Education Competition, Fertility Decline, and Actuarial Risk Transformation in China

Xintong Chen
FBE, The University of Melbourne, Actuarial Studies, Melbourne, Victoria 3053, Australia

Abstract: China's low fertility is no longer only a demographic issue; it can also reshape insurance risk pools, liability duration, reinsurance pressure, and pension sustainability. This article treats education competition as a potential upstream constraint on fertility choice and translates the resulting demographic shift into actuarial language. Using annual China observations for 2010-2024, it combines a Gaokao-based education-competition proxy, Ridge shrinkage, leave-one-out cross-validation, permutation importance, bootstrap sign stability, and scenario indices for annuity reserves and pay-as-you-go pension pressure. The education proxy remains negatively associated with fertility in the benchmark model, with a standardized coefficient near -0.360, a permutation-importance probability near 0.035, and bootstrap sign stability of 1.00. Scenario results indicate a gradual shift from young-family mortality exposure toward longevity, health, care, annuity, and pension risk. The evidence is predictive and scenario-based rather than causal or company-level reserving evidence.

Keywords: Education Competition; Fertility Decline; Gaokao Applicants; Actuarial Risk; Pension Pressure

1. Introduction

China is experiencing sustained low fertility and rapid ageing. The 2024 national statistical communique reports a population of 1,408.28 million, 9.54 million births, a crude birth rate of 6.77 per thousand, and population shares of 22.0 percent aged 60+ and 15.6 percent aged 65+ [12]. Insurance has become large enough for such changes to matter financially: original premium income reached RMB 5,696.3 billion in 2024, including RMB 3,191.7 billion from life insurance and RMB 1,071.5 billion from health and accident insurance [12]. Fertility decline can therefore affect pricing, duration, reinsurance needs, and social security sustainability.

The central proposed mechanism is education competition. The quantity-quality framework predicts that families reduce the number of children when the expected price of child quality rises [1,2]. In China, this price is not only tuition. It also includes school-district housing, tutoring, commuting, homework supervision, parental time, maternal career interruption, and uncertainty about future examination outcomes. Recent child-rearing cost evidence also treats education and housing burdens as major fertility constraints [15]. International low-fertility research emphasizes delayed marriage and tempo effects [3,10]; this article adds a risk-transfer interpretation.

The contribution is threefold. First, it separates education competition from general childrearing cost. Second, it uses Ridge, LOOCV, permutation importance, and bootstrap sign stability to avoid over-interpreting a 15-year macro sample. Third, it translates fertility decline into insurance language: shrinking birth cohorts may weaken young risk-pool renewal, while ageing may raise longevity, health, care, annuity, and pension exposure.

2. Data Structure and Methods

The sample covers 2010-2024. Fertility, age structure, life expectancy, GDP growth, and GDP per capita are mainly from World Bank WDI; national demographic, insurance, and education-examination facts are checked against NBS, NFRA, MOE, and NEEA releases [12,13]. UNESCO is used to cross-check education expenditure indicators [14]. The education-competition proxy is national Gaokao applicants indexed to 2010. It is a competition signal rather than a full household measure of tutoring, anxiety, or school-district housing pressure.

The mechanism is summarized by two hypotheses and two scenario expectations. H1: a higher Gaokao-based proxy is associated with lower fertility. H2: the proxy remains negative after macro-demographic controls. S1: low fertility is expected to shift insurance exposure away from young-family mortality protection toward longevity, health, and care. S2: mortality improvement and ageing are expected to raise annuity reserve and pension pressure.

Predictive models standardize covariates and use Ridge shrinkage:

$$\hat{\beta}^{ridge}=arg\ min_{\beta}\left[\sum_{t}(y_t-X_t\beta)^2+\lambda\sum_{j}\beta_j^{\,2}\right] \quad (1)$$

$$RMSE_{LOO}=\sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(y_t-\hat{y}_{-t}\right)^2} \quad (2)$$

Benchmark: λ = 1.0. Variable importance is the average LOOCV RMSE increase after permutation:

$$\hat{p}_j=\frac{1+\sum_{b=1}^{B}1\left(\Delta RMSE_{j,b}\le 0\right)}{1+B} \quad (3)$$

with B = 1000. This is a predictive-importance probability, not a conventional causal significance test. The modelling choice is conservative: with only 15 annual observations, ordinary least squares is unstable once several controls are included, while Ridge makes coefficient signs and relative predictive contribution easier to evaluate without claiming structural identification.

Insurance scenarios use normalized pressure indices. Mortality-risk demand (MRD) is tied to birth volume and working-age population; longevity-risk demand (LRD) is tied to the 65+ share, old-age dependency, and life expectancy; adjusted ORD combines them with a volatility adjustment. Reserve sensitivity uses a stylized annuity present-value factor, and PAYG pressure compares contribution capacity with beneficiary pressure under retirement ages 60 and 65. These are directional scenario measures, not pricing or public-pension valuations.

The insurance transmission is represented by the following normalized scenario formulas:

$$MRD_t=\left(\frac{B_t}{B_0}\right)\left(\frac{W_t}{W_0}\right),\quad LRD_t=\left(\frac{E_t}{E_0}\right)\left(\frac{OADR_t}{OADR_0}\right), \quad (4)$$

$$ORD_t=[(1-w)MRD_t+wLRD_t]V_t, \quad (5)$$

$$Reserve_x=\sum_{t=1}^{n}v^t\,p_{x,t}\,b_t,\quad b_t=(1+g)^{t-1}, \quad (6)$$

$$I_t=c\pi\sum_{a}Pop_{a,t}w_{a,t},\quad E_t^{a*}=\pi\sum_{a\ge a*}Pop_{a,t}b_{a,t}, \quad (7)$$

$$G_t^{a*}=E_t^{a*}-I_t,\quad P_t^{a*}=G_t^{a*}-G_{2010}^{a*},\quad a*\in\{60,65\}. \quad (8)$$

In the permutation equation, B denotes 1,000 random permutations; it is not the birth-volume term used in the actuarial scenario block. The scenario formulas map birth volume, working-age population share, elderly population share, old-age dependency, volatility, discounting, survival probability, and projected benefits into reserve and PAYG pressure indices relative to 2010.

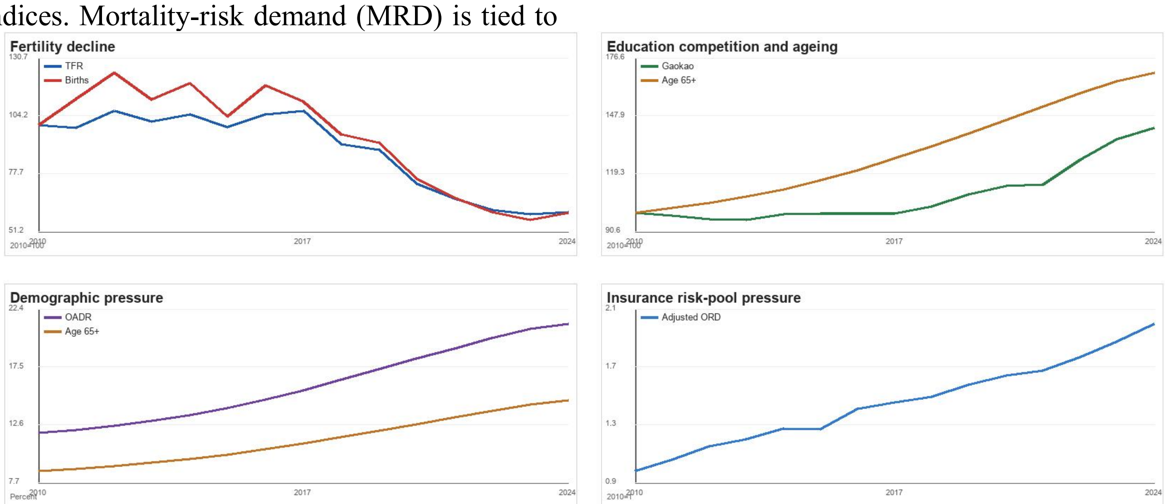

Figure 1. Compressed Data Structure

Note: Fertility and births decline after 2017, while Gaokao applicants, the old-age share, OADR, and adjusted ORD rise. The figure is descriptive, but it motivates examining education competition and insurance risk together.

3. Findings and Discussion

Figure 1 shows the empirical setting. After 2017, fertility and births fall sharply, while education competition and ageing indicators strengthen. The 2024 rebound in births does not reverse the low-fertility pattern. Correlations are descriptive rather than causal, but they indicate that the education proxy, fertility decline, and ageing move together before model-based checks are applied.

Empirically, the benchmark model associates the education proxy with lower fertility: the standardized coefficient is about -0.360, the permutation ΔRMSE is 0.066, the empirical predictive-importance probability is about 0.035, and bootstrap sign stability is 1.00. OADR and the 65+ share also enter negatively, although their permutation evidence is weaker. Robustness checks keep the education coefficient negative after adding a time trend, dropping 2024, using crude birth rate or birth volume as alternative outcomes, and selecting λ by LOOCV. Lag checks from zero to three years remain negative. These results are best read as predictive evidence within a short annual sample, not as causal estimates.

This empirical pattern is consistent with the paper's theoretical channel, but it does not identify the channel by itself. A fertility decision is made before the family knows the child's academic outcome, while families can observe the local and national intensity of competition. If the perceived cost of keeping a child competitive rises, the expected marginal cost of another child may rise even when household income improves. The mechanism is therefore better framed as a forward-looking risk interpretation rather than a demonstrated structural pathway.

Substantively, the coefficient is best read as a warning indicator rather than a stand-alone causal estimate. Rising examination pressure and credential competition may make fertility recovery more difficult, but the proxy has clear limitations: Gaokao applicants partly reflect cohort size, repeat-taker behavior, admission expansion, and expected returns to credentials. The result is therefore interpreted as a national signal of education competition and credential pressure, not as a direct household-cost measure. The paper does not treat the Gaokao as a direct driver of low fertility; it uses the examination system as an observable signal of a broader educational competition environment.

Insurance markets partly depend on stable risk-pool renewal. Fewer births can reduce natural growth in children's insurance, young-family protection, and mortality cover. Ageing can raise the relevance of health insurance, long-term care, annuities, and longevity transfer. Prior insurance-demand research links life insurance to income, education, dependency, social security, and financial development [6]; mortality and longevity research shows why trend uncertainty matters for long liabilities [4,7,9,11].

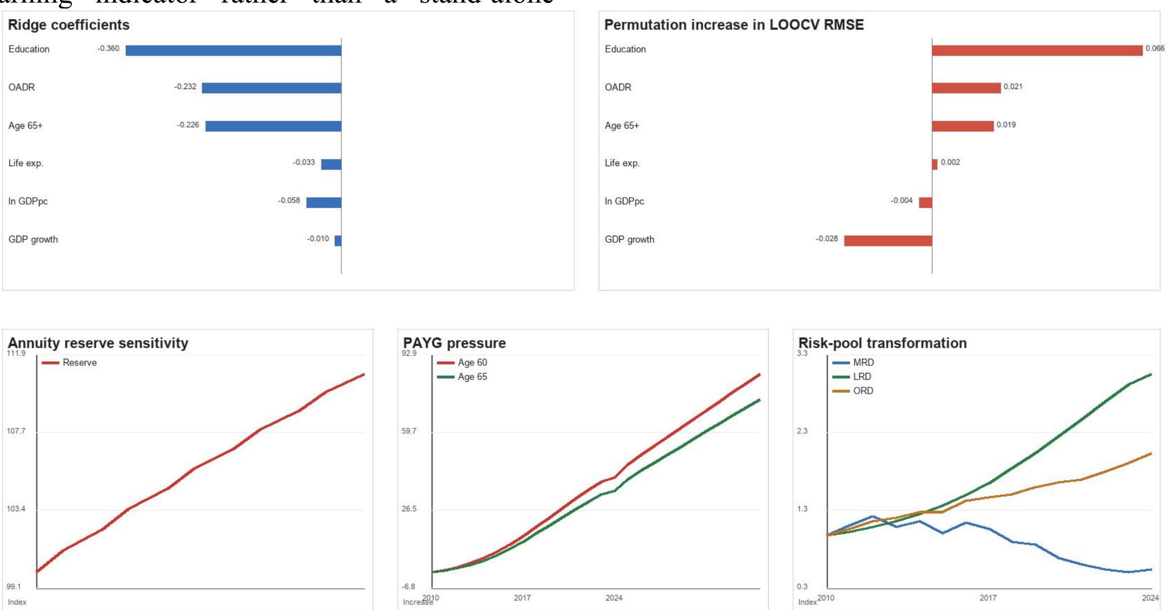

Figure 2. Model and Actuarial Scenarios

Note: The upper panels report standardized Ridge coefficients and permutation importance. The lower panels report annuity reserve sensitivity, PAYG pension pressure, and risk-pool transformation.

The scenario exercise translates the demographic pattern into actuarial terms. Adjusted ORD rises from 1.000 in 2010 to about 2.021 in 2024, which is consistent with stronger longevity-side reinsurance pressure under the paper's normalization. In the annuity stress, the reserve index rises from 100.0 to about 110.8 as mortality-improvement stress increases from 0 to 25 per 1,000. PAYG pressure rises under both retirement-age assumptions; a higher retirement age reduces, but does not eliminate, the modeled pressure. These outputs are scenario results, not empirical product prices, company reserves, or pension-deficit estimates.

The practical implication is portfolio-level, but it is best treated as an inference from the empirical and scenario evidence. Insurers may need to view low fertility not only as slower new-business growth, but also as a possible shift in liability mix, capital duration, lapse sensitivity, morbidity-longevity correlation, and the balance between mortality protection and retirement-income business. A smaller young cohort may reduce natural inflow into family protection products, while a larger older cohort may increase exposure to health spending, long-term care incidence, annuity payouts, and retirement-income guarantees. For reinsurers and regulators, the analysis suggests that demographic risk modelling can support mortality-improvement, medical-cost, care-incidence, lapse, and long-duration stress testing [8].

The product-design implication is more speculative. In a high-fertility environment, cohort renewal can create repeated entry points through new parents, child policies, education savings, and family protection. In a low-fertility environment, those entry points may weaken, and the same customer relationship may carry more retirement, morbidity, and longevity risk over a longer period. This suggests, rather than demonstrates, a gradual shift toward lifecycle retention, hybrid health-care protection, deferred annuities, and products that manage uncertainty in medical cost and survival improvement. Traditional life protection need not disappear; its growth role may become more closely connected with retirement and health-risk planning.

There may also be a solvency implication. Long-duration liabilities are sensitive to small changes in mortality improvement, discount rates, lapse behavior, and care incidence. If fertility decline contributes to faster ageing, errors in these assumptions could accumulate in the same direction. A cautious implication is that scenario testing would benefit from linking demographic projections with product-mix projections rather than treating population structure only as a background macro variable. One useful stress test would ask how reserves, capital strain, and reinsurance needs might change if low fertility persists, old-age dependency rises faster than expected, and younger cohorts purchase less protection than historical cohorts at the same age.

4. Conclusion

The paper offers three bounded conclusions. First, the empirical finding is that a national education-competition proxy is negatively associated with fertility in a small annual sample after conservative predictive checks. Second, the actuarial scenario results indicate a directional shift from young-family mortality exposure toward longevity, health, care, annuity, and pension pressure. Third, the policy and product implications are conditional: fertility support may need to address the expected cost of raising a competitive child, while insurers may need to monitor whether low fertility gradually changes product demand and liability duration.

The paper's limits are important. The education proxy cannot observe household spending, tutoring time, school-district premiums, or subjective anxiety. The annual sample has only 15 observations, so common trends and ecological-inference risk remain. The insurance and pension models are scenario indices, not company-level estimates. Future research could combine provincial panels, education-regulation shocks, household surveys, and insurer policyholder-cohort data.

These limitations define the next empirical step. A provincial panel could separate national time trends from local variation in school competition, childcare supply, housing pressure, and insurance penetration. Household survey data could test whether perceived education pressure affects second- or third-child intentions after controlling for income and marriage timing. Insurer-level policy data could then connect cohort size to actual product demand, lapse, claims, and annuity take-up. The present paper is best read as a compact bridge: it links education competition, fertility behavior, and actuarial risk in one framework, while leaving causal identification and company-level valuation for later work.

References

[1] Becker, G.S.; Lewis, H.G. On the interaction between the quantity and quality of children. J. Political Econ. 1973, 81, S279-S288.

[2] Becker, G.S.; Tomes, N. Child endowments and the quantity and quality of children. J. Political Econ. 1976, 84, S143-S162.

[3] Bongaarts, J.; Sobotka, T. A demographic explanation for the recent rise in European fertility. Popul. Dev. Rev. 2012, 38, 83-120.

[4] Cairns, A.J.G.; Blake, D.; Dowd, K. A two-factor model for stochastic mortality with parameter uncertainty. J. Risk Insur. 2006,

73, 687-718.

[5] Doepke, M.; Kindermann, F. Bargaining over babies: Theory, evidence, and policy implications. Am. Econ. Rev. 2019, 109, 3264-3306.

[6] Browne, M.J.; Kim, K. An international analysis of life insurance demand. J. Risk Insur. 1993, 60, 616-634.

[7] Lee, R.D.; Carter, L.R. Modeling and forecasting U.S. mortality. J. Am. Stat. Assoc. 1992, 87, 659-671.

[8] Lee, R.; Mason, A. Population Aging and the Generational Economy; Edward Elgar: Cheltenham, UK, 2011.

[9] Li, N.; Lee, R. Coherent mortality forecasts for a group of populations. Demography 2005, 42, 575-594.

[10] Jones, G.W. Delayed marriage and very low fertility in Pacific Asia. Popul. Dev. Rev. 2007, 33, 453-478.

[11] Pitacco, E.; Denuit, M.; Haberman, S.; Olivieri, A. Modelling Longevity Dynamics for Pensions and Annuity Business; Oxford University Press: Oxford, UK, 2009.

[12] NBS; NFRA; MOE; NEEA. Official demographic, insurance-market, and education-examination releases. Available online: stats.gov.cn; nfra.gov.cn; moe.gov.cn; neea.edu.cn (accessed on 24 June 2026).

[13] World Bank. World Development Indicators for China. Available online: data.worldbank.org (accessed on 24 June 2026).

[14] UNESCO Institute for Statistics. Government expenditure on education indicators. Available online: uis.unesco.org (accessed on 24 June 2026).

[15] YuWa Population Research Institute. China Child-Rearing Cost Report 2024. Available online: yuwa.org.cn (accessed on 24 June 2026).

