should reduce prolonged contract insecurity, protect career development during parental leave, and make flexible work arrangements available to all genders. Relationship education and counseling services could help couples discuss reproductive preferences, expectations about childcare, financial responsibilities, and anticipated work-family arrangements before conflict becomes entrenched. Family-support initiatives should encourage relatives to provide practical and emotional assistance without exerting pressure or undermining reproductive autonomy. Public communication should represent caregiving as a shared responsibility and increase the visibility of men's participation in parental leave, domestic labor, and childcare. Taken together, coordinated housing, employment, relational, and gender-equality interventions are more likely to support informed and freely chosen fertility decisions than isolated attempts to influence reproductive preferences.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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